Device and method for optimizing personal well-being

Description of the problem

It is widely known that diet has a significant impact on human well-being and health. A balanced diet rich in fruits and vegetables, for example, reduces the risk of developing typical lifestyle diseases such as cardiovascular disease and cancer. The antioxidants contained in fruits and vegetables play an important role in this, as they act as radical scavengers and help prevent the negative effects of oxidative stress. The World Health Organization and many national health ministries therefore recommend eating large amounts of fruits and vegetables every day. The German Nutrition Society (Deutsche Gesellschaft für Ernährung), for example, recommends eating 650 g per day. Carotenoids are substances with a strong antioxidant effect and are considered the best marker for fruit and vegetable consumption (see Institute of Medicine, National Academies, "Dietary Reference Intakes for Vitamin C, Vitamin E, Selenium, and Carotenoids," National Academies Press, 2000, hereinafter referred to as Lit.1).

Despite many recommendations and campaigns by health authorities, doctors, nutritionists, and other public and private institutions, the actual consumption of fruits and vegetables is usually well below these recommendations (see, for example, Nationale Verzehr Studie II, published by the Max Rubner-Institut, Bundesforschungsinstitut für Ernährung und Lebensmittel, Germany 2008, hereinafter referred to as Lit.2). The associated health costs worldwide are correspondingly high. The question is therefore whether there are technical means by which a change in citizens' behavior can be initiated and sustainably promoted.

The quality of nutrition and the amount of exercise play, for example, a decisive role in another problem: obesity. In 2015, 2.2 billion people worldwide were overweight. Between 1980 and 2015, the number of obese people (BMI > 30) doubled. Overweight and obesity are usually associated with secondary diseases such as type 2 diabetes mellitus, gout, atrial fibrillation, or coronary heart disease.

In addition, there are a large number of people worldwide who are not considered overweighted in the medical sense, but who struggle with unwanted pounds for aesthetic reasons and whose well-being suffers greatly as a result of subjectively perceived weight problems. Increasing stress at work, insufficient exercise, an unbalanced diet, and eating convenience food or fast food instead of cooking meals at home are some of the reasons for unwanted weight gain. Even desperate attempts to lose those extra pounds through dieting and exercise usually fail. This raises the question: are there technical means or technical support available to help people cope with this problem?

According to the current state of technology, there are only solutions or technical devices that independently address individual aspects of these problems using different technical approaches: Bathroom scales enable body weight to be checked, and also measure body fat percentage, pedometers count the number of steps taken each day as a measure of exercise and use this to determine calorie consumption, smart watches and fitness watches also measure heart rate and oxygen saturation and inform the user when a heart rate is reached during training at which fat burning begins. applications show the distance covered while cycling and hiking, the associated elevation profiles, and calculate the calories burned.

Monitoring individual aspects with different technical solutions may only provide an incomplete picture if the real physiological interconnection of these aspects influences the measurement result and the measurement cannot be carried out simultaneously with different systems.

What is missing is a system that integrates aspects of well-being into a single measurement process so that, for example, different aspects of nutrition and lifestyle can be monitored simultaneously in order to achieve comprehensive health and well-being in the long term.

The invention described here shows a technical system that, for example, records various parameters and/or substances in the human body through a joint measurement, estimates the physiological state of an individual based on this, and automatically provides individual user recommendations based on algorithms and collected data, for example with regard to behavior, nutrition, medication intake, or automatically identifies other influencing factors that help stabilize or improve the user's well-being.

Summary

The invention discloses a spectroscopic device for the non-invasive measurement of substance concentrations or biomarkers in human or animal tissue, skin or blood, and a method for evaluating the measurement data and deriving recommendations that stabilize and/or improve the well-being of the user.

Conventional sensors for biomarkers can usually only determine the concentration of a single substance, and this is usually done either with a technically complex device that is not suitable for everyday use, or with low accuracy, so that changes in user behavior do not lead to a clear change in the measured values.

In its exemplary embodiments, the device according to the invention enables non-invasive determination of multiple substance concentrations using a sensor that is small enough to be integrated into everyday objects such as smartwatches or mobile phones and can partially share the hardware available there.

In a spectroscopic system designed to determine biomarkers, the emitters and detectors must emit or detect photons in wavelength ranges in which the sought-after biomarkers absorb photons. To determine the concentration of these biomarkers, more than one emitter and detector are required in each case. According to the state of the art, the accuracy of the measurement is increased if emitters with the same emission spectrum are present multiple times on the sensor. Surprisingly, it has now been found that the measurement accuracy improves significantly if the emission spectrum of these emitters differs within the limits of an interval, e.g., in relation to their peak wavelength or half-value width. Emitters that are within a common interval are considered to be approximately equal emitters. A sensor that detects the concentration of different biomarkers simultaneously has several intervals with approximately equal emitters. The intervals then jointly cover the wavelength range required for the detection of the biomarkers. The same applies analogously to detectors that are present in multiple instances on a sensor.

This application presents a method that exploits the properties of such devices to increase measurement accuracy. The increase can be so significant that, in addition to displaying the measured values, behavioral recommendations can also be calculated automatically from the measurement data. These recommendations may include dietary recommendations, for example, changes in substance concentrations. Such changes often occur only slowly because the body has its own storage for many substances, so that even a significant change in user behavior results in only a slow change. If the system can reliably measure small changes, it can still provide the user with timely feedback on his/her behavior. Positive behavior can be praised and negative behavior reprimanded, so that the user is highly motivated to eat healthily, for example.

This invention is considered an optimization of the invention already known from patents EP 3013217; EP 3175783; US 10,416,079; US 11,08,5876 and applications US 17/396,556, EP 4005469A1. All aspects presented in this invention can therefore be combined with the embodiments mentioned in the present invention. The disclosure of this invention is to be regarded as part of the present disclosure.

Some of the particularly advantageous embodiments of the invention can only unfold their full potential when a novel, particularly advantageous method of evaluating the measurement data is used. Since this is based in part on machine learning methods, the following section describes the state of the art in this field.

Conventional machine learning methods are based on the raw data to be processed being recorded uniformly and consistently. Each raw data set has the same form and each data point in the data set always represents the same information. However, this is often not the case with sensors. Due to fluctuations, including production inaccuracies and/or failure of individual

emitters or detectors, the raw data sets from different sensors differ from one another. These deviations mean that, from a machine learning perspective, the raw data sets are no longer uniform and consistent, causing conventional methods to generate further inaccuracies.

For conventional methods, missing data is usually interpolated (A. R. T. Donders, G. J. van der Heijden, T. Stijnen, and K. G. Moons, “Review: A gentle introduction to imputation of missing values,” Journal of Clinical Epidemiology, vol. 59, no. 10, pp. 1087–1091, 2006, hereinafter referred to as Lit.3) or imprecise data is cleaned up using other machine learning methods (P. K. Sharpe and R. J. Solly, “Dealing with missing values in neural network-based diagnostic systems,” Neural Computing & Applications, vol. 3, no. 2, pp. 73–77, Jun 1995, hereinafter referred to as Lit.4).

Some machine learning methods, known as "convolutional neural networks" (CNN) (Y. Lecun, L. Bottou, Y. Bengio, and P. Haffner, "Gradient-based learning applied to document recognition," Proceedings of the IEEE, vol. 86, no. 11, pp. 2278–2324, 1998, hereinafter referred to as Lit.5) can process such inconsistencies and inaccuracies with the aid of continuous filter kernels (D. W. Romero, A. Kuzina, E. J. Bekkers, J. M. Tomczak, and M. Hoogendoorn, “Ckconv: Continuous kernel convolution for sequential data,” CoRR, vol. abs/2102.02611, 2021, hereinafter referred to as Lit.6), (K. T. Schütt, P.-J. Kindermans, H. E. Sauceda, S. Chmiela, A. Tkatchenko, and K.-R. M̈uller, “Schnet: A continuous-filter convolutional neural network for modeling quantum interactions,” in Proceedings of the 31st International Conference on Neural Information Processing Systems, 2017, p. 992–1002, hereinafter referred to as Lit.7), (W. Wu, Z. Qi, and L. Fuxin, “Pointconv: Deep convolutional networks on 3d point clouds,” in 2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2019, pp. 9613–9622, hereinafter referred to as Lit.8). Such CNNs exhibit what is known as translation invariance. Translation invariance means that the result of the process is independent of the position of the input.

The sensor principle presented here belongs to the class of MSRRS sensors (MSRRS = Multiple Spatially Resolved Reflection Spectroscopy; see patent numbers above).

A new aspect of this application is the representation of data from MSRRS sensors as a collection of values, each with a "position" in the measurement range. In an advantageous variant, this position is defined by its assigned wavelength and by its assigned emitter-detector distance. The consideration of the radiation and detection direction characteristics can be a further position parameter.

However, since a shift in the measurement points in wavelength or emitter-detector distance implies a change in the meaning of the values (thus making the data position-dependent), the

translation invariance of CNNs is explicitly counterproductive for the evaluation of data from MSRRS sensors. This is a disadvantage of the previously known approaches.

In order to exploit the advantageous properties of continuous filter kernels for the evaluation of MSRRS sensor data, a novel method of machine learning is presented.

Previous works on continuous filter kernels have primarily focused on their application in CNNs. In Lit.6, continuous filter kernels are used to process various types of inconsistently recorded sequential data. Furthermore, different types of continuous filter kernels are analyzed and compared. Lit.7 uses continuous filter kernels in CNNs to represent and process atoms in a non-grid-based manner. In Lit.8, continuous filter kernels are used to process three-dimensional point clouds directly without having to rasterize them first.

Continuous filter kernels are advantageously implemented using neural networks. Analysis of the usability of neural networks as a learnable representation of a continuous function, a so-called "implicit neural representation," is known from (J. J. Park, P. Florence, J. Straub, R. Newcombe, and S. Lovegrove, "Deepsdf: Learning continuous signed distance functions for shape representation," in 2019 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), 2019, pp. 165–174, hereinafter referred to as Lit.9), (K. Genova, F. Cole, A. Sud, A. Sarna, and T. Funkhouser, "Local deep implicit- s for 3D shape," in 2020 IEEE/CVF Conference on Computer Vision and Pattern Recognition (CVPR), Jun 2020, pp. 4856–4865, hereinafter referred to as Lit.10) for the representation of signed distance functions, which are required for the representation of three-dimensional geometry. In (V. Sitzmann, J. N. P. Martel, A. W. Bergman, D. B. Lindell, and G. Wetzstein, “Implicit neural representations with periodic activation functions,” in Proceedings of the 34th International Conference on Neural Information Processing Systems, 2020, hereinafter referred to as Lit.11) is disclosed a network architecture called SIREN as an implicit neural representation suitable for generic data, including audio, images, and signed distance functions. Based on the use of these basic methods for kernels, a novel architecture for neural networks is presented, that enables higher precision in measuring substance concentrations by taking differences between sensors into account.

Brief description of the figures

Further advantages of the invention are apparent from the description and the figures. Likewise, the features mentioned in the text and those contained in the figures can be used individually or in any combination. The embodiments shown and described are not to be understood as an exhaustive list, but rather as examples for illustrating the invention.

Fig. 1-1a shows an example of a sensor (20) with 6 emitters (1) and 3 detectors (2) in top view (Fig. 1a) and sectional view (Fig. 1). It has a three-dimensional sensor surface element component (3) that is in contact with the skin (4) and is preferably identical in size to the sensor surface. The area (3a) occupied by the sensor surface element and the area (3b) occupied by the emitters and detectors on the printed circuit board (6) are shown. In a preferred solution, the emitters can emit photons in different wavelength ranges and the detectors can detect photons in different wavelength ranges. The sensor surface element (3) can be made of transparent material or it can consist of transparent and non-transparent parts. It has a thickness (3.1). The surface of the skin (4.1) is at least partially in contact with the sensor surface element (3) during measurement.

Fig. 2-2a The figures show an example of a sensor (20) with at least two emitters (1) and one detector (2) in cross-section, in which the three-dimensional sensor surface element (3) that is in contact with the skin (4) has one or more convex bulges toward the skin. In Fig. 2a, there are two convex bulges toward the skin, while in Fig. 2 there is only one convex bulge. Fig. 2 is an example of how the bulge can extend over the entire sensor. The emitters (1) and detectors (2) are mounted on the printed circuit board (6).

Fig. 3-3a show an example of a sensor (20) with at least two emitters (1) and a detector (2) on a printed circuit board (6) in cross-section, in which the three-dimensional sensor surface element (3) that is in contact with the skin (4) has a concave curvature toward the skin. In Fig. 3a, there are two concave curvatures toward the skin, whereas in Fig. 3 there is only one concave curvature extending over the entire sensor.

Figs. 4-4a show an example of a sensor (20) with six emitters (1) and three detectors (2) mounted on a circuit board (6) in a top view (Fig. 4a) and a cross-section (Fig. 4). There are many possibilities for choosing the shape of the cavities. In the example shown here, the three-dimensional sensor surface element (3) has partially beveled corners. Such adjustments to the shape of the sensor surface element (3) can be used to generate different radiation directions or to form openings (3.2) of different geometries above the sensor components. An opening is understood to be a passage for light. This can also be formed by transparent material. The sensor surface elements are in contact with the outermost layer of the skin (4.1). In Fig. 4a, the sensor components (1, 2) are shown with examples of geometrically

different shapes of the openings (3.2). In a preferred solution, the emitters (1) can emit photons in different wavelength ranges, even if it is not specified here which emitter emits which wavelength. In the preferred variant, the detectors (2) can detect photons in different wavelength ranges.

Fig. 5-5a show, as in Fig. 4, an example sensor (20) with 6 emitters (1) and 3 detectors (2) arranged on a printed circuit board (6), in top view (Fig. 5a) and sectional view (Fig. 5). The three-dimensional components (5) are components made of a material that is not transparent, preferably, a material that is almost impenetrable to photons. This may be a single element (5) or several individual elements. The non-transparent elements (5) and the printed circuit board (6) enclose the sensor components in such a way that when, for example, the hand is placed on the sensor, the emitted photons must pass through the skin (4) before they can be detected by the detector. A cavity (8) is formed above the sensor components (1 and 2), which can be filled with a gas, e.g. air, or another transparent material. The sensor surface elements (3) that are permeable to photons have different geometric shapes due to the geometry of the components (5). Component (5) and transparent parts of the sensor surface elements (3) do not form any height differences relative to the skin. The skin surface (4.1) can therefore lie flat on the sensor. Fig. 5a shows a top view of the sensor components as a dotted line above which the sensor surface elements (3) are located. In a preferred solution, the emitters can emit photons in different wavelength ranges and the detectors can detect photons in different wavelength ranges. Transparent elements (3) with a thickness (3.1) mechanically seal the cavities with a height (3.3) in which the optoelectronic components are located, but allow photons to enter and exit.

Fig. 6-6b show, as in Figures 5 and 5a, an example of a sensor (20) with six emitters (1) and three detectors (2) in plan view and in section, in which three-dimensional components (5) which are virtually impenetrable to photons, and sensor surface elements (3) enclose the sensor components in such a way that when, for example, the hand is placed on the sensor, the emitted photons must pass through the skin (4) before they can be detected by the detector. In Fig. 6, the sensor surface element (3) is arranged such that there is a height difference (3.3) in the direction of the skin (4) relative to the component (5), creating a cavity (8) above the sensor components (1, 2). Fig. 6b shows an alternative in which the sensor surface elements are, for example, retrofitted into the enclosed spaces in which the sensor

components (1, 2) are located, so that there is no longer a cavity above the sensor components. Fig. 6a shows a top view with the sensor components and the geometric shape of the sensor surface elements (3) indicated by dashed lines. In a preferred solution, the emitters can emit photons in different wavelength ranges and the detectors can detect photons in different wavelength ranges. The remaining reference symbols have the same meaning as in Fig. 5.

Fig. 7-7a show an example of a sensor (20) in which either one emitter (1) or two emitters or two detectors (2) are located in each of the enclosed spaces formed by component (5) and sensor surface elements (3). The sensor has a total of 9 emitters and 6 detectors. In a preferred version, the emitters can emit photons in different wavelength ranges and the detectors can detect photons in different wavelength ranges. Fig. 7a shows the arrangement of emitters and detectors of the sensor in the enclosed spaces. Fig. 7 shows that there is no step between the component (5) and the sensor surface element (3) in the direction of the skin (4) or the outer layer of the skin (4.1). However, this sensor may have openings (3.2) in the sensor surface element. An opening is shown in Fig. 7. The dashed lines (1c) symbolically show the path that the photons take through the skin before they are detected by the detector. The other reference symbols have the same meaning as in Fig. 5.

Fig. 8-8a show, as in Fig. 6b, an example of a sensor (20) with 6 emitters (1) and 3 detectors (2) in a top view (Fig. 8a) and a sectional view (Fig. 8), in which three-dimensional components (5), which are virtually impenetrable to photons, and sensor surface elements (3) enclose the sensor components in such a way that when, for example, the hand is placed on the sensor, the emitted photons must pass through the skin (4) before they can be detected by the detector. In contrast to Fig. 6b, however, there is no height difference between component (5) and sensor surface element (3) in the direction of the skin (4). In Fig. 8a, the sensor components are shown as dashed lines and the size of the sensor surface elements (3) as solid lines. In a preferred solution, the emitters can emit photons in different wavelength ranges and the detectors can detect photons in different wavelength ranges. The other reference symbols have the same meaning as in Fig. 5.

Fig. 9-9c Fig. 9 shows an example of a unit consisting of a sensor surface element and a component (5) which can be manufactured, for example, by injection molding. The thickness of the sensor surface element (3.1) is selected such that when the

unit (9) is placed on the printed circuit board (6), the sensor components (1, 2) do not come into direct contact with the sensor surface element. In a preferred solution, the unit (9) is connected to the contact point (6.1) with the printed circuit board (6) in such a way that photons cannot pass through the contact point. As in Fig. 7 and 7a, after the unit (9) is placed, there is one emitter or two emitters or two detectors in a closed space. In total, the sensor has 9 emitters and 6 detectors. Fig. 9a shows a top view of the arrangement of the sensor components. Fig. 9b shows a cross-section of an alternative to the variant in Fig. 9. In this case, a unit (5b) consisting of components (5) that are virtually impenetrable to photons and have three-dimensional openings (3.2) is placed on the circuit board and connected to it. Fig. 9c shows a top view of the sensor (20), on which the surface dimensions of the openings (3.2) can be seen. The arrangement of the sensor components is not shown. It corresponds to the arrangement in Fig. 9a. In a preferred solution, the emitters can emit photons in different wavelength ranges and the detectors can detect photons in different wavelength ranges. The remaining reference symbols have the same meaning as in Fig. 5.

Fig. 10-10b Fig. 10, 10a, and 10b show examples of sensor component arrangements. The limiting solid angles under which the photons can leave the sensor to penetrate the skin or reach the detector from the skin are determined by an additional component (5a) that is impassable or virtually impassable for photons and is located on the component (5b) and in contact with the skin (4). The limiting spatial angles are shown as dashed arrows. The angles (5.1) show the limits that can occur for angles between the printed circuit board and emitted or detected photons in the intersection plane. The differences between the three figures lie in whether and where transparent parts of sensor surface elements (3) are included. Fig. 10 has no sensor surface element. The additional component (5a) has three-dimensional openings (3.2) through which the photons can pass through the component (5a). This also applies to Fig. 10a. However, in this sensor, sensor surface elements that are passable for photons are located between the components (5), so that the sensor components (1, 2) are located in completely enclosed spaces (8). In Fig. 10b, the sensor surface elements (3) are located in the openings of the additional component (5a). Therefore, in this variant, the sensor components are also located in enclosed spaces. In a preferred solution, the emitters can emit photons in different wavelength ranges and the detectors can

detect photons in different wavelength ranges. The remaining reference symbols have the same meaning as in Fig. 5.

Fig. 11 The figure shows an example of arrangement of the sensor components (1, 2). Compared to Fig. 10a, the additional component (5a), which is made of a material that is impervious or nearly impervious to photons, has a transparent material (7) with a convex shape. Between the transparent material and the additional component (5a) there is a cavity (8) which can be filled with gas, for example air. In an alternative and also preferred variant, the transparent material (7) can also be a component which rests over the entire surface of the component (5a) so that there is no longer a cavity (8). In a preferred solution, the emitters can emit photons in different wavelength ranges and the detectors can detect photons in different wavelength ranges. Further reference symbols have the same meaning as in Fig. 10.

Fig. 12-12a The figure shows an example of arrangement of sensor components (1, 2). There are no sensor surface elements that are permeable to photons between the components (5) that are impermeable or virtually impermeable to photons. The sensor components (1, 2) are therefore located in enclosed spaces that are open toward the skin (4) or the outer layer of the skin (4.1). In the preferred embodiment shown as an example, additional components (5a) are arranged on two enclosed spaces so that they are located at a defined distance parallel to or nearly parallel to each other on the components (5). The emitted photons can therefore only leave the sensor in certain preferred directions toward the skin (4). For illustrative purposes, the components (5) are arranged orthogonally to each other above the two emitter chambers, so that one chamber has a preferred direction in the north-south direction, while the preferred direction of the photons leaving the sensor in the other emitter chamber is in the west-east direction, as shown in Fig. 12a. The other reference symbols have the same meaning as in Fig. 10.

Fig. 12b-12b2 The arrangement of the sensor components (1, 2) shown in the figures corresponds to Fig. 12a. In the direction of the skin (4), the sensor has a transparent, convex-shaped material layer (7), which is in contact with the outer layer of the skin (4.1) during measurement. The additional components (5a), which are located above two emitter spaces, are located below the layer (7) in the cavity (8). Variants in Fig. 12b1 and 12b2 show solutions in which the transparent

layer (7) is a three-dimensional, transparent component that allows photons to pass through, the upper side of which is convexly curved toward the skin (4) and the lower side of which is flat toward the circuit board (6). The difference between Fig. 12b1 and 12b2 is that the additional components (5a) in Fig. 12b1 are integrated into the transparent component (7), while in Fig. 12b2 the transparent component (7) rests on the components (5a). The other reference symbols have the same meaning as in Fig. 10.

Fig. 12b3-12b5 The difference between the sensor shown in this example and those shown in Figs. 12b-12b2 is that the sensor has a sensor surface element that is permeable to photons. It is located between the components (5) and has no height difference to the components (5) in the direction of the skin (4). In Fig. 12b3, the transparent, convexly shaped material (7) forms a cavity (8) on its underside, in which the additional components (5a) are located, while the curved upper side is in contact with the outer layer (4.1) of the skin. In Figures 12b4 and 12b5, the transparent material (7) forms a three-dimensional, transparent component with a convex curvature toward the skin, as described in Fig. 12b1. The difference between the two figures is that the additional material (5a) in Fig. 12b4 is integrated into the component (7), while in Fig. 12b5 the component (7) rests on the component (5a).

Fig. 12c-12c5 The arrangements shown in the examples in Figs. 12c to 12c5 correspond almost exactly to Figs. 12b-12b5. The difference lies in the curvature of the transparent material (7) or the transparent component (7). In Figs. 12c to 12c5, the curvature is concave so that less extraneous light can penetrate between the outer skin layer (4.1) and component (7) when the sample, e.g., the hand, is placed on top and influence the measurement result. It is obvious to the skilled person that the component (7) has light protection, e.g., a film that photons cannot pass through, wherever ambient light can penetrate directly into the transparent material or component.

Fig. 12d-12e The exemplary arrangement of the sensor components (1, 2) is shown in Fig. 12e. Figs. 12d-12d5 essentially correspond to Figs. 12b-12b5. The difference lies in the fact that an additional component (5a) limits the spatial angles under which photons can be emitted or photons escaping from the skin (4) can reach a detector. In the example shown, the middle detector (2) is additionally enclosed by component (5a), as can be seen in Fig. 12e. However, this component also limits the solid angles of the two emitters (1) located next to the detector when emitting

photons, as can be seen in the sectional drawings on the emitter to the left of it. The steepness of the solid angle when photons are emitted is no longer determined by the edge of the surrounding component (5), but by the position of the additional component (5a) located on the component (5), as shown by the dashed arrow. In a preferred variant, such an additional enclosing component (5a) may be located above more than one detector. In a further preferred variant, this additional enclosing component (5a) is located above all detectors. The same applies to the components (5a) located above the emitters, which are shown in Fig. 12e with different orientations above two emitters. In a preferred variant, they can be located above one or more emitters. In a further preferred variant, these components (5a) have the same orientation. In a further preferred variant, they are located above one or more detectors, whereby they may have the same and/or different orientations.

Fig. 13-13a show advantageous procedures and definitions for determining the emitter-detector distances (1c). These are also referred to elsewhere in this document as photon light paths. In one variant, the emitter-detector distances (1c1) and (1c4) may be the same. In a particularly advantageous variant, the emitter-detector distances (1c1) and (1c4) are approximately the same. In a particularly advantageous variant, the emitter-detector distance (1c1) of a manufactured sensor is different from the emitter-detector distance (1c1) of another manufactured sensor. In a preferred variant, this applies not only to one distance (e.g., 1c1) but to a plurality of emitter-detector distances.

Fig. 14 Fig. 14 shows an example of the distribution of the peak wavelengths of the emitters. The wavelength in nm is plotted along the horizontal (x) axis. The relative intensity of the emission is plotted along the vertical (y) axis. Four intervals (10) of the peak wavelength (1a) of approximately identical emitters can be seen. These intervals are as follows: (10cb) lies in the blue light range. (10cg) lies in the green light range. (10cr) lies in the red light range. (10cir) lies in the near-infrared light range. The graph shows the relative intensity of the light emission of the emitters in the example. The interval length (10) is 10 nm in each case, with (10a) describing the lower limit and (10b) the upper limit of the interval length. Together, the four intervals cover a wavelength range (11) of 400 nm, with (11a) describing the lowest lower limit of the wavelength range and (11b)

describing the highest upper limit of the wavelength range. The interval gaps (10c) between the intervals are different.

Fig. 14a Fig. 14a shows an example of four intervals (10) of the wavelength ranges covered by the half-width of the emitters. The wavelength in nm is plotted along the horizontal (x) axis. The relative intensity of the emission is plotted along the vertical (y) axis. Four intervals (10) of approximately equal emitters can be seen. These intervals are as follows: (10cb) lies in the blue light range. (10cg) lies in the green light range. (10cr) lies in the red light range. (10cir) lies in the near-infrared light range. The intensity limit (1b) defines which wavelength range lies within the half-width of an emitter. The range (10) and its interval length show the wavelength range of approximately equal emitters in which at least one of the emitters emits radiation of the corresponding wavelength with an intensity of at least 0.5. Although the emitters of an interval all have the same half-width, the wavelength range covered by the respective half-width differs from emitter to emitter within an interval. The four intervals, each with a different interval length (10), are located in the blue, green, red, and near-infrared wavelength ranges. The interval gaps (10c) between the intervals are different. The boundaries (10a) and (10b) show the limits of the intervals. Together, the four intervals cover a wavelength range (11), where (11a) describes the lowest lower limit of the wavelength range and (11b) describes the highest upper limit of the wavelength range.

Fig. 14b shows an example of two intervals with different peak wavelengths (1a) from approximately equal emitters, where the emitters of one interval are not distributed over the entire interval length (10). The other reference symbols correspond to Fig. 14.

Fig. 14c shows an example of two intervals (10) with different peak wavelengths (1a) from approximately equal emitters, with a non-approximately equal emitter (U1) located between the two intervals. In both intervals there are 3 approximately equal emitters, which the peak wavelengths of do not cover the entire interval length. The other reference symbols correspond to Fig. 14.

Fig. 14d shows an interval (10) of the wavelength ranges covered by the half-width of the emitters (FWHM) (1b) covered by the half-value width of the emitters in the wavelength range from 538 nm to 576 nm and the half-value widths (FWHM) of two non-approximate emitters located in the wavelength range below and above

the interval. The interval length (10) is 38 nm and is not completely filled by the three emitters. The dashed lines show that the wavelength range covered by the half-width of the three emitters lies within the limits 10a (538 nm) and 10b (576 nm) of the interval. The other reference symbols correspond to Fig. 14a.

Fig. 14e shows an example of 5 intervals of the peak wavelength of approximately equal emitters with different peak wavelengths, each containing 2 emitters. The interval length is 13 nm and 15 nm, respectively. The reference symbols correspond to Fig. 14.

Fig. 15 shows an example of an interval (10) of 3 approximately identical detectors of which the emitted current at a specific wavelength and a reception power of 10mW/cm² lies between 0.2 mA, lower limit (10a), and 10mA, upper limit (10b). The light intensity arriving at the sensor is plotted on the horizontal (x) axis in mW/cm². This is given for an example of detectors with integrated amplification factor in mA. However, detectors without amplifiers can also be used in an advantageous variant. In such cases, the relationships apply analogously. The current emitted by the detector is plotted along the vertical (y) axis. Detector (2.1) delivers 0.6 mA at 10 mW reception power, detector (2.2) delivers 3 mA, and detector (2.3) delivers 7.5 mA, each at the same wavelength. The figure has logarithmic scales.

Fig. 15a shows another example. The reference symbols correspond to Fig. 15. In 15a, a different criterion for assigning detectors to an interval of approximately equal detectors is shown. This is the current emitted at the same wavelength and photon reception power, which must differ by a certain factor (12) under the detectors. The light intensity arriving at the sensor is plotted along the horizontal (x) axis in mW/cm². This is given for an example of detectors with integrated amplification factor in mA. In an advantageous variant, however, detectors without amplifiers can also be used. In such cases, the relationships apply analogously. The current emitted by the detector is plotted along the vertical (y) axis. The current emitted by detector (2.1) is only 1/5 of that emitted by detector (2.2) at 0.6 mA, or 12.5 times lower than the current emitted by detector (2.3) at 7.5 mA.

Fig. 16 This figure shows the peak wavelength (2b) of two non-approximate-equal detectors that differ in terms of their peak wavelength. The wavelength in nm is plotted along the horizontal (x) axis. The relative sensitivity of the detectors is

plotted along the vertical (y) axis. The difference in peak wavelengths between detector (2.5) and detector (2.4) is 360 nm.

Fig. 16a The example shows a combination of two non-approximate-equal detectors with approximate-equal emitters. The wavelength in nm is plotted along the horizontal (x) axis. The relative sensitivity of the detectors is plotted along the vertical (y) axis. The basis is Fig. 16 and the reference symbols have the corresponding meanings. In Fig. 16a, four intervals of approximately equal emitters are plotted in relation to the half-width (1b). These are the intervals from Fig. 14a. Fig. 16a shows the advantages of combining non-approximate detectors with approximate emitters. The combination is preferred because it achieves a higher spectral resolution.

Fig. 17 shows an example of the system's user interface. The screen display is shown in German as an example. Text (1701s) means: "Measured value." Text (1702s) means: "Studies show that people with this carotenoid value need to eat more fruits and vegetables on average every day to meet the WHO/DGE nutritional recommendations." Text (1703s) means: "Please replace some of your daily food with fresh fruits and vegetables. We have calculated how much more fruits and vegetables you should eat:". Text (1704s) means: "additional daily requirement 290 grams". This is an example of how the measurement results for the carotenoid value and the amount of fruits and vegetables that the user should eat in addition to his/her normal daily intake over the next 4 weeks in order to achieve the target value are described and presented.

Fig. 17a shows an example of the system's user interface. The screen display is shown in German as an example. Text (1710s) means: "Weight management." Text (1711s) means: "What are your preferences?" Text (1712s) means: "Moderately reduce body weight" and stands, for example, for a reduction of 250 kcal less energy intake than the user's energy consumption. Text (1713s) means: "Significantly reduce body weight" and stands, for example, for a reduction of 500 kcal less energy intake than the user's energy consumption. Text (1714s) means: "Maintain body weight" and stands, for example, for an energy intake that corresponds to the user's energy consumption. Text (1715s) means: "Moderately increase body weight" and stands, for example, for an energy intake that is 250 kcal more than the user's energy consumption. Text (1716s) means: "Increase body weight significantly" and stands, for example, for an energy intake that is 500 kcal more

than the user's energy consumption. The illustration shows a selection option for the preference to be set by the user using the example of weight management. Selectable rates of change are offered. The user can set his/her preference, for example, by placing a cross below the category.

Fig. 17b shows an example of the system's user interface. The screen display is shown in German for illustrative purposes. Text (1720s) means: "Target daily intake." Text (1721s) means: "Total." Text (1722s) means: "Selected preference." Text (1723s) means: "Recommended target value, e.g., German Nutrition Society." Text (1724s) means: "Own target value." Text (1725s) means: "Fruit." Text (1726s) means: "Vegetables." The figure shows an example of how to enter a suggested and/or self-selected target value.

Fig. 17c shows an example of the system's user interface. The screen display is shown in German as an example. Text (1730s) means: "Nutritional quality." Text (1731s) means: "How quickly would you like to improve your nutritional quality?" Text (1732s) means: "Slow improvement / increasing target value." Text (1733s) means: "Moderate improvement / target value measured requirement." Text (1734s) means: "Rapid improvement / 2x measured requirement for fruit + vegetables." Text (1735s) means: "User-defined target value ... grams of fruit + vegetables." By entering this information, the user determines the speed at which he/she wants to achieve his/her daily fruits and vegetable intake targets. The reference value is, for example, the carotenoid status determined by measurement, which corresponds to a certain amount of metabolized fruits and vegetables. Carotenoids are considered the best indicator of fruit and vegetable intake. With the preference "Moderate improvement," the additional amount of fruits and vegetables that the user should consume daily corresponds to the requirement determined by measurement. If he/she selects the preference "Rapid improvement," he/she should consume twice the requirement determined by measurement. The more fruits and vegetables the user consumes daily, the faster the carotenoid levels measured in tissue and blood change. He/she can specify his/her preference for a speed category, for example, by placing a cross below the category.

Fig. 18 shows an example of the system's user interface. The screen display is shown in German for illustrative purposes. Text (1801s) means: "Suggestions for meals for one day." Text (1802s) means: "Selection." Text (1803s) means: "Meal." Text

(1804s) means: "Recipe No.". Text (1805s) means: "Dish". Text (1806s) means: "Breakfast Banana roll Vegetarian". Text (1807s) means: "Photo of the meal". Text (1808s) means: "Main dish Baked cod from the oven with vegetables Vegetarian". Text (1809s) means: "Photo of the meal". Text (1810s) means: "Main dish Green risotto with spring vegetables Vegan". Text (1811s) means: "Photo of the meal". Text (1812s) means: "Snack". Text (1813s) means: "Daily balance". Text (1814s) means: "815 grams, 0 grams, 125 grams". Text (1815s) means: "How well do the meals match your selected preferences?" Text (1816s) means: "Weight management." Text (1817s) means: "Moderate weight reduction." Text (1818s) means: "Nutritional quality." Text (1819s) means: "Moderate improvement." Text (1820s) means: "How well do the meals support your long-term well-being?" Text (1821s) means: "Healthy Food Relation," which stands for the "proportion of healthy food." Text (1822s) means: "Effect on your body weight." Text (1823s) means: "Vegetables." Text (1824s) means: "Fruit." Text (1825s) means: "ORAC." Text (1826s) means: "Fish." Text (1827s) means: "Meat". Text (1828s) means: "You are losing weight". Text (1829s) means: "15,199 µmol TE". Text (1830s) means: "-759 cal". Text (1831s) means: "Overall degree of fulfillment." Text (1832s) means: "Restart monitoring." Text (1833s) means: "Date 08/20/2022." Text (1834s) means: "Save daily balance." The user interface shows examples of the information the user receives when recipes or complete meals from a restaurant are suggested for his/her entire daily food intake and he/she selects certain suggestions. The daily selection is preferably evaluated automatically on the basis of the measurements determined by the measuring device and the preferences and higher-level categories selected by the user and displayed, for example, as a graph. The selection and evaluation for one day is shown as an example. The user can preferably make the selection for more than one day, for example for a period of one week, and have a corresponding shopping list generated or have the ingredients delivered by a supplier.

Fig. 19 shows an example of the system's user interface. The screen display is shown in German for illustrative purposes. Text (1901s) means: "Weight management history – ratio of kcal intake to daily energy requirement." Text (1902s) means: "Target kcal reduction achieved." Text (1903s) means: "Reduction < than target". Text (1904s) means: "Target kcal reduction achieved". Text (1905s) means: "History period in days". Text (1906s) means: "kcal intake greater than energy

requirement". Text (1907s) means: "Start 08/02/2022". Text (1908s) means: "On average, your kcal reduction is much better than your 4-week goal". Text (1909s) means: "Goal -250". Text (1910s) means: "Current average -456". Text (1911s) means: "Today 08/20/2022". As an example of automated, digital nutrition counseling, Fig. 19 shows the user the results of his/her weight management over the last 18 days, e.g., in the form of a bar chart. The chart shows the ratio of the caloric value of the food consumed (in kcal) to the user's daily energy requirement (in kcal) based on the preferences he/she has selected. Based on a zero line, the user has consumed less than his/her average daily intake on all days with negative values. On these days, he/she is losing weight. The dotted line shows whether he/she is achieving his/her target of -250 kcal/day. On all days where the bar crosses the line, he/she has achieved his/her self-set target. In this example, the user has decided that the calorie intake should be 250 kcal below the daily energy requirement, which was the case on 6 days. The automated nutrition advice also shows him/her that, based on the last 18 days, he/she has significantly undershot his goal/preference on average. The freely selectable maximum observation period in this example is 30 days.

Fig. 19a shows an example of the system's user interface. The screen display is shown in German for illustrative purposes. Text (1920s) means: "Calculation of the user's average daily energy consumption." Text (1921s) means: "Basal metabolic rate." Text (1922s) means: "Energy expenditure (basal metabolic rate*(PAL value-1))." Text (1923s) means: "Energy consumption (including factor for food intake)". Text (1924s) means: "Harris-Benedict". Text (1925s) means: "(kcal/day)". Text (1926s) means: "(kJ/day)". Text (1927s) means: "WHO & FAO*". Text (1928s) means: "DGE**". Text (1929s) means: "Mark preference with 'X'". Text (1930s) means: "Average value from the various calculations for daily energy consumption in kcal". Text (1931s) means: "*FAO=Food and Agricultural Organization of the United Nations" and is an explanatory text for text (1927s). Text (1932s) means: "* *DGE= German Nutrition Society (Deutsche Gesellschaft für Ernährung)" and is an explanatory text for text (1928s). This figure shows an example of the automatic calculation of the user's average energy consumption, whereby basic data such as age and gender have been entered by the user beforehand. The user has the option of selecting a specific calculation method or having the daily energy consumption determined as the average of four

calculation methods. In this example, the user has opted for the average of different calculation methods.

Fig. 20 shows an example of the system's user interface. The screen display is shown in German for illustrative purposes. Text (2001s) means: "Carotenoid measurement history." Text (2002s) means: "History period in days." Text (2003s) means: "Carotenoid measurements." Text (2004s) means: "Reduce/stop dietary supplement." Text (2005s) means: "Target range." Text (2006s) means: "Average value in: D, A, CH," which stands for Germany, Austria, and Switzerland. Text (2007s) means: "Critical zone." Text (2008s) means: "Start 02.08.2022". Text (2009s) means: "Your average carotenoid value is only slightly above the average value for – but the values show an upward trend". Text (2010s) means: "Today 08/20/2022." As an example of automated, digital nutritional counseling, Fig. 20 shows the user his/her carotenoid measurements for the last 18 days, as determined by the measuring device. Both a target range for the measurement values and a critical zone that should not be exceeded are indicated. To help users better classify their own measurements, the average values of users from other countries, such as Germany, Austria, and Switzerland, are also displayed. In this example, the freely selectable maximum viewing period is 30 days. By mutual agreement, users can also display their readings to each other for guidance or motivation. This can also be enabled for other information displayed by the system according to the invention.

Fig. 21 shows an example of a user interface of the system. The screen display is shown in German as an example. Text (2101s) means: "History of degree of fulfillment – How well the meals of a day correspond to all of your selected goals." Text (2102s) means: "Degree of fulfillment." Text (2103s) means: "Recipes No.:". Text (2104s) means: "Breakfast." Text (2105s) means: "Main course 1". Text (2106s) means: "Main course 2". Text (2107s) means: "Snack". Text (2108s) means: "Start 08/02/2022". Text (2109s) means: "On average, your meals provide you with an acceptable fulfillment of all your goals." Text (2110s) means: "History period in days." Text (2111s) means: "Current average 76.1%." Text (2112s) means: "Today 08/20/2022." As another example of automated, digital nutrition counseling, Fig. 21 shows the user how well the meals he/she has chosen over the last 16 days have corresponded to his/her various preferences or goals and what the overall degree of fulfillment is. For each day's meals, the respective dishes or

recipes are displayed, the overall degree of fulfillment for each day is shown, and the average fulfillment over the current period of use (16 days) is determined. The freely selectable maximum viewing period in this example is 30 days.

Fig. 22 shows an example of the system's user interface. The screen display is shown in German for illustrative purposes. Text (2201s) means: "Nutritional quality history – fruit and vegetable consumption and requirements." Text (2202s) means: "Fruit/vegetable content of selected recipes." Text (2203s) means: "Measured value – Additional fruit/vegetable requirement to meet the DGE recommendation." Text (2204s) means: "Grams of fruit + vegetables." Text (2205s) means: "DGE recommendation 650 g/day." Text (2206s) means: "Start 08/02/2022." Text (2207s) means: "You have exceeded your priority goal for the selected speed of behavior change on average. However, the measured biomarker shows that an equivalent of 650 g of fruits and vegetables is not yet present in your body." Text (2208s) means: "History period in days." Text (2209s) means: "Priority: moderate." Text (2210s) means: "Today 08/20/2022." As another example of digital nutrition counseling that users can automatically display on a display device, Fig. 22 shows the ratio of actual fruit and vegetable consumption to the daily requirement determined by the measuring device over the last 16 days, based on a speed (moderate) selected by the user to achieve the priority target of 650 g/day. The bars show the proportion of fruits and vegetables in the selected recipes or meals consumed, while the lines show the additional daily requirement for fruits and vegetables determined by the measuring device. Although the fruit/vegetable proportion is often more than 200 g above the target value of 650 g/day, the measuring device determines that the biomarker has not yet accumulated in the user's body to an extent that corresponds to an equivalent of 650 g of fruit/vegetables. This result points, on the one hand, to individual metabolism and possible quality problems with the fruit/vegetables consumed and, on the other hand, to the speed of the individual accumulation process of the biomarker in the user's body. The freely selectable maximum observation period in this example is 30 days.

Fig. 23 shows an example of the system's user interface. The screen display is shown in German for illustrative purposes. Text (2301s) means: "Healthy Food Relation history – ratio of grams of fruit + vegetables/kcal of the selected meals." Text (2302s) means: "History period in days." Text (2303s) means: "Grams/kcal." Text

(2304s) means: "Target value." Text (2305s) means: "Today 08/20/2022." Text (2306s) means: "Start 08/02/2022." Text (2307s) means: "On average, the ratio of fruit + vegetable consumption to the caloric value (kcal) of your meals is significantly worse than your target value." Text (2308s) means: "Current average 0.60." Fig. 23 shows an example of a digital nutrition consultation with automatic calculation of the ratio of fruit and vegetable consumption (e.g., in grams) to the caloric value of the meals (e.g., in kcal) consumed by the user. In this example, this ratio is called the "Healthy Food Relation." The target value for the ratio of grams/kcal is 1.0. In this example, it has not been reached by the user even once in the last 16 days. The example of bar chart clearly shows this: no bar reaches the target level of 1 (dashed line). The average value over the last 16 days is only 0.6. The freely selectable maximum observation period for the display of fruit/vegetable consumption was set to 30 days in this example.

Fig. 24 shows an example of the system's user interface. The screen display is shown in German for illustrative purposes. Text (2401s) means: "ORAC value history (µmol TE) – selected meals for one day." Text (2402s) means: "History period in days." Text (2403s) means: "ORAC value." Text (2404s) means: "7,000 µmol TE." Text (2405s) means: "Today 08/20/2022." Text (2406s) means: "Start 08/02/2022." Text (2407s) means: "On average, the target value of 7,000 µmol TE/day was significantly exceeded." Text (2408s) means: "Pulse 197%." Text (2409s) reads: "Current average per day." As another example of digital nutrition counseling that users can automatically display on a display device, Fig. 24 shows the automatic calculation of ORAC values for the meals selected by the user for a day. In this example, the target value per day is assumed to be 7,000 µmol TE. The meals selected by the user for a day usually exceed this target value significantly. The average value for the last 16 days is 13,816. The freely selectable maximum observation period for the display of ORAC values was also set to 30 days in this example.

Fig. 25 shows the back of a smartphone (1001) with a multi-camera unit (1002). This contains four cameras (1003), (1004), (1005), (1006)

Fig. 26 shows an example of how the smartphone from Fig. 25 can be expanded to a sensor according to the present invention. For this purpose, several light emitters are arranged in close proximity to the cameras. An example of a light emitter is (1007).

Fig. 27 shows the smartphone from Fig. 26 supplemented by a scale (1008) and a scale (1009), which facilitate the description of individual emitters. Two examples of light-emitting diodes are the emitter (1010) and the emitter (1011). A detector (1012) is also shown.

Fig. 28 shows a sectional view of a design example of a sensor integrated into a smartphone. The camera module (1012) shown in the section consists of an image sensor (1022) with numerous pixels. These include the pixels (1015) and (1016) selected as examples. There is also at least one lens (1014) mounted in a lens holder (1021). The lens holder and lens are preferably movable. A transparent cover (1013) protects the camera. The numbers (1018) to (1020) represent emitters. (1017) is a transparent surface that protects the emitters. Preferably, it forms a smooth surface with element (1013) and the non-transparent housing parts (5b). The object or sample (1023) to be measured is, in an advantageous variant, human tissue.

Fig. 29 uses Fig. 28 as an example to illustrate an area of the sample traversed by photons. The numbers have the same meaning as in Fig. 28. In addition, an area traversed by photons is marked with lines (1024) and (1025).

Fig. 30 uses Fig. 28 to illustrate another area of the sample traversed by photons. The numbers have the same meaning as in Fig. 28. In addition, an area traversed by photons is marked with lines (1026) and (1027).

Fig. 31 shows an advantageous structure of an evaluation algorithm. Level (I) shows the raw data. A number i of raw data is assumed. The raw data has a position in a feature space. For clarification and explanation, it should be noted that this is typically not a classic spatial position in the sense of a location. The crosses on the surface symbolize a raw data value of the i raw data on a two-dimensional feature surface, for example. Level (II) shows an example of a number k of continuous filter kernels, which represent functions that, in an advantageous variant, determine at least one output value for a plurality of the raw data values, taking into account their positions in the feature space. To symbolize the filter kernels, a representation is chosen that is familiar from maps showing the elevation of locations on a two-dimensional plane. Different elevations are represented by different colours and contour lines. The area over which the filter kernels are displayed corresponds to the area of the raw data features from layer (I). The grey scale above each point on the plane symbolizes a weighting applied by the filter

kernel. Output values are calculated for the filter kernels for the raw data points. The output values are represented in level (III) as k vectors with the elements $w_{i,k}$, where k stands for the number of the filter kernel and i for the number of the raw data. Level (IV) describes the reduction of the respective vector, preferably to a value for each filter kernel. Preferably, a reduction function is used for this purpose, i.e., in a particularly preferred variant, a sum. The reduction function is symbolized by a circle with a "+" sign. Level (V) shows an algorithm (ALG) that calculates an overall result value from the results of level (IV). In an advantageous variant, the algorithm (ALG) can be a multi-layer perceptron. The overall result value (ERG) is shown in level (VI).

Fig. 32 shows the improvements achieved by an evaluation algorithm according to Fig. 31 as a function of the number of unusable detectors. The vertical axis (y) shows the mean square of the prediction errors. The horizontal axis (x) shows the percentage of detectors excluded from the evaluation. The left column (cfn) shows the algorithm of the method according to Fig. 31. The right column (mlffn) shows the results that could be achieved with traditional methods. These show significantly larger errors.

Fig. 33 shows the distribution of the frequency of prediction errors as a histogram depending on the number of unusable emitters when using the advantageous design of the evaluation algorithms according to Fig. 31. The vertical axis (y) shows the frequency of occurrence of errors. The horizontal axis (x) shows the size of the errors. The percentage entered in the respective diagram area indicates the percentage of detectors that were blocked for the evaluation of the measurement.

Fig. 34 shows the distribution of the frequency of prediction errors as a function of the number of unusable emitters without using the advantageous design of the evaluation algorithms according to Fig. 31. A comparison of Fig. 33 and Fig. 34 shows that the frequency of larger errors is significantly higher without using the evaluation algorithm according to Fig. 31.

Fig. 35 shows an example of the housing of a miniaturized measuring device (30) with an example of sensor (20). It consists of a unit (9) of transparent parts of the sensor surface element (3) that allow photons to pass through and three-dimensional components (5) that are impenetrable or virtually impenetrable to photons. The measuring device has a removable positioning aid (P) for placing the sample, in

this example the hand, on the sensor, in such a way that the inside of the hand is measured in a specific area of the palm. In an advantageous design, the positioning aid (P) can be removed or moved or replaced by another positioning aid. This makes it possible to adapt the device to different hand sizes. Furthermore, the measuring device has a socket (3501), e.g., USB. Advantageously, the measuring device has operating elements, for example, an on/off switch and/or a button for establishing a radio connection. These can be arranged, for example, at locations (3502) provided for this purpose. In an advantageous design, openings for mechanical buttons can be provided in the housing. In an advantageous manner, these openings can also be closed in versions that do not require operating elements, as shown in the example in the figure.

Fig. 35a shows the example housing from Fig. 35 from a different perspective. The housing shown has signal LEDs for the WiFi function display (S1a), for the measurement progress (S1b) and a status display (S1c) (e.g., whether the device is switched on or not).

Fig. 36 shows the example sensor (20) from Figs. 35 and 35a without the transparent parts of the sensor surface element (3). The detectors and emitters of the sensor are shown, which are located in openings in the component (5b), the material of which is impermeable or virtually impermeable to photons. For reasons of space, only the detectors are numbered in Fig. 36. The example of sensor has 8 single-channel (2) and 1 multi-channel (2.4) detectors. Two dashed lines in Fig. 36 show examples of the length of a photon path or light path (1c). The distance between the two lines represents the photon path/light path between an emitter and a detector. The dashed lines identify the center of the emitter and of the detector, respectively. In an advantageous variant, the circuit board is coated together with the electronic components to protect the electronics from moisture.

Fig. 36a shows the example of sensor (20) from Fig. 35 with the emitters numbered. It has 28 emitters (1.1) that emit photons in a wavelength range, whereby the wavelength ranges may differ. Additional emitters (1.3) can emit photons in three different wavelength ranges, e.g., they can be RGB emitters. In an advantageous variant, the emitters (1.3) can emit yellow, green, and blue light. The emitters (1.3) can differ from one another in terms of the three wavelength ranges they can emit. The sensor has nine emitters of type (1.3). The emitters (1.1 and 1.3) can be

present in multiple instances within an opening. The sensor (20) contains four openings (see corner areas of the sensor) in the non-transparent element (5b), each of which contains an emitter and a detector, while all other openings contain either emitters or detectors. In one opening in the element (5b), a temperature sensor (40) is located in addition to optoelectronic components, for example. As an example of the length of a photon path or light path (1c), two dashed lines are shown in Fig. 36a. The distance between the two lines indicates, for example, the photon path/light path between an emitter and a detector. The dashed lines identify the center of the emitter and of the detector, respectively.

Fig. 36b illustrates that the part of the measuring device (30) labeled (20) is shown in detail in Figures 36 and 36a.

Fig. 37 shows a cross-section of a design example of the sensor surface element. It consists of one or more opaque elements (5b) and one or more transparent elements (3). It has a surface that can be brought into contact with the skin (4). The opposite side preferably rests on the printed circuit board. The side with the printed circuit board (not shown) is marked with (6). In an advantageous variant, the shape of the elements (3) and (5b) has a form-fitting connection that prevents the element (3) from slipping out of the element (5b) in the direction of the skin (4). In an alternative advantageous variant, the shape of the elements (3) and (5b) has a form-fitting connection that prevents the element (3) from slipping out of the element (5b) in the direction of the printed circuit board (6) (not shown). In a particularly advantageous variant, form-fitting connections prevent any movement of the element (3) relative to element (5b).

Fig. 38 shows an example of the transparent elements (3) from Fig. 37 or Fig. 35. In an advantageous variant, the sprue area (3ag) is arranged so that it is located to the side of the optically used window area. In an alternative (not shown in the figure) advantageous arrangement, the sprue is located in the center of the window area. In an alternative (not shown in the figure) advantageous arrangement, the sprue is located in the window area, but not centrally above an emitter. The step (3st) is an advantageous design feature for the form-fitting connection (Fig. 37, 5st) already explained in Fig. 37 for fixing the transparent elements (3).

Fig. 39 shows the elements of Fig. 38 from the underside. The reference symbols correspond to those in Fig. 38.

Fig. 40 shows a non-transparent element (5b) matching the transparent elements shown in Figs. 38 and 39. It may preferably have form-fitting elements for fixing (5st). Elements (5p) may be provided to facilitate precise positioning of the element (5b) relative to electronic components. In an advantageous variant, the cavities in the component (5b) have bulges (5ab). This can be advantageously used to create the space that is required, for example, for sprues of the transparent elements or for electronic components or their connections. In an advantageous variant, the element (5b) can be manufactured by producing it in a 2K injection molding process together with the transparent elements (as shown, for example, in Fig. 38). In an advantageous variant, the non-transparent elements are injection molded first, after which the transparent elements are. In an advantageous variant, the plastic of the transparent components has a lower softening temperature than the plastic of the non-transparent parts. In an advantageous variant, the transparent and non-transparent components are connected in such a way that no water can pass through the gap between these components to the printed circuit board.

Fig. 41 shows an advantageous variant of the structure of the transparent and non-transparent components of the sensor surface. An opaque component (5b1) is shown on the left side of the image. A transparent component (3) is inserted into this. In an advantageous embodiment, the transparent component is connected to an element (3ag) which connects several, or, preferably, all of the transparent parts. This facilitates the insertion, for example, since each transparent part does not have to be inserted individually and in a specific position. The right-hand side of the image shows the component (5b2) which is attached. In an advantageous variant, the parts (5b1) and (5b2) are connected, e.g. by gluing, welding or locking. In an alternative variant, the elements (5b2) and (3) can also be clamped between the printed circuit board and (5b1). In an alternative embodiment, (5b1) and/or (5b2) are connected to (3). In an advantageous embodiment, the components have a separation point (3tg) at which plastic parts not required for the device can be separated. Preferably, the separation process interrupts connections made of transparent material, ensuring that light must pass through the sample in order to travel from the emitter to the detector. In an advantageous variant, parts (3ar) are not incorporated into the end product but are removed beforehand, for example.

Fig. 42 shows an advantageous variant of the structure of the transparent and non-transparent components of the sensor surface. An opaque component (5b) is shown on the left of the image. A transparent component (3) is inserted into it, which is shown on the right-hand side of the image from above and below. In the center of the image, the transparent components (3) are inserted into the non-transparent component (5b). In an advantageous arrangement, the shape of the components is designed so that they cannot fall out onto the skin contact side. In an advantageous arrangement, the shape of the components is designed so that the transparent components can rest on the circuit board. In an advantageous design, the non-transparent element also touches the circuit board. In an alternative advantageous design, the circuit board does not touch the elements shown in Fig. 42 directly, but via a layer of adhesive or double-sided adhesive tape. In an advantageous variant, the transparent and non-transparent components can be manufactured in a common 2K injection molding process. In an advantageous variant, the transparent elements are injected first, after which the non-transparent ones are. In an advantageous variant, the plastic of the non-transparent components has a lower softening temperature than the plastic of the transparent parts.

Fig. 43 shows an advantageous variant of the structure of the transparent and non-transparent components of the sensor surface. An opaque component (5b) is shown on the right of the image. A transparent component (3) is inserted into it. In an advantageous design, the transparent component is connected to an element (3ag), which connects several, or, preferably, all of the transparent parts. This facilitates the insertion, for example, as each transparent part does not have to be inserted individually. In an advantageous variant, the parts (5b) and (3) are connected, e.g., by gluing, welding, or locking. In an alternative variant, the elements (5b) and (3) can also be glued to the printed circuit board. In an alternative variant, (5b) is connected to the printed circuit board by inserting elements (5p) through openings in the printed circuit board. These elements can preferably hook into the printed circuit board. In an alternative advantageous variant, such elements can also be deformed after being inserted in order to establish a connection with the printed circuit board. The elements (5p) are preferably deformed by heat and/or force.

Fig. 44 shows an advantageous variant of the structure of the transparent and non-transparent components of the sensor surface. An opaque component (5b) is shown on the left of the image. Transparent elements (3) are shown on the right of the image. The center of the image shows the connection between the transparent and non-transparent elements. In an advantageous design, the element (5b) is shaped so that it can be produced by milling. Preferably, element (5b) is made of metal. Preferably, the metal is aluminum. Preferably, the transparent elements (3) are made of plastic. In a preferred variant, the elements (3) are made of a thermosetting plastic. In an alternative variant, the elements (3) are made of a thermoplastic. In a preferred variant, the elements (3) are made of epoxy resin or silicone. In a preferred method, the non-transparent element (5b) is produced first. Then, preferably, a plastic in liquid form is introduced into the cavities (5k) of the non-transparent element (5b). In a preferred variant, the plastic is prevented by a mold from occupying the space of the cavities (3k). In a particularly preferred variant, the mold displaces the plastic from the area in which the cavities (3k) are to be formed. In an advantageous variant, the mold has elements (3st) and/or (5st) which effect a form-locking connection in at least one direction of force. In an advantageous variant, the transparent elements are shaped so that they completely enclose the electronic components arranged on the printed circuit board together with the printed circuit board. In an advantageous embodiment, the electronics are protected from moisture by waterproof bonding of the transparent component (3) and the printed circuit board.

Fig. 45 shows an example of the prediction quality of the body mass index (BMI). The actual BMI of the test subjects is plotted on the horizontal axis (x). The vertical axis (y) shows the value determined from the non-invasive optical analysis of human tissue on the palm of the hand according to the invention. There is a good correlation between the values. In an advantageous variant, the value determined by the non-invasive sensor corresponds better to the amount of body fat than the BMI.

Description

It should be noted that all features apparent to a person skilled in the art from the present description, the drawings, and the claims even if they are only described in connection with certain other features, can be combined individually or in any combination with other features or

groups of features disclosed herein, unless this has been expressly excluded or unless technical circumstances make such combinations impossible or meaningless. For the sake of brevity and readability of the description, a comprehensive, explicit presentation of all conceivable combinations of features is omitted here.

The system consists of at least one or more sensor components, one or more data processing devices and, in an advantageous variant, additionally one or more display devices. In an advantageous variant, the system also includes at least one data storage device.

The above-mentioned system components can be integrated into a single device. However, their functionality can also be divided among several devices. In particular with regard to data processing and display, advantageous variants use systems with which users are already equipped. These can be, for example, smartphones, smartwatches, computers, or similar devices. In particular, data processing functions can also be performed in the cloud. In an advantageous variant, data is stored on a server accessible via the Internet. In an advantageous variant, data from different users can be used to calculate recommendations for a user. In an advantageous variant, statistical bases for optimizing the recommendations can be automatically incorporated.

In an advantageous embodiment, the system according to the invention can be designed as a stand-alone measuring device that is used exclusively for measuring certain parameters and/or substances and/or physiological states of humans. In a further preferred embodiment, the device according to the invention or parts of the device, such as the sensor components, can be integrated into other technical systems that have their own functionality and which the user uses in different contexts, for example, in cooking, hygiene, sports, communication, hiking, transportation, transportation, with the help of technical devices such as airplanes, cars, two-wheelers, or in the work process. The integration can be carried out, for example, in the following technical systems, objects, or materials: smartphones, smart watches, fitness trackers, pedometers, wristbands, compasses, altimeters, walking aids, clothing, gloves, computer mice, telephone handsets, armrests, handles, steering wheels, kitchen appliances, bathroom scales, kitchen scales, toilet seats, glasses, gear levers, dashboards, machines used in the production of goods. In a particularly advantageous variant, the sensor components are integrated into surfaces of devices that come into direct contact with human skin. In a particularly advantageous variant, they are integrated into handles or control elements. Integration into devices that serve at least one other function besides measuring the user is particularly advantageous, so that the user of these devices can be measured without having to spend time on the measurement that he/she would not have needed to spend on using another function of the device anyway. Integration into

a surface of the device that the user touches with his/her skin when using the other function is advantageous.

In an advantageous variant of the system, the measurements and/or measurement results and/or recommendations made with the system can not only be made available to the user of the system, but can also be digitally forwarded to third parties or handed over to third parties in printed form. The group of third parties may include natural persons, legal entities, or institutions.

Digital forwarding can take place automatically or on a case-by-case basis at the request of the user, the person authorized by the user, or the owner of the system. Natural persons may include medical personnel such as doctors or alternative practitioners, but also nutritionists. For example, the person or institution receiving the data may supplement or comment on the measurement results and/or recommendations with their own data, store measurement results and/or recommendations and/or additions and/or comments on a medium, and/or transmit them to the person measured, e.g., digitally. In the case of comments or additions to the measurement results, this data may also be used to subsequently optimize the advice given to the individual user or to improve the advice given to an individual user based on a summary and/or analysis of comments or additions made by different persons.

The stored data may also be transferred to a medium belonging to the person being measured, which can then be presented to a doctor, for example. This may be a storage medium on which the person's medical data is stored, such as an electronic health card. Alternatively, the data may be stored on the person's smartphone. Storage does not have to take place immediately after digital transmission, but can be done later by downloading from a server that is accessible via the Internet, for example.

The institutions may be, for example, hospitals, health insurance companies, or public institutions such as health authorities, state or federal ministries, statistical offices, or, in the context of a survey, the institution conducting the survey.

The measurement results and/or recommendations may be forwarded to third parties in encrypted or unencrypted form. In an advantageous variant, the results are anonymized or pseudonymized.

Examples of parameters and body parts that can be measured with the system

In an advantageous embodiment, for example, one or more of the following parameters can be measured in a single measurement process with the measuring system: body fat, water, blood sugar, carotenoids, in each case in tissue and/or blood.

In a further technical embodiment, the invention enables the simultaneous or alternative measurement of cortisol, alpha-linolenic acid (omega-3 fatty acid), arachidonic acid (omega-6 fatty acid), linoleic acid (omega-6 fatty acid), riboflavin (vitamin B2), and C-reactive protein.

In a version that goes beyond the aforementioned versions, the invention enables the simultaneous or alternative measurement of telomeres or advanced glycation end products (AGE). In a further preferred version, the system detects one or more of the following parameters: inflammation, local inflammation of the skin, sunburn, the skin's sensitivity to sunlight, applied sunscreen, and the skin's antioxidant protection potential. In a further advantageous embodiment, the measuring device can be used to detect malaria, for example by measuring plasmodia in the blood. Alternatively, the pathogens of other diseases or the effects thereof can be detected.

In an advantageous variant, the substance or disease is not detected directly by optical measurement, but instead, a variable correlating with the disease of interest and affecting the optical properties of the skin is detected. This allows the detection of substances and conditions that cannot be determined directly, or only very inaccurately.

In a particularly advantageous embodiment, the device can determine or at least estimate at least two, preferably three, and particularly preferably four or more of these parameters. In a particularly advantageous embodiment, at least several of the parameters can be determined in a single measurement.

The measurement of parameters and/or substances with which the physiological condition of a person can be assessed is advantageously performed transcutaneously and can be performed at different locations on the body. In a preferred variant, the measurement is performed at body locations that are not normally covered by clothing. In a further preferred variant, the measurement is performed at body locations with lower pigmentation. For example, this can be the inside of the hand in the area of the ball of the thumb or the sole of the foot of the person to be measured. The measurement is also possible, for example, on the wrist, cheek, arm, thigh, buttocks, or any other part of the body that can be brought into contact with the sensor. In an advantageous variant, the measurement is performed on areas of skin with little hair. For example, on the hand, foot, or face.

Surprisingly, it was found that in a preferred embodiment, when measuring with the device, the body part to be measured does not need to be pretreated by washing, disinfecting, preheating, cooling, rubbing dry, removing calloused or dead skin layers, or evaporating the uppermost skin layer in order to produce correct and repeatable measurement results. Surprisingly, it was found that in a further preferred embodiment, the body part to be measured in the aforementioned sense

can be pretreated in different ways without affecting the accuracy of the measurement results and that the type of pretreatment can be determined from the measurement results, for example. An advantageous method for performing the measurement is that the measurement does not take place at body locations where there is a tattoo and/or a scar and/or a wound and/or an injury and/or a sebaceous gland and/or a sweat gland and/or a blood vessel and/or contamination and/or moisture and/or sweat and/or blood and/or hair and/or birthmarks and/or age spots and/or wrinkles and/or skin dimples and/or skin cream and/or sunscreen or sun milk and/or skin lotion and/or perfume.

In a surprising finding, an advantageous embodiment of the invention has shown that the measurement produces accurate and repeatable results even when the measurement is taken at body locations where part of a tattoo and/or a scar and/or a wound and/or an injury and/or a sebaceous gland and/or a sweat gland and/or a blood vessel and/or contamination and/or moisture and/or sweat and/or blood and/or hair and/or birthmarks and/or age spots and/or wrinkles and/or skin dimples and/or skin cream and/or sunscreen or sun milk and/or skin lotion and/or perfume are located. This is possible with an advantageous design of the sensor, as shown in the embodiments. Embodiments that use more light paths over a larger area are particularly advantageous.

Surprisingly, it was found in a preferred embodiment that measurements at the aforementioned body locations yielded accurate and repeatable measurement results from which, for example, the respective measurement location can be determined.

Sensor components

Preferably, an optical system that measures various parameters and/or substances and/or physiological states of the individual uses emitters (1) and detectors (2) as sensor components, which emit and detect photons in wavelength ranges that are tuned to the respective parameters, substances and/or physiological states. Depending on the parameter, substance, or physiological state and/or the number of parameters, substances, or physiological states to be measured, the systems have a different number of emitters (1) and detectors (2). Together, they cover wavelength ranges that enable the measurement of the parameters and/or substances and/or physiological states. For example, it is made use of one wavelength at which the substance to be measured absorbs the light and of a second wavelength at which the substance does not absorb the light. By comparing the measurement results of both wavelengths, conclusions can be drawn about the substance concentration. However, more complex arrangements are usually advantageous. This involves using multiple wavelengths at which a substance absorbs light and

multiple wavelengths at which the substance does not absorb light or absorbs less light. This allows a substance to be detected more reliably, and also takes into account the influence of other substances that absorb light. For this reason, it is advantageous to use light emitters with different wavelengths and/or light detectors with different wavelength sensitivities. In an advantageous variant, the arrangement is designed so that there are several light paths of one wavelength. This means, for example, that there are several emitters with the same or approximately the same wavelength and/or that there are several detectors with the same or approximately the same wavelength detection range. The advantage of such an arrangement is that deviations affecting a light path, e.g. because the skin at the point of incidence has a special feature or because contact with the skin was not optimal, can be detected and compensated for. To illustrate a simple variant, one can say that several measurement paths of comparable wavelength for light paths from an emitter to a detector are compared. In a simple, advantageous variant, outliers in the measured values can be detected and excluded from the evaluation, which makes the overall measurement result more accurate. For this reason, it is advantageous to use several light emitters with the same or approximately the same wavelength and/or light detectors with the same or approximately the same wavelength sensitivity. It should be noted here that the simple direct comparison of the measured values with the same wavelength is only a greatly simplified example to illustrate the motivation for using emitters with the same wavelength, for example. More sophisticated and powerful data processing approaches are possible, which will be explained later.

It has been explained that it is advantageous to use emitters and/or detectors with both the same and different wavelengths. In the prior art, there are therefore arrangements in which several groups of emitters with the same colour are used. For example, there are arrangements with four red LEDs as emitters and four green LEDs as emitters. In such arrangements, there is a clear difference in wavelength between the two groups, red and green, but within a group, an attempt is made to keep the emitted wavelength as constant as possible in order to ensure direct comparability between the measurement signals obtained using different emitters of the same colour. In an advantageous variant according to the invention, however, a significant improvement in measurement accuracy is achieved by not selecting the emitters so that they have exactly the same wavelength. In an advantageous variant, the emitters are only approximately the same and the differences between the emitters are deliberately exploited. This means that the system comprises sensor components, e.g., emitters and detectors, which may be identical, approximately identical, and/or non-identical and/or non-approximately identical in their technical properties.

The emitters can be LEDs, incandescent lamps, or generally components that emit photons at approximately the same or different wavelengths.
Detectors can be, for example, photodiodes, phototransistors, or other light-sensitive electronic components, in particular semiconductors or, in general, components that can receive photons emitted or radiated by emitters and convert them into signals, for example, to measure parameters, substances, and/or physiological states of the individual.

Approximately identical sensor components

In an advantageous variant, the system comprises emitters in which approximately identical emitters and/or emitters of the same type exhibit fluctuations in at least one of their optical properties in comparison with each other. This applies, for example, to optical properties such as the emitted wavelength spectrum (lowest wavelength to highest wavelength), the peak wavelength, the center wavelength, the peak half-width, the full half-width (FWHM), the half half-width (HWHM), the radiation characteristic, the temperature dependence, the brightness (luminous intensity and radiance), and the current consumption. In an advantageous variant, the system comprises detectors in which approximately identical detectors and/or detectors of the same type exhibit fluctuations in at least one of their optical and/or electrical properties. This applies, for example, to the peak wavelength and center wavelength of the wavelength range in which the detectors receive photons, the amplification factor with which the received photons are converted into electrical signals, the signal response, the responsivity, and the signal-to-noise ratio.
By variations in approximately identical sensor components, i.e., variations in emitters or emitters of the same type and variations in approximately identical detectors or detectors of the same type, we mean limited differences in at least one optical and/or electrical property of the emitters and detectors among themselves.
In order for different values of a technical property to be considered fluctuations of approximately identical sensor components or sensor components of the same type, the respective values must lie within the limits of a defined interval. The intervals may vary depending on the technical property. In a preferred variant, a sensor can have several intervals with different interval lengths for a given property, e.g., the peak wavelength of the sensor components. In a preferred variant, the sensor of a measuring device can only have one interval of approximately equal emitters and/or one interval of approximately equal detectors.
In a particularly advantageous variant, the distribution of the values of the optical and/or electrical properties of approximately equal sensor components in measuring devices produced

in series is not the same for every measuring device produced. The distribution of the variation can be introduced into the measuring device in various ways. An advantageous method consists of selecting sensor components and, when equipping the measuring device with emitters and detectors, of specifically using some components with higher values and some with lower values of the respective property. In an alternative variant, the variation in the optical properties of approximately identical sensor components is generated by forming a set of sensor components in which the value of the optical and/or electrical property lies within a selected interval. When equipping the measuring device with emitters and detectors, a random selection of a component from this set can be made for each mounting position, so that the variation is statistical in nature. In an advantageous variant, this statistical method is cost-effective and functional if the number of approximately identical components is large enough, and, in particular, if at least 4 components of a group have the same properties, but preferably at least 5, at least 6, or, most preferably, at least 8 components are approximately identical.

The advantage of using approximately-equal emitters and/or detectors that exhibit variations in at least one property within certain limits is that, as a result of the variation, more information about the parameter to be measured and/or the substance to be measured and/or the physiological state to be measured is collected than with a device that does not exhibit these variations with equal emitters or detectors. The greater breadth of information obtained in this way increases the measuring accuracy of the measuring device. It is particularly advantageous if the dependence of the optical signal on the varying parameter is highly informative about the substance to be detected. This is advantageous, for example, in the case of variations in the peak wavelength of the emitters, as this allows the wavelength-dependent absorption gradient of a substance to be determined. In an advantageous variant, this gradient can also be compensated if it could produce a result-distorting effect. This is particularly relevant because there are substances that one would like to distinguish, and which differ in their absorption only in ranges that exhibit strong absorption gradients. However, measurement in ranges where the absorption varies greatly with wavelength is often not possible with the desired accuracy using known methods.

Surprisingly, it was found that it is possible, in the production process, to transfer the higher measurement accuracy to all devices produced, to reduce the standard measurement error of the devices, and to calibrate the devices so that, for example, when measuring the same person, the measurement results of the devices deviate less from each other. For example, measurements can be taken on test specimens during the production process and the larger amount of data resulting from the variation of approximately identical sensor components can be analyzed using algorithms. The result is, for example, device-specific algorithms for determining the

concentration of parameters, substances, or physiological states of humans. In an advantageous variant, device-specific algorithms are understood to mean that the algorithms of several devices of the same device type are different. In an alternative variant, the algorithms of several devices of the same device type have different parameters for the algorithms used. In a particularly advantageous variant, there are more parameters than just the correction of the zero point of the result and the amplification factor. In an advantageous variant, the number of parameters used is at least as large as the number of components in at least one group of components of the same type.

Algorithms can also be understood as methods of artificial intelligence.

In addition, cost advantages arise because the use of such sensor components means that lower requirements can be placed on the manufacture of the emitters and detectors or their selection after manufacture.

Description of the intervals of approximately identical sensor components

Depending on the substances to be measured or on the physiological states to be measured, the measuring device advantageously has emitters that can irradiate photons with specific wavelengths into the skin and detectors that detect these photons. As soon as more than one emitter is required for the measuring range in order to determine the concentration of a substance or the physiological state, the emitters and the detectors suitable for detecting the photons can be assigned to wavelength intervals.

In this patent specification, the size of the interval (interval length) is defined as the value between the lower and upper limits of the interval.

In a preferred embodiment, individual emitters or detectors can only belong to one interval. In another preferred solution, the limits of the intervals must not overlap. In another preferred solution, the difference between the upper limit of one interval and the lower limit of another interval is up to 1 nm. In further preferred variants, the difference is up to 2 nm, up to 5 nm, up to 10 nm, up to 20 nm, up to 50 nm, up to 100 nm, up to 200 nm, up to 500 nm, up to 1000 nm. In a preferred embodiment, the difference between the upper limit of the interval and the lower limit of each interval above it is at least one of the specified values.

In a preferred solution, the measuring device may also have emitters or detectors that cannot be assigned to an interval. These sensor components are considered non-approximate sensor components. In another preferred solution, the measuring device may have several such emitters or detectors.

The wavelength range covered by all intervals with approximately equal sensor components of a measuring device is defined as follows: When comparing all intervals of a measuring device with each other, the wavelength range covered by all intervals together is determined by the lowest lower limit and the highest upper limit of all intervals. Figures 14 and 14a show corresponding examples.

In a preferred embodiment, this difference between the lowest lower value and the highest upper value of all intervals is a maximum of 10 nm. In other preferred embodiments, it is a maximum of 20 nm, up to 50 nm, up to 100 nm, up to 200 nm, up to 500 nm, up to 1000 nm, up to 1500 nm, or up to 3000 nm. In an alternative preferred embodiment, the wavelength range between the lowest and highest values is at least 50 nm, preferably at least 150 nm, and in a further preferred embodiment at least 400 nm. In a particularly preferred variant, for example, the intervals of a measuring device are distributed over at least 2, preferably at least 3, and alternatively preferably all frequency ranges of blue, green, red, and near-infrared (NIR) light.

Fig. 14 shows an example of this with regards to the technical property of the peak wavelengths of emitters. In a preferred variant, the interval lengths of the different intervals of a technical property can be identical, as shown in the example of the peak wavelength of emitters in Fig. 14. The interval lengths for the different intervals in the blue, green, red, and NIR ranges of light are, for example, 10 nm each.

Examples of intervals of peak wavelengths of approximately equal emitters			
Frequency range	Lower interval limit	Upper interval limit	Interval length
Blue	460 nm	470 nm	10 nm
Green	530 nm	540 nm	10 nm
Red	650 nm	660 nm	10 nm
NIR	850 nm	860 nm	10 nm

In another preferred variant, there are differences in the interval lengths of a technical property, as shown in the example of the half-value width of emitters (see Fig. 14a).

Note: Among the wavelength intervals covered by the half-width, this is not understood as the half-width of a single emitter, but as the interval within which the wavelengths of all emitters of the interval are located, which are emitted by the respective emitter with at least 50% of the intensity of its peak wavelength.

Examples of wavelength intervals covered by emitters with approximately equal half-widths

Frequency range	Lower interval limit	Upper interval limit	Interval length
Blue	454 nm	476 nm	22 nm
Green	520 nm	547 nm	27 nm
Red	640 nm	668 nm	28 nm
NIR	840 nm	870 nm	30 nm

In a particularly preferred variant, the measuring device may have intervals which the interval limits of are designed such that there are no gaps between the intervals over the entire frequency range covered, for example, by the emitters of a measuring device.

Figures 14 and 14a use the example of emitters to illustrate that using approximately identical sensor components that nevertheless vary within interval limits generates more information because the bandwidth of the emitted light is greater. Measuring devices in which approximately identical sensor components do not exhibit these fluctuations necessarily have a lower bandwidth for the emitted light. The range of information generated by the measurement is therefore smaller.

As can be seen in Fig. 14a, using the example of the wavelength intervals covered by the half-width, the emitters of an interval all have the same half-width, but the wavelength range covered by the respective half-width differs from emitter to emitter. In Fig. 14a, the dashed line (1b) shows the intensity limit of the half-width. It applies to all emitters in the four intervals. In the "green" interval, the interval length covers the wavelength range from 520 nm to 547 nm. However, the wavelength intervals covered by the half-width of the four emitters in this interval together cover a wavelength range that is smaller than the wavelength range determined by the length of the green interval (10cg). This is different in the "blue" interval (10cb). The wavelength intervals covered by the half-width of the six emitters together cover exactly the interval from 454 nm to 476 nm, since the half-width coverage of the first emitter begins at 454 nm and the half-width coverage of the sixth emitter ends at 476 nm.

In an advantageous embodiment, the accuracy of the measurement of a substance is influenced by the design of the intervals for approximately equal sensor components which the technical properties of vary within an interval. The following principle applies: the smaller the interval length and the greater the number of sensor components in an interval, the higher the spectral resolution when measuring the substance or a physiological state. In many applications, this allows a more accurate determination of the corresponding concentration. However, the method of using the measurement data obtained from several emitters located in an interval to determine the slope of the function of the measured light intensity as a function of wavelength is

particularly advantageous. Advantageously, it is not necessary to use emitters with precisely predefined peak wavelengths; instead, a sufficient number of emitters that differ in peak wavelength and which the peak wavelength of is known or determinable is sufficient. Furthermore, known information about the sample can be entered, for example, if it is known that the aforementioned slope in the wavelength interval can be considered to be almost constant. The method described can also be applied to other parameters, and, in particular, to other wavelength measurements. The center wavelength of an emitter, which can optionally be weighted, e.g., with the wavelength-dependent sensitivity of the detector, is particularly advantageous here. In a further preferred solution, individual emitters or detectors can belong to more than one interval.

In a preferred solution, there may be overlaps between the upper limit of one interval and the lower limit of another interval. In another preferred variant, the overlap may be up to 2 nm, up to 5 nm, up to 10 nm, up to 20 nm, or up to 50 nm. In a preferred variant, the overlaps for the respective range do not have to be the same; there may be combinations of different overlap widths. In a further preferred variant, there are gaps between the intervals as well as intervals directly adjacent to an interval, and overlaps between the intervals. This is illustrated by the example of the peak wavelength of emitters for the wavelength range from 250 nm to 460 nm:

an interval with an interval length of 50 nm covers the range from 250 nm to 300 nm, a directly adjacent interval with an interval length of 10 nm covers the range from 301 nm to 311 nm, another interval with an interval length of 50 nm covers the range from 320 nm to 370 nm, an overlapping interval with an interval length of 30 nm covers the range from 360 nm to 390 nm, and another interval with an interval length of 50 nm covers the range from 410 nm to 460 nm.

In a preferred embodiment, the wavelength range covered by all intervals of approximately equal sensor components for a property is a maximum of 50 nm. In other preferred variants, it is a maximum of 100 nm, up to 200 nm, up to 400 nm, up to 600 nm, up to 800 nm, or more than 800 nm. In a preferred embodiment, the wavelength range covered by all intervals of approximately equal sensor components for a property is at least 50 nm. In further preferred variants, it is at least 100 nm, up to 200 nm, up to 400 nm, up to 600 nm, up to 800 nm or more than 800 nm.

In a further preferred variant, the wavelength range covered by all intervals of approximately equal sensor components for a property begins between 200 nm and 250 nm. In further preferred variants, it begins between 250 nm and 350 nm, between 350 nm and 450 nm, between 450 nm and 550 nm, between 550 nm and 800 nm, or between 800 nm and 1400 nm.

In another preferred variant, the wavelength range covered by all sensor components with approximately the same sensor components for a property ends below 2000 nm. In further preferred variants, it ends between 1500 nm and 2000 nm, between 1000 nm and 1500 nm, between 500 nm and 1000 nm, or between 200 nm and 500 nm.

Emitters

For the assignment of emitters to a group of approximately identical emitters, an interval length in the following size ranges is selected in a preferred variant for the interval length of the peak wavelength and/or the center wavelength of the emitters: 1 nm to 5 nm, 2 nm to 20 nm, 10 nm to 50 nm, 20 nm to 150 nm. In an advantageous variant, there must be at least 2 emitters in each interval. In further advantageous variants, there must be at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, at least 10 emitters in an interval.

In a preferred variant, there are at least two emitters in an interval of which the peak wavelength and/or center wavelength differ by at least 0.5 nm. In further preferred embodiments, the difference is at least 1 nm, at least 2 nm, at least 4 nm, at least 8 nm, at least 10 nm. In an alternative advantageous variant, the difference in peak wavelength and/or center wavelength of the emitters described above occurs only in some of the measuring devices produced, preferably in at least 1%, particularly preferably in at least 10% and particularly preferably in at least 90% of the measuring devices.

The wavelength range covered by the half-width of an emitter can also be used to assign emitters to a group. An example is shown in Fig. 14d. In an advantageous variant, the measuring device in the aforementioned sense has at least one property of the emitters within a group of approximately equal emitters with an emitter number of at least 2, preferably at least 3, preferably at least 4, preferably at least 5, preferably at least 6, preferably at least 7, preferably at least 8, preferably at least 9, preferably more than 10 emitters.

Fig. 14e shows five groups with two emitters each using the example of the peak wavelength; Fig. 14b shows an example of four emitters in a group, and Fig. 14 shows an example of six emitters in a group for the intervals blue (10cb), red (10cr), and NIR (10cir).

In a preferred embodiment, the measuring device in the aforementioned sense includes, for at least one property of the emitters, several groups of approximately equal emitters, which have a larger number of emitters, while other groups have a smaller number of emitters. For example, Fig. 14 shows three groups with six approximately equal emitters and one group with four approximately equal emitters.

For one property of the emitters, it is advantageous to form a group of at least two, but preferably three, four, five, six, or more than six groups, each group having an interval for the corresponding property. Advantageously, for at least one property of the emitters, the measuring device has at least a first group number of approximately equal emitters from the above set of advantageous numbers, which contain at least one emitter number from the above-mentioned advantageous emitter numbers. With reference to the peak wavelength, for example, Fig. 14 shows three groups, each with 6 emitters.

Advantageously, the measuring device has at least one further group from the above set of advantageous group numbers for at least one further property of the emitters, which contain at least one emitter number from the above advantageous emitter numbers.

The measuring device is particularly advantageous if at least one property of the emitters has, for example, at least 3 groups of approximately equal emitters with at least 4 emitters each. In an advantageous variant, at least one property of the emitters additionally has at least one group of approximately equal emitters with at least 5 emitters. In a further advantageous variant, there are at least 4 groups of approximately equal emitters with at least 2 emitters each for at least one property of the emitters. An example of such an arrangement is shown in Fig. 14e. The term "group or groups" introduced above is often used synonymously with the term "interval" in the relevant context. For a measuring device, therefore, the statements "number of intervals" or "number of groups" refer to the same fact in the relevant context. However, the term "interval" is always used in the figures, as this also allows the lower and upper interval limits of the wavelength range in which approximately equal emitters or approximately equal detectors are located to be determined.

In preferred variants, a measuring device has at least 5, at least 6, at least 7, at least 8, at least 9, at least 10 intervals with approximately equal emitters, whereby the intervals each cover different wavelength ranges that do not overlap and the intervals each contain at least 2 approximately equal emitters. In another preferred variant, there is also a measuring device which, analogous to the aforementioned measuring device, has an equal number of intervals with approximately equal emitters, but in which at least two intervals overlap with approximately equal emitters. In a preferred variant, the emitters of an interval do not cover the entire width of the interval. This means that for emitters assigned to an interval, the values of the property do not scatter so widely, or the values do not differ so greatly, and that the full bandwidth of the interval is required in order for these emitters to be assigned to the interval. Fig. 14b and 14e show, using the example of the peak wavelength, that the emitters of an interval are not distributed over the entire interval length.

In another preferred variant, there are no gaps between the intervals of approximately equal emitters in an optical property of the emitters. In an advantageous variant, the method is used in the production of a device according to the invention, whereby at least one optical property of at least one part of the emitters is measured. In an alternative advantageous variant, the measurement during production can be omitted by inferring at least one optical property of the emitters from the measured values of several measurements performed by the user. This can be done, for example, by mathematical or statistical methods or AI algorithms.

In an advantageous variant, numerous product pieces of the device according to the invention are produced and placed on the market. The product pieces placed on the market are used to perform numerous measurements. It is particularly advantageous to record a large number of measured values and, in an advantageous variant, to store them, e.g., by transferring the measured values to one or more external servers, e.g., by using an Internet connection.

In an advantageous embodiment, the measured values recorded in this way are used, for example, to gain insights into possible improvements to the product. In an alternative advantageous embodiment, the accuracy of the devices in the field can be improved either on the basis of their individual measured values or on the basis of statistical values of all devices, or by a combination of both.

In an advantageous embodiment, the device is designed so that the raw optical data can be recorded individually. In a particularly preferred embodiment, the individually recorded data can be stored. This allows a subsequent optimization of the device using the above-mentioned methods, even if these are not yet in use at the time of market launch, for example. In this context, raw optical data is understood to mean information from which the properties of individual emitters can be inferred. In a particularly advantageous variant, it is therefore stored the information which is recorded by one or more detectors when only one of the emitters is activated.

In an advantageous manner, not only is recorded the information in which several emitters of an interval with approximately the same optical properties are activated simultaneously and are therefore located in close proximity to each other, and therefore cannot be used to draw conclusions about the optical properties of the individual emitters. In an advantageous variant, only one emitter of the measuring device is activated. In an alternative advantageous variant, several emitters are activated simultaneously, whereby the emitters are selected such that when the first emitter is activated alone, the measured value at a first detector increases by less than 50%, preferably less than 20%, and, alternatively, preferably less than 8%, and, in the best case, less than 2% when the emitters that are to be activated simultaneously are activated.

Approximately equal detectors

For example, sensitivity is used to assign detectors to a group of approximately identical detectors. Sensitivity in the relevant spectral range is an important criterion when selecting detectors. In this document, this refers to a detector's ability to detect incident photons at a specific wavelength with a specific probability. In order to compare detectors with each other, the maximum sensitivity of detectors is normalized to 1. The resulting scale from 0.0 to 1.0 is referred to as relative sensitivity. In a preferred variant, the relative sensitivities of two approximately equal detectors at the same wavelength, e.g., the peak wavelength, should not differ by more than 0.02 within an interval. In other preferred variants, the relative sensitivities of two approximately equal detectors with the same wavelength, e.g., the peak wavelength, should not differ by more than 0.04, 0.0, 0.15, 0.2, 0.4, or 0.8 within an interval. In a further preferred variant, the relative sensitivities of 3 approximately equal detectors at the same wavelength, e.g. the peak wavelength, should not differ by more than 0.04, 0.06, 0.08, 0.1, 0.15, 0.2, 0.4, 0.8.

With regard to relative sensitivity differences, in an advantageous variant, there are at least 2 detectors in each interval of approximately equal detectors. In further advantageous variants, there are at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, at least 10 detectors in an interval.

For assigning detectors to a group of approximately equal detectors, the peak wavelength and/or center wavelength of the wavelength range in which detectors receive photons from emitters is selected, for example. With regard to the peak wavelength and/or center wavelength, intervals with approximately equal detectors advantageously have, for example, at least the following interval lengths: 5 nm, 10 nm, 20 nm, 50 nm, 100 nm, 300 nm. With regard to the peak wavelength, approximately equal detectors advantageously have intervals with, for example, the following maximum interval lengths: 10 nm, 20 nm, 50 nm, 100 nm, 200 nm, 350 nm.

In an advantageous variant, there are at least two detectors in each interval of approximately equal detectors with regard to the peak wavelength. In further advantageous variants, there are at least three, at least four, at least five, at least six, at least seven, at least eight, at least nine, and at least ten detectors in an interval. In a preferred variant, there are at least two detectors in an interval of approximately equal detectors which the peak wavelengths of differ by at least 0.5 nm. In further preferred embodiments, the difference is at least 1 nm, at least 2 nm, at least 4 nm, at least 8 nm, at least 10 nm, at least 50 nm, at least 100 nm, or at least 200 nm. In an alternative advantageous variant, the difference in peak wavelength and/or center of gravity wavelength of

the detectors described above occurs only in some of the measuring devices produced, preferably in at least 1%, particularly preferably in up to 10%, and especially preferably in up to 90% of the measuring devices.

The current (in mA) emitted by the detector as a result of detected photons (in mW/cm²) can also be used to assign detectors to a group of approximately equal detectors. Detectors are considered to be approximately equal if the current they emit at a specific wavelength lies within a common interval. Fig. 15 shows a corresponding example. In a preferred variant, the interval length (10) is defined as a range for the emitted current (in mA) resulting from the detection of photons at 10 mW/cm². In the example, the lower limit of the interval (10a) is, for example, 0.2 mA and the upper limit (10b) is, for example, 10 mA. The interval length (10) at 10 mW/cm² is then 9.8 mA. For a detector to be considered approximately equal, its output current at a specific wavelength and a reception power of 10mW/cm² must be between 0.2mA and 10mA. The reception power of the detectors is plotted on the X-axis as a logarithmic value and the output current as a logarithmic value on the Y-axis. As the figure shows, the three detectors are within the interval limits. Detector 2.1 delivers 0.6 mA at 10 mW reception power, detector 2.2 delivers 3 mA, and detector 2.3 delivers 7.5 mA, all at the same wavelength.

Based on the current output at a specific wavelength, in preferred variants, the interval length (10) is, for example, between 0.1 mA and 1 mA, between 1 mA and 2 mA, between 2 mA and 5 mA, between 5 mA and 7.5 mA, between 7.5 mA and 10 mA, between 10 mA and 20 mA, between 20 mA and 50 mA, between 50 mA and 100 mA. Based on the current emitted at a specific wavelength, in preferred variants, there are at least 2 detectors, at least 3 detectors, at least 4 detectors, at least 5 detectors, at least 6 detectors, at least 7 detectors, at least 8 detectors, at least 9 detectors, at least 10 detectors, between 10 and 20 detectors or more than 20 detectors. In a preferred variant, at a specific wavelength, the differences in the current output of 2 approximately equal detectors of a common interval at a given wavelength are up to 2 times, up to 4 times, up to 8 times, up to 12 times, up to 16 times, up to 20 times, up to 30 times, up to 50 times, or up to 100 times.

An example is shown in Fig. 15a. The current emitted by detector 2.2 is 3 mA, which is five times the current emitted by detector 2.1, which is 0.6 mA. Detector 2.3 has the highest conversion of received power to current. It delivers 7.5 mA. The current output at the same reception power and wavelengths is thus 2.5 times higher than that of detector 2.2 and 12.5 times higher than that of detector 2.1. This clearly shows that the three detectors are approximately equal detectors, since both the interval length and the conversion of received power into emitted current are within the previously defined limits for approximately equal detectors. In a preferred

variant, there are at least two detectors in an interval of approximately equal detectors of which the conversion of received power in mW/m² to current in mA differs by up to a maximum of 10%. In further preferred embodiments, the difference is max. up to 20%, max. up to 50%, max. up to 100%, max. up to 200%, max. up to 500%, max. up to 1000%. Fig. 15 shows an interval in which the conversion factors of the 3 detectors contained differ by up to 500%.

The detectors used in the above advantageous example have integrated amplifiers. In an alternative variant, detectors without amplification are used. These generate a lower current flow with the same light irradiation. For an alternative variant without amplification, absolute currents that are a factor of 10 or a factor of 100 or another factor lower are therefore to be expected. However, the relationships otherwise apply accordingly.

In an alternative advantageous variant, the difference in the conversion factor of the detectors described above only occurs in some of the measuring devices produced, preferably in at least 1%, particularly preferably in at least 10% and especially preferably in at least 90% of the measuring devices.

The following section discusses variants in which the measuring device has advantageous properties. However, several measuring devices may also be used in the system in these variants. In this case, "the measuring device" refers to one or more of the measuring devices used. In an advantageous variant, the measuring device, as defined above, has at least one group of approximately equal detectors for at least one property of the detectors. In a preferred variant, the measuring device has at least 2, at least 4, at least 8, at least 16 or more such groups.

In a preferred embodiment, the measuring device in the aforementioned sense comprises, for at least one property of the detectors, several groups of approximately equal detectors, which have a larger number of detectors, while other groups have a smaller number of detectors. Advantageously, the measuring device has, for at least one property of the detectors, at least a first group number of approximately equal detectors from the above set of advantageous group numbers, which contain at least one detector number of the above-mentioned advantageous detector numbers. Advantageously, the measuring device has at least one further group number from the above set of advantageous group numbers for at least one property of the detectors, which contains at least one detector number from the above-mentioned advantageous detector numbers. It is particularly advantageous if the measuring device has at least one property of the detectors, for example at least 3 groups of approximately equal detectors with at least 4 detectors each. In an advantageous variant, at least one property of the detectors additionally has at least one group of approximately equal detectors with at least 5 detectors. In a further advantageous variant, at least one property of the detectors additionally has at least 4 groups of approximately

equal detectors with 2 detectors each. In a preferred variant, the detectors of an interval do not cover the entire width of the interval. This means that for detectors assigned to an interval, the values of the property do not vary so greatly, or the values do not differ so greatly, that the full bandwidth of the interval is required for these detectors to be assigned to the interval. Fig. 15 shows an example with three detectors which the conversion factors of are above the lower limit of the interval and below the upper limit of the interval. In a more preferred variant, the detectors of an interval cover the entire width of the interval. This means that for detectors assigned to an interval, the values of the property vary or differ so much that the full bandwidth of the interval is required for all detectors to be assigned to the interval. In a preferred variant, the measuring device has a total of at least 2 detectors. In further preferred variants, the measuring device has, for example, at least 4, up to 8, up to 16, up to 20, or more than 20 detectors.

Explanation of the terms "sensor components with approximately the same properties" and "sensor components with non-approximately the same properties"

Sensor components are components of the measuring device or sensor. In particular, emitters and detectors are components of the sensor. The measuring device claimed here for measuring substances or parameters for determining physiological states of humans can, in a preferred embodiment, contain, in addition to the sensor components described above as being identical, sensor components that differ from these approximately identical sensor components in at least one technical characteristic. Sensor components are considered to be non-approximate sensor components if the value of a technical characteristic does not lie within the interval length of an interval of approximate sensor components, but rather outside the interval, for example in an interval gap. An example of a non-approximate emitter in a gap of intervals of approximate emitters is shown in Fig. 14c, where the non-approximate emitter has a peak wavelength of 580 nm.

The measuring device claimed here, for example, in its preferred embodiment, has at least one property in which it has both approximately identical sensor components and sensor components which differ in the aforementioned sense from the approximately identical sensor components in at least one property. Examples of this are shown in Figures 14c and 14d based on the peak wavelength and half-width of emitters. Fig. 14c shows a single non-approximate-same emitter between two intervals of approximate-same emitters, and Fig. 14d shows two single non-approximate-same emitters between which there is an interval with approximate-same emitters. In a further preferred variant, the measuring device in the aforementioned sense has, for example, only approximately equal emitters and approximately equal detectors for at least one

property. In a further preferred variant, the measuring device in the aforementioned sense has, for example, approximately equal emitters and non-approximately equal detectors, or approximately equal detectors and non-approximately equal emitters, for at least one property. An example of the combination of approximately equal emitters and non-approximately equal detectors is shown in Fig. 16a.

Fig. 16a shows two detectors (2.4 and 2.5) that are not even close to being the same and differ in terms of their peak wavelength (2b). The peak wavelengths of the two detectors are shown as dotted lines at 580 nm and 940 nm. The four intervals for the half-widths (1b) of approximately equal emitters, as shown in Fig. 14a, are marked as dashed areas in Fig. 16a. The advantages of this combination are clearly evident. The relative sensitivity with which the photons from the approximately equal emitters are detected is high for all emitters, since the wavelength ranges for absorbing photons are so broad that they still overlap despite the different peak wavelengths (2b) of the two detectors (2.4 and 2.5). The photons of the first interval of the approximately identical emitters are detected with a relative sensitivity of at least 0.72, the photons of the second interval with at least 0.9, the photons of the third interval with 0.7, and the photons of the fourth interval with at least 0.98. In a further preferred variant, the measuring device in the aforementioned sense has, for example, approximately equal emitters and approximately equal detectors with at least one property, and approximately equal emitters and/or non-approximately equal detectors with a further property, and/or non-approximately equal emitters and approximately equal detectors with the further property.

It is clear to the skilled person from the description that, in the aforementioned sense, the combination of approximately equal and non-approximately equal sensor components results, for example, in terms of the number of respective properties, the interval length for approximately equal sensor components, the combination of intervals to cover a range or the complete wavelength range from UV to infrared, in that there are a large number of variants that have approximately equal and/or non-approximately equal sensor components and that improve the measurement accuracy and/or repeatability and/or comparability of the results when measuring parameters and/or substances and/or physiological states of humans for the respective application.

In a preferred variant, for a specific width of the wavelength range or the entire wavelength range from UV to infrared in the above sense, the intervals of approximately equal emitters and the intervals of approximately equal detectors are combined with each other. In a preferred embodiment, the measuring device has a total of up to 6 emitters and detectors with respect to the sum of emitters and detectors, and in a further preferred embodiment, a total of up to 9

emitters and detectors, which in the aforementioned sense are either considered to be approximately equal sensor components and/or differ in at least one technical property from the sensor components considered to be equal. In other preferred embodiments, the measuring device has a total of 10 to 16, 17 to 30, 31 to 50, 51 to 70, 71 to 100 or more than 100 emitters and detectors in the aforementioned sense. In the aforementioned embodiments, emitters that can emit multiple wavelengths are counted as many emitters as they emit wavelengths. For example, RGB emitters are counted as 3 emitters. In the above, "sum of emitters and detectors" means that when the number of emitters is added to the number of detectors, the sum of both components is, for example, 10. It is therefore expressly not meant that the sum of the emitters is 10 and the sum of the number of detectors is also 10.

The preferred design may also depend on the intended use. For example, devices may be designed to have a greater number of functions or a higher degree of accuracy, and, therefore, command slightly higher prices. In such devices, it is advantageous to integrate more components. Other devices may need to be as small, energy-efficient or inexpensive as possible. In such cases, variants with a smaller number of emitters and detectors may be advantageous.

In an advantageous design, the number of emitters is greater than the number of detectors. This approach allows better measurement quality to be achieved in advantageous variants with the same technical effort. Advantageously, the number of emitters is at least twice as large as the number of detectors. In an alternative, more advantageous design, the number of emitters is at least three times greater than the number of detectors. In an alternative, more advantageous design, the number of emitters is at least four times greater than the number of detectors.

In an advantageous variant, at least some detectors are designed to be sensitive to multiple wavelength intervals of groups of approximately identical emitters. An advantageous variant has a number of emitters within the wavelength intervals to which the detectors are sensitive that is greater than half the number of wavelength intervals of the emitters multiplied by the number of detectors sensitive to these wavelength intervals. In an alternative advantageous variant, the number of emitters is at least equal to the number of wavelength intervals of the emitters multiplied by the number of detectors sensitive to these wavelength intervals. In an alternative advantageous variant, the number of emitters is at least equal to twice or three times the number of wavelength intervals of the emitters multiplied by the number of detectors sensitive to these wavelength intervals. The optimal ratio between the number of emitters and the number of detectors depends, among other things, on the spatial conditions and the technical effort required between the emitters and detectors. In an advantageous variant of a design, the technical effort required for an emitter is less than that for a detector.

In many cases, it is advantageous if the number of emitters does not exceed the number of detectors by too much. In an advantageous design, the number of detectors is less than the number of emitters divided by 20. In an alternative advantageous design, the number of detectors is less than the number of emitters divided by 10. In an alternative advantageous design, the number of detectors is less than the number of emitters divided by 7. In an alternative advantageous embodiment, the number of detectors is less than the number of emitters divided by 5. In an alternative advantageous embodiment, the number of detectors is less than the number of emitters divided by 4. In an alternative advantageous embodiment, the number of detectors is less than the number of emitters divided by 3. In an advantageous variant, at least one subgroup of approximately equal detectors is designed so that they are sensitive to several wavelength intervals of groups of approximately equal emitters. In an advantageous embodiment, the number of emitters lying in a wavelength interval to which the detector is sensitive is smaller than the number of detectors of this subgroup multiplied by the number of wavelength intervals to which detectors of the subgroup are sensitive. In an alternative advantageous variant, the number of emitters lying within a wavelength interval to which the detector is sensitive is smaller than twice the number of detectors of this subgroup multiplied by the number of wavelength intervals to which detectors of the subgroup are sensitive. The above rules for limiting the number of emitters offer particular advantages for devices that must be of limited size because they are intended to be wearable or handy portable devices. The rules for limiting the number of emitters specified in this text offer particular advantages for devices that must be of limited size because they are intended to be used at measuring points of limited size. Examples of measuring points include: fingers, hands, palms, backs of hands, wrists, arms, faces, cheeks, ears, earlobes, foreheads, eyes, chests, feet, soles of feet, buttocks, and legs. The above rules for limiting the number of emitters are particularly advantageous for devices that must be kept to a low cost. This is particularly true for devices intended for use by end customers or consumers. In an advantageous embodiment, the system described here uses the inventions disclosed in patents EP 3013217; EP 3175783; US 10,416,079; US 11,08,5876, US 11,662,309 and applications US 18/203,359, EP 4005469A1 to estimate the physiological condition of the individual by measuring various parameters and/or substances with the aid of sensor components.

In an advantageous embodiment, the concentration of substances is determined transcutaneously at different depths of the human skin down to the blood. Inhomogeneously distributed substances and homogeneously distributed substances are detected. In an advantageous embodiment, the concentration of a substance can be determined both in a person's blood and in other parts of the

tissue, e.g., in the tissue fluid. In an advantageous embodiment, conclusions can be drawn about changes in concentrations from the concentration measurements of a substance in the blood and in other parts of the tissue.

In an advantageous variant, substance concentrations can be determined as a function of depth, i.e., the distance from the skin surface. In an advantageous variant, conclusions can be drawn about the dynamics of the substance concentration values or the behavior of the person from differences in substance concentration as a function of depth. In an advantageous variant, the times and effects of individual meals can be recorded and the user can receive feedback on this. In an alternative variant, the effect of sporting or physical activity or the effect of exposure to sunlight or other radiation can be determined.

Approximately equal properties of emitter-detector pairs

In a preferred embodiment, not only groups of technical properties of emitters or detectors are formed. It is also advantageous to select certain properties that can only be defined in pairs between emitters and detectors in such a way that groups of approximately equal pairs are formed. In a particularly preferred variant, emitter-detector pairs are formed which have an approximately equal distance. In an advantageous variant, emitter-detector pairs are formed which, in the interaction of the emission characteristic of the emitter with the detection characteristic of the detector, have an approximately equal wavelength characteristic. In an advantageous variant, emitter-detector pairs are formed which, in the interaction of the emission directional characteristic of the emitter with the detection directional characteristic of the detector, have an approximately equal average photon penetration depth into a sample. An average sample or a reference sample is preferably used for this purpose. The advantageous variants and designs described for approximately equal emitters and approximately equal detectors can be transferred to approximately equal emitter-detector pairs, and thus represent advantageous designs. Fig. 13 shows an emitter-detector distance (1c). In an advantageous variant, a group of approximately equal emitter-detector distances has intervals that lie in the range between 1 mm and 3 mm, or between 2 mm and 4.5 mm, or between 4 mm and 6 mm, or between 5 mm and 10 mm, or between 8 mm and 18 mm. In an advantageous embodiment, there is a second group of approximately equal emitter-detector distances which lie in a second of the above-mentioned ranges. In a particularly preferred embodiment, there is a third and/or a fourth group of approximately equal emitter-detector distances which lie in a second of the above-mentioned ranges.

Measurement procedure

In a preferred embodiment, the emitters of the measuring device are switched on individually and in a specific sequence to measure parameters or substances or physiological states of an individual. The sequence may vary. In an equally preferred embodiment, two emitters of the measuring device are always switched on simultaneously to measure parameters or substances or physiological states of an individual. The order in which the two emitters are switched on first and then subsequently can vary. Analogous to the above, in other equally preferred embodiments, three emitters, four emitters, or five emitters are switched on simultaneously. The order in which three, four, or five emitters are switched on first and which three, four, or five emitters are switched on next may vary.

In a preferred embodiment, the two, three, four, or five emitters that are switched on together are approximately equal emitters that differ, for example, in their peak wavelength or center wavelength but belong to an interval. In a further preferred variant, the two, three, four, or five emitters each belong to more than one interval. In another preferred embodiment, the variants described above are not approximately equal emitters. The distribution of the emitters over the wavelength range from ultraviolet to infrared is designed such that, in a preferred embodiment, the differences in peak wavelength or center wavelength are, for example, greater than 50 nm. In further preferred variants, the differences are, for example, more than 75 nm, more than 100 nm, more than 150 nm, or more than 200 nm. In a preferred embodiment, the described methods for activating the emitters can be combined. In an advantageous variant, this results in an activation sequence in which there are times when only one emitter is activated and times when several emitters are activated.

In an advantageous variant, there are points in time in the activation sequence at which no emitter is activated. Such points in time allow the influence of light sources that do not belong to the emitters to be detected. An example is sunlight. In a preferred variant, several emitters are activated simultaneously for emitters with a wavelength that is strongly absorbed by the sample to be measured and therefore does not travel far through the sample. In an advantageous variant, when measuring human skin, several emitters in the wavelength range below 575 nm are activated simultaneously. In an advantageous variant, simultaneously activated emitters in the wavelength range below 575 nm have a distance on a common plane relative to the respective center of the emitters of more than 5, or alternatively more than 7, or alternatively more than 9, or alternatively more than 11 millimeters. In a preferred embodiment, emitters with a wavelength greater than 600 nm are activated individually during the measurement of human tissue at least at one point in the measurement sequence. In a preferred embodiment, several emitters are activated simultaneously. This makes it possible to increase the light intensity measurable at the

detector in comparison with the sequential activation of individual emitters, so that the detector enters a working range in which it operates more accurately. In an advantageous variant, several emitters are activated which are at approximately the same distance from a detector. In an advantageous variant, additional emitters are activated which are at a greater distance than the aforementioned emitters. Due to the greater distance, these emitters do not have a disruptive influence on the measurement. In an advantageous variant, it is possible to choose an arrangement such that the advantageous situations described in this section also apply to a second detector or, in an advantageous variant, even to 3, 4, or more detectors.

Description of measuring device - distribution of sensor components

In a preferred embodiment, the measuring device has a sensor surface that is in direct contact with the outer layer of the skin when measuring various parameters and/or substances and/or physiological conditions of humans. In a preferred embodiment, this skin contact does not occur continuously throughout the entire measurement period. In an alternative preferred embodiment, this skin contact is maintained throughout the entire measurement period. In a further preferred embodiment, contact and non-contact alternate during a measurement. In the preferred embodiment, the user is signaled when to establish or interrupt contact. In a further preferred variant, only part of the sensor surface is in continuous contact with the outer layer of the skin during the entire measurement period. In a further preferred variant, part of the sensor surface is not in continuous contact with the outer layer of the skin during the entire measurement period.

A sensor surface element is understood to be a three-dimensional component (3) with a specific thickness, which has a surface that has a contact surface with the sample. The material of the sensor surface element can be transparent, less transparent, translucent, scattering, or absorbent, depending on the wavelength range. The sensor surface element can consist of one or more individual components which, in a preferred variant, can form a single unit. Parts of the sensor surface element can be made of non-transparent material. In an advantageous design, the sensor surface element has sufficiently transparent materials so that the light from each emitter used for the measurement can penetrate into the sample. In an advantageous embodiment, the sensor surface element has sufficiently transparent materials so that the detector used to measure the light that has passed through the sample can be reached by the light emerging from the sample. In an advantageous embodiment, the sensor surface element has sufficiently opaque materials so that the light must pass through the sample to be measured in order to travel from a selected emitter to a selected detector. In an advantageous embodiment, the preceding sentence applies to more than 50% of the possible pairings of emitters and detectors, and even more advantageously

to more than 80%. In an advantageous variant, however, there are pairings of emitters and detectors in which the light does not have to pass through the sample in order to reach the detector from the emitter.

Wherever reference is made in this document to the three-dimensional sensor surface element or simply to the sensor surface element, this always refers to the component described above. In a preferred embodiment, this three-dimensional component has a curvature toward the side of skin contact. In a more preferred embodiment, the curvature is concave, and in another preferred embodiment, the curvature is convex. Figures 2 and 2a show an example of a convex curvature of the three-dimensional component of the sensor surface (3), while Figures 3 and 3a show examples of a concave curvature of the three-dimensional component of the sensor surface. In a further preferred embodiment, the three-dimensional component has concave and convex curvatures, but these are not opposite each other. In relation to the two-dimensional extension (3a) of the sensor surface element (3) shown in Fig. 1a, this size is determined by the arrangement and/or placement of the emitters and detectors. In a preferred embodiment, the size and shape of the two-dimensional extension of the sensor surface element is determined by the area that the emitters and detectors together occupy as components when they are mounted on a common printed circuit board (PCB) of the measuring device or are located on a common plane (3b). Fig. 1a shows an example of the differences between the two-dimensional extension of the sensor surface element (3a) and the two-dimensional extension of the area occupied by the emitters and detectors on a common plane (e.g., PCB) (3b). In a preferred variant, the printed circuit board or the common plane on which the emitters and/or detectors are mounted is impassable or virtually impassable for photons. In another preferred variant, the printed circuit board or the common plane can be completely or partially heated or cooled, e.g. electrically, for example by providing the board with heating coils or cooling coils. Alternatively, this can be achieved by means of Peltier elements. In a preferred embodiment, the printed circuit board is designed to be impervious to light by shielding the light with metal layers, preferably made of copper, gold, or solder. In an alternative form, the printed circuit board is made opaque by using opaque solder resist or opaque printing. In an alternative embodiment, the base material of the printed circuit board is opaque. In a particularly advantageous variant, the above methods are combined so that some metallic surfaces are present and the other methods are used where metallic surfaces cannot be used for insulation reasons. In an advantageous design, the surface of the printed circuit board is black. In an alternative advantageous design, the surface of the printed circuit board is white, e.g. to increase the light output.

In further preferred variants, the two-dimensional extension of the sensor surface element (3a) is up to 5% larger, up to 15% larger, up to 30% larger, up to 100% larger, up to 200% larger, up to 400% larger or up to 800% larger than the area (3b) occupied by the emitters and detectors as components when they are mounted, for example, on a common printed circuit board (PCB) (6).
In a preferred variant, the three-dimensional sensor surface element is designed such that the emitters and detectors are not in direct contact with the skin during measurement. In a preferred embodiment, this is achieved by the three-dimensional sensor surface element having continuous openings (3.2) in the area of the emitters and detectors. The shape of these openings may vary. In a preferred variant, the openings are rectangular, while, in further preferred variants they are square or round or have square or rectangular openings with beveled corners or consist of a mixture of the aforementioned openings. Figures 4 and 4a show examples of the geometric shapes of the opening (3.2) and the beveling of an opening in section and in top view. Openings for light can also be closed with transparent elements.
In a preferred variant, the three-dimensional sensor surface element (3) is designed so that photons can be emitted and detected through the three-dimensional component. The volume can be transparent so that photons can pass through the volume almost unhindered and without noticeable scattering. In a preferred embodiment, this volume is less transparent or diffuse, and photons are scattered by the material of the volume in such a way that, when they leave the volume, they penetrate the skin in almost all possible directions, i.e., without a preferred direction. This can be achieved, for example, by scattering bodies that are part of the volume or are deliberately introduced into it. However, other methods of influencing the direction of movement of the photons are also known to those skilled in the art (see, for example, patents EP 3175783B1 or EP 3013217B1).
In another preferred embodiment, the material for the sensor surface element is selected such that only photons of certain wavelength ranges can pass through this material. It can be selected a material which has different absorption and/or scattering properties for different wavelengths. In another preferred embodiment, the photons are bundled as they pass through the volume by the design and choice of material, so that, when they leave the volume, they enter the outer layer of the skin in one or more preferred directions, for example. The material can, for example, be designed to be lens-shaped. Alternative possibilities for influencing the direction of the emitted photons include, for example, the use of reflective surfaces, prisms, optical gratings, curved surfaces, in particular at transitions between materials of different optical densities. Further possibilities consist in restricting the direction of movement of photons by using material which is not transparent. In an advantageous embodiment, this can also be achieved by using several

non-transparent materials. In particular, an arrangement is also possible in which there is not just one but several paths for photons to travel from their point of origin to the sample, for example, by creating several channels for the photons from an arrangement that may consist of several transparent elements and possibly several non-transparent elements. In an advantageous variant, the transparent elements and the non-transparent elements are connected in such a way that they form a structured solid. In an advantageous variant, structured materials known from privacy films for laptop screens, which restrict the viewing angle, can be used. However, materials and arrangements known from light field displays can also be used. In a more preferred embodiment, the three-dimensional sensor surface element (3) contains three-dimensional components (5) which the material of is selected so that it is impassable or at least nearly impassable for photons. Fig. 5 and Fig. 5a show such components (5) in section and in top view. It is also shown that the components (5) can also have bevels. Other shapes are also possible. The individual components (5) can be connected to form a monolithic, continuous component (5b), as shown in Fig. 9b. Materials that can be used for the components include metals, aluminum, ceramics, glass, or plastics. In a similarly preferred manner, these components can be present in all versions of the measuring device. Fig. 1a, 4a, 5a, and 6a show arrangements in which emitters and detectors are arranged in a regular rectangular pattern. However, other arrangements are also possible. These can be regular or irregular. An advantageous arrangement positions emitters and/or detectors on one or more circular paths. In a preferred embodiment, the thickness and placement of the impassable or nearly impassable parts are chosen such that they spatially separate the emitters and detectors located under the sensor surface element from each other in such a way that emitted photons cannot reach the detectors within the measuring device. Figures 6, 7, and 8 show examples of how the emitters and detectors are separated from each other by the components (5). In a preferred embodiment, the spatial separation of the emitter and detector can be designed in such a way that, in conjunction with the three-dimensional sensor surface element are created enclosed spaces which the basic geometric shape of corresponds to round, rectangular, or square volumes which, as described above, may have beveled corners or edges. In an alternative embodiment, the volumes may contain additional bulges or have a different shape, including an irregular shape. Fig. 5 shows the connection between component (3) and component (5), which results in completely enclosed spaces in which emitters (1) and detectors (2) are located. Cavities (8) may be created above the respective sensor components, which are filled with air, for example. In a preferred embodiment, the width of the parts (5) that are impassable for photons is greater than the width of the transparent parts of the sensor surface element (3). In a preferred embodiment, the step between the two bodies resulting from the difference in width can be

located on the side of the sensor surface that faces the skin during measurement. Fig. 6b shows a corresponding example. In a further embodiment, the step may be located on the underside. This refers to the side of the three-dimensional component (3) that is not facing the skin. The step can ensure advantageous form-fitting force transmission, and thus divert forces acting on the non-transparent parts when the sample is placed on the transparent parts. In this variant, for example, the transparent parts of the sensor surface element (3) and the components (5) that are impervious to photons can form a smooth or almost smooth surface on the side facing the skin. Fig. 5 shows a corresponding example.

In a preferred variant, the transparent parts of the sensor surface element (3) and the components (5) that are impervious to photons form a form-fitting unit that improves the stability of this unit. In a preferred variant according to Figure 6, the transparent sensor surface elements (3) and non-transparent elements (5) are designed so that they do not form any corners or edges on the side facing the skin. This makes the surface easier to clean. In an advantageous variant, this arrangement ensures that the skin does not come into direct contact with the transparent elements (3) under normal pressure. This reduces contamination and wear of the surfaces of the transparent elements (3). In an advantageous variant, the arrangement is designed such that, for example, when the hand is placed on the sensor, the pressure exerted by the skin on the sensor during the pressure intended for the measurement process acts either essentially or exclusively on the area that is not covered by transparent elements 5. This results in a higher pressure in the contact area between the skin and the arrangement, which reduces the proportion of light that has not penetrated the sample. This reduces the proportion of light that reaches the detector from the emitter without penetrating the skin, e.g. along a skin fold.

In an advantageous variant, the arrangement is designed such that the skin does not come into direct contact with the transparent sensor surface elements (3) under normal pressure. This results in a defined contact situation or contact type between the skin and the surface of the transparent elements (3). The influence of the type of contact can thus be significantly reduced, which leads to more accurate results. The type of contact refers to whether the skin is in direct contact with the transparent surface or whether it is separated by a thin layer of liquid, which may consist of water, sweat, fat, or a mixture of these substances. Another type of contact is the presence of a thin layer of air. The surface structure of the skin often results in mixed forms of contact, which, for example, have a different type of contact in the grooves and folds of the skin than on other areas of the skin. Since different types of contact have a significant optical influence, particularly in the area of the transparent elements (3), which can interfere with the measurement, the aforementioned design of the measuring arrangement enables a more accurate

measurement, as the interfering influences caused by the type of contact are reduced. In an advantageous variant, when the pressure is stronger than the pressure intended for the measurement, the skin comes into contact with the surfaces of the transparent elements (3). This can be detected from the optical measurement data, and the user receives as a feedback that he/she is applying too much pressure to the sensor surface.

In an alternative advantageous variant, the pressure is estimated based on the optically measured amount of blood in the tissue. In an advantageous alternative, both methods can be combined.

In another preferred embodiment, the thickness of the parts (5) that are impenetrable to photons is such that there is a step (3.3) on both the side facing the skin and the side facing away from the skin relative to the three-dimensional volume of the sensor surface (3). The two steps can be seen in Fig. 6. Depending on the thickness of (3), a cavity (8) may again be formed above the sensor components, which is filled with air, for example. In a preferred embodiment, the resulting enclosed spaces may each contain an emitter or a detector. In a further preferred embodiment, there is more than one emitter and/or more than one detector in each of the spaces, either individually or in several or in all of the spaces. Fig. 7 shows an example of two emitters (1) and two detectors (2) in a respective common space formed by the components (5) and the sensor surface element (3). In an advantageous embodiment, an RGB emitter or another emitter capable of emitting photons in multiple wavelength ranges is not considered as one emitter, but as multiple emitters. Figures 7 and 7a show an example of two emitters and two detectors in an enclosed room. Several emitters and/or several detectors can be arranged in an enclosed room. The enclosed rooms can have single or multiple openings (3.2) in the sensor surface element (3). Fig. 7 shows an example of an opening (3.2) in the sensor surface element.

An enclosed space can also be understood as an area of space that is enclosed by non-transparent material or skin. Such an area of space can be important for sensor design, as photons can only leave or enter it if they pass through the skin. Since this is an important aspect for a measuring device that measures optical properties of the skin, emitters and/or detectors are advantageously arranged in such enclosed spaces. Fig. 9b shows a variant in which the components (5) are connected to form a unit (5b) that has no transparent parts of the sensor surface element (3). This results in three-dimensional openings (3.2) in the component (5b). The unit with the three-dimensional openings (3.2) can be retrofitted to the printed circuit board (6). The advantage of such a solution is that there is no loss of light, e.g., as a result of absorption by the transparent sensor surface elements. In a preferred embodiment, however, the unit (5b) can also be part of the housing of the measuring device. In an advantageous variant, the printed circuit board (6) is inserted into the housing and connected to the unit (5) or (5b) in such a way that photons cannot

migrate from a space enclosed by the printed circuit board (6) and component (5) and the skin (4) placed on top to the other without passing through the skin. The advantage of this solution is that the housing and sensor surface element can be manufactured in a single production step, which reduces manufacturing costs. Fig. 8 shows that, for example, the openings (3.2) from Fig. 9b can also be filled or molded with transparent material of the three-dimensional sensor surface element (3) in a second step, so that the sensor components are enclosed by this material and a flat, homogeneous surface is created toward the skin (4). Due to the surface tension of the casting material, the surfaces of the cast openings may be concave, for example. Other curvatures or waviness of the surfaces are also possible.

It should be noted that the sensor surface element may also consist of one or more transparent elements (3) and one or more non-transparent elements. Similarly, the non-transparent elements (5) may be separate or connected elements. This makes it difficult to use singular and plural forms correctly in the description. The use of the singular should therefore not be seen as restrictive in the context of this description. It is clear to those skilled in the art that the function according to the invention can generally also be performed by several elements. Conversely, when using the plural form in the description, the multiple elements can often be combined into one, and the resulting single element can perform the function according to the invention. In this respect, the use of the plural form should not be seen as a limitation towards the use of a single element.

In another preferred variant, the enclosed spaces each contain a cavity (8) filled with gas, for example air (see Figs. 5, 6, 7). In a particularly preferred embodiment, a unit (9) is produced, for example by injection molding, which consists of the three-dimensional volume of the sensor surface element (3), which has a certain thickness (3.1), and the components (5) that are at least almost impenetrable to photons. This unit (9) can be subsequently applied to the printed circuit board with the emitters and detectors in such a way that the emitters and detectors are located in enclosed spaces. The components (5) and the thickness of the three-dimensional sensor surface element (3.1) are then dimensioned such that no collisions with the emitters (1) and detectors (2) occur when the unit (9) is placed on the printed circuit board. Fig. 9 and Fig. 9a show a corresponding example. The advantage of this solution is that the unit (9) can be manufactured as a 2k component in a single step and, unlike with casting, there is no bulging of the volume of the sensor surface element (3) as a result of the casting process. In a preferred embodiment, the unit (9) is connected to the printed circuit board in such a way that the contact point (6.1) between the printed circuit board (6) and the unit (9) is also virtually impassable for photons. The connection between the printed circuit board (6) and the unit (9) can be made, for example,

by liquid bonding or by double-sided adhesive tape or by melting and pressing the material that is virtually impenetrable to photons onto the printed circuit board or by screwing it to the printed circuit board.

In Fig. 7, the dotted lines show the emission of photons, their passage through the skin, and their arrival at the detector. During measurement, some of the photons emitted by the emitters (1) pass through the three-dimensional component of the sensor surface element (3), penetrate the outer layer of the skin (4.1) into the skin (4), travel through it and leave it, e.g. at another point on the skin, and overcome or pass through the three-dimensional component of the sensor surface element (3) again in the aforementioned sense. This occurs either through openings in the sensor surface element (3.2) or by passing through the material of the three-dimensional sensor surface element (3). Subsequently, some of the photons reach a detector (2) of the measuring device and are detected there. The optical properties of the measured sample can be determined from the quantity and wavelength of the photons that travel from the emitter to the detector as described above and are not absorbed or scattered to other locations. By combining the results of measurements from different combinations of emitters and detectors, conclusions can be drawn about the substances present in the skin and the underlying tissue and about their concentration in favorable arrangements. In another preferred variant, additional three-dimensional components (5a) that are almost impenetrable to photons can be located above a unit (5b) and have openings (3.2) through which photons can pass. These openings can be referred to as windows. Fig. 10 shows an example. In another preferred variant, the windows may contain a material that is permeable to photons, e.g., the material of the three-dimensional sensor element (3). Fig. 10b shows such a variant. As can be seen in Fig. 10b, in another preferred variant, the thickness of the material (3) that is permeable to photons can correspond to the thickness of the additional components (5a) that are almost impermeable to photons, so that the side facing the skin has a smooth and/or flat surface. The windows can, for example, or they can form any patterns. As shown in Fig. 10a in a preferred variant, the additional components (5a) having openings (3.2) can be in contact with the three-dimensional sensor surface element (3). In another preferred variant, the components (5a) are located at a defined distance above parts of the sensor surface element (3) formed from transparent material. The additionally arranged components (5a) can together form a monolithic unit.

In a preferred variant, this additional monolithic unit can be a separate component that is only placed on the sensor surface for specific measurements. It can rest directly on the sensor surface or be located at a defined distance above the sensor surface. The advantage of this solution is that certain substances, which are located, for example, at a certain depth within the sample, in this

case skin or tissue, can be detected more accurately because the geometry of the openings (3.2) means that the photons only penetrate the sample at certain angles and thus pass through the skin layers in which the substances are primarily located. This improves the accuracy of detection of these substances.

In a preferred embodiment, a monolithic unit (5a) specially tailored to each substance to be detected can exist, which is then placed on the measuring instrument in the sensor area when this substance is measured. As described above, in a preferred embodiment, the windows in the additional components (5a) can be designed and arranged so that photons can only leave the measuring device at limited angles in order to penetrate the skin. This applies analogously when photons are detected by the detector. They only reach the detector at limited angles, which are predetermined by the design of the windows in the additional components (5a). In Figs. 10, 10a and 10b, such limiting angles are shown as dashed lines. In a preferred embodiment, additional components (5a) are designed and arranged such that they are located at a defined distance parallel to each other on the components (5). Figs. 12 and 12a show such a case. The resulting distances between the additional components may vary, resulting, for example, in slot-like windows. The arrangement restricts the directions in which photons are emitted from the measuring device to certain solid angle ranges. In one embodiment, the arrangement reduces radiation in certain solid angle ranges. Figures 12 and 12a show an example. For clarification, a wind rose with four cardinal directions is drawn there. If the slit-like windows run in a north-south direction, the radiation in east-west solid angle areas is particularly restricted. If the slit-like windows run in an east-west direction, the restriction particularly affects the solid angle areas in a north-south direction. It is clear to the skilled person that, depending on the arrangement of the additional components, the restrictions in radiation can also occur in all other directions in between. In a preferred embodiment, a transparent component (7) may be located above the additional components (5a) so that it is in contact with the skin (4) during measurement. Figures 11 and 12b to 12e show corresponding examples. The material thickness of the component (7) can be designed such that a common cavity (8) is formed, within which the components (5, 5a) that are impervious to photons and the emitters (1) and detectors (2) are located. This can be seen, for example, in Figures 12b, 12b2, 12c, and 12c2. In a further preferred embodiment, the additional components (5a) are integrated into the volume of the component (7). Examples can be seen in Figures 12b1, 12b4, and 12c1, 12c4. In a further preferred variant, a transparent three-dimensional component (3), which is part of the sensor surface element, is located above the emitters (1) and detectors (2), so that the additional

components (5a) and the component (7) are located above this part (3) of the sensor surface element. Corresponding examples are shown in Figures 12b3, 12b5 and 12c3, 12c5.

In an alternative version, the additional components (5a) are not parallel. In another alternative embodiment, the additional components (5a) have a different shape than the rectangular shape shown in the drawing. For those skilled in the field of optics, it is easy to calculate which shape has which effect on the direction of the photons that can pass through this arrangement and which photon directions cannot pass through such an arrangement. This results in numerous alternative designs with which the emission direction of the photons can be influenced.

By influencing the direction of emission, the photons take different paths through the tissue to be measured. In an advantageous variant, this allows paths that are particularly advantageous for the measurement to be set. In an alternative advantageous variant, paths are also set which do not allow the measured variable to be recorded particularly well, but which allow effects that interfere with the measurement to be assessed. For this reason, it is particularly advantageous if different paths of the photons can be set. In an advantageous variant, this is also achieved by providing different influences on the emission directions. In an advantageous variant, components (5a) are used to influence the emission direction of an emitter, but these have different effects in conjunction with two different detectors. For example, an arrangement that can emit photons relatively flat in a westerly direction, in conjunction with a detector located west of the emitter, receives photons that have mainly passed flat through the sample. A detector to the north of the emitter will preferentially receive photons that have penetrated deeper into the tissue. Devices for influencing the emission characteristics can also be used in the same way to influence the reception characteristics of detectors. The physical relationships and advantageous embodiments are considered to be part of the invention without being explicitly described here.

In a preferred embodiment, the component (5a) can break through the transparent component (7) in such a way that it is impossible or virtually impossible for photons to travel within the material thickness of the component (7) and thus reach the detectors without first passing through the skin. Figures 12d, 12d1, and 12d2 show corresponding examples.

The component (7) may, for example, be made of plastic or glass or any other material that photons can pass through; it may have optical properties that, for example, allow photons to pass only in certain preferred directions and/or certain wavelengths; it can be a lens that directs the photons in a specific manner, the material can be opaque or scattering, the component can have thermal properties, and, for example, be electrically heatable or have a temperature-compensating effect, for example to establish comparable temperatures between the skin and the

measuring device during measurement. The component (7) can also be located above all other variants of the measuring device described.

In a preferred variant, component (7) can have a concave, three-dimensional curvature in the direction of the sample, e.g., the skin, which acts as a positioning aid for a hand, so that a user who wants to have skin contact with the sensor for measurement always performs the measurement on the same skin area or at least on approximately the same skin area when he/she aligns his/her hand with the positioning aid in a predetermined manner, e.g., pictorially and/or textually communicated to the user. The shape of component (7) in Figures 12c to 12c5 indicates this bulge. In a preferred variant, the three-dimensional bulge not only serves as a positioning aid, but also prevents, for example, the sensor from being scratched when the measuring instrument rests with the sensor side on a table or is stored in such a way. In a preferred variant, the sensor has a convex bulge. This is shown in Figures 12d and 12d1 to 12d5.

In an equally preferred variant, a positioning aid consisting of transparent material and/or material that is virtually impervious to photons can be located as a separate component on component 7 or component 5, 5a or 5b. In a preferred variant, the positioning aid is three-dimensionally shaped in such a way that it prevents ambient light from penetrating into the sample from the side during measurement, e.g., into the skin in the area of the edge of the hand, from passing through the skin and tissue, from reaching the detectors and thus from influencing the measurement result. In an equally preferred variant, the positioning aid is removable and can be attached by the user, e.g., to the sensor side of the measuring instrument housing before a measurement and removed again after the measurement. Fig. 35 shows an example. In a preferred variant, the removable positioning aid is fixed to the sensor side of the measuring instrument in such a way that the positioning aid has, for example, pins that are inserted into small openings in the measuring instrument and snapped into place there, for example in a reversible manner. It will be apparent to those skilled in the art that other types of reversible fixation of the positioning aid on the sensor side are also possible, e.g., fixation by means of magnets. In a preferred embodiment, the positioning aid, unlike that shown in Fig. 35, may also have a curved contour that at least approximates the contour of the hand, and it may also have laterally sloping and/or rising flanks. In a preferred variant, the three-dimensional positioning aid is not a separate component that is placed on the components (5) or (5a), for example, but is an integral part of the components (5) or (5a). In a preferred variant, the three-dimensional positioning aid is part of the housing of the measuring instrument. Due to the components (5) and (5a) being impenetrable or almost impenetrable to photons, detectors, in an advantageous design, can only detect photons from an emitter that have passed through the skin or the human

body at a certain depth and in a certain direction. The light paths of the photons vary depending on the wavelength of the emitted photons, the geometric or spatial placement of the emitters and detectors, their number, and the respective direction of entry of the photons into the measuring point/contact point on the skin.

The light paths also depend on the skin being measured. As a rule, measuring devices are designed to include light paths that provide sufficient measurement accuracy for all or average skin types. In a particularly advantageous design, the sensor has additional light paths that optimize the measurement of certain skin types. In a particularly advantageous design, the sensor has additional light paths that enable measurement accuracy at particularly high concentrations of a specific substance.

In a further advantageous design, the sensor has additional light paths that enable measurement accuracy at particularly low concentrations of a specific substance.

The arrangement may be designed for the purposes described in the three preceding sections in such a way that particularly short light paths and/or light paths with particularly high detection intensity are provided for wavelength ranges of substances in which the substance exhibits strong absorption and/or for wavelength ranges for which a particular skin type exhibits stronger absorption. In the variants described above, the components (5, 5a) that are at least almost impassable for photons can be arranged and designed in such a way that the angle of the photons upon entering the contact surface of the skin, and thus the direction of travel of the photons in the skin, is specifically influenced. In this way, it is possible to influence the amount of photons that enter the skin at a steep or shallow angle and, on average, travel through the skin at shallow or greater depths before exiting it and, if present, pass through the three-dimensional component of the sensor surface element again and are then detected by the sensors. Due to this influence, the detector (2) can only detect photons that exit the skin at certain spatial angles and pass through the sensor surface elements at certain angles to reach the detector. The respective angles for emission and detection may be different. An example is shown in Figs. 10, 10a and 10b. Beyond the influence on the angle of emission described above, the component (7) can also influence the angle of entry of the photons into the skin. This can be achieved, for example, with the lens function or possible scattering bodies in this component. During detection, any influence on the angle caused by component (7) affects the number of detectable photons that reach the detector at a certain angle. Components (5) and (5a) limit the angle ranges from which a large percentage of the incoming photons can be detected. Examples of the steepest angle are shown as dashed lines in Figures 10 and 10a. In Figures 10, 10a, and 10b, it is assumed that photons that strike components 5 or 5a are absorbed. This is the case for an advantageous design variant in which

components 5 and 5a are made of highly absorbent material, e.g., black material. In an alternative design, there can also be made use of materials from which photons that strike component (5) or component (5a) are reflected. This results in different angle ranges for the emitted photons.

Distribution of emitters and detectors

In a preferred technical design, the emitters (1) and detectors (2) are distributed approximately evenly across the sensor surface, resulting in both different emitter-detector distances and redundant emitter-detector distances. In an advantageous variant, emitter-detector distances are measured on the plane of the sensor surface as a direct line from the center of one of these components to the center of the other component. Fig. 13a shows different distances between the emitter and detector. They are marked as distance arrows (1c1) to (1c4). The distances (1c1) and (1c4) are identical and can be referred to as redundant distances. In the case of a curved sensor surface, the curvature is not taken into account when determining the distance in an advantageous simplified variant. As shown in Figure 13, the distance (1c) between the emitter and the detector is determined as follows in this variant: A perpendicular line is drawn through the center of an emitter onto the circuit board (6) or the common plane on which the emitter and detector are located. A second perpendicular line is drawn through the center of a detector onto the circuit board (6) or the common plane on which the emitter and detector are located. The distance is determined by the distance between these two parallel perpendicular lines. In an advantageous embodiment, the emitter-detector distance (1c) is a characteristic quantity for the path that the photons travel from the emitter to the detector. In this document, the term "light path" can therefore refer to the distance from the emitter to the detector in the relevant context.

In an alternative, advantageous variant, the distance between the emitter and the detector is defined as the shortest line from the transparent area of the contact surface on which the emitter acts to the transparent area of the contact surface on which the detector acts. In an alternative, advantageous variant, the distance between the emitter and the detector is defined by the spatial extent of the light paths of an average or typical sample. This spatial extent is determined by the paths taken by the photons that travel from the emitter to the detector. Each photon follows its own path, which can be simulated using statistical methods. The light path length is then determined from the average length of these paths. Alternatively, the light path length is determined by the distance from the center of gravity of the exit points from the measuring device of the photons that get from the emitter to the detector to the center of gravity of the entry points of the photons that get from the emitter to the detector into the measuring device for each

emitter-detector pair. The use of different definitions allows, in some cases, a more physically precise representation and, in other cases, a more easily comprehensible but also more simplified physical analysis. Such variations in the distance definitions for the design of comparable sensors are well known, have already been published elsewhere, and are in common practice. The advantageous arrangements described can be applied appropriately under several of these definitions.

In another preferred embodiment, emitters and detectors, which are preferably used to detect a specific substance, are distributed in such a way that the distances between emitters and detectors are predominantly those that contribute most to the detection of this substance. In a preferred technical embodiment, the advantageous distances are up to 10% higher, in another preferred embodiment up to 20%, in a further embodiment up to 30% higher, and in a particularly preferred embodiment up to 40% higher, and in particularly preferred embodiments up to 50% higher, up to 100% higher, up to 200% higher, up to 400% higher than the less significant distances. In a preferred embodiment, the number and distribution of emitters and detectors result in a total of at least 50 light paths, and, in a further preferred embodiment, of at least 100 light paths. In more preferred embodiments, there are at least 200, at least 400, at least 800, at least 1600 light paths, whereby more than one emitter may be located in a previously described enclosed space. In a preferred embodiment, the measuring device has a total of up to 6 emitters and detectors, and, in a further preferred embodiment, a total of up to 9 emitters and detectors, which in the aforementioned sense are either considered to be approximately equal sensor components and/or differ in at least one technical characteristic from the sensor components considered to be approximately equal. In the aforementioned sense, in other preferred embodiments, the measuring device has a total of 10 to 16, in further preferred embodiments the sum of emitters and detectors is between 17 and 30, in other particularly preferred embodiments the sum of emitters and detectors is between 31 and 50, in further preferred embodiments, the sum of emitters and detectors is between 51 and 70, in further preferred embodiments, the sum of emitters and detectors is between 71 and 100, and in additionally preferred embodiments, the sum of emitters and detectors is greater than 100. In the embodiments mentioned, RGB emitters are counted as 3 emitters. The same applies to other emitters that can emit different wavelengths.

Through targeted design and combination of the above-mentioned influencing factors, the sensor can be specifically aligned to the substances to be measured. In a particularly advantageous embodiment, the combination of emitters, detectors, and their wavelength ranges and emitter-detector distances is selected such that at least two, preferably three, and in an even more advantageous manner four or five or more different substances can be measured. In an

advantageous design, some of the light paths intended for one substance are also used to determine or improve the accuracy of the determination of at least one other substance. In a preferred design, the emitters are switched on in a specific sequence so that only one emitter emits photons at a time. In another preferred embodiment, more than one emitter can be switched on simultaneously to measure a substance. The composition of the emitter groups that are switched on one after the other, as well as the number of emitters belonging to a group, can vary. Surprisingly, it was found that within a measurement sequence, the following factors influence the accuracy of the detection of a substance concentration: sequence, duration, light intensity, and frequency of switching on the respective emitters. In an advantageous variant, it is selected a measurement sequence in which the same combination of an emitter and a detector is activated several times and the same light path is measured. In an advantageous variant, a time curve of temporally variable substance concentrations, such as those caused by the human pulse or heartbeat, is also recorded. In a further advantageous embodiment, multiple measurements of the same light path are performed in order to determine it under variable conditions and to incorporate the measurement results of the different conditions into an optimized calculation of a result. For example, the light path is first measured at one temperature, and, afterwards, at least a second time at a different temperature. This measure allows the temperature dependencies of the emitters and detectors to be exploited in a targeted manner. In a particularly advantageous variant, the fact that emitters sometimes have temperature-dependent wavelength characteristics is exploited. In this way, more information can be obtained in a targeted manner. A particularly advantageous variant uses this method to determine the wavelength-dependent change in the measurement results of a light path. The slope of the absorption as a function of wavelength determined in this way can be used to correct and optimize measurement results.

In an advantageous variant, the change in temperature is caused by activating the emitters. In an advantageous variant, the temperature increase is brought about by multiple activation of the emitter and/or another emitter in close proximity. In an alternative, particularly energy-saving and advantageous variant, the heating is generated by placing a body with an approximately known temperature on the emitter. In an advantageous variant, the temperature increase is generated by placing the sample, which as living human tissue has temperatures above 30 and typically below 40 degrees Celsius, on the emitter. In an advantageous variant, this results in an evaluable gradient, at least for measurements that begin at normal room temperature. In an alternative advantageous variant, the temperature change is achieved by waste heat from other electronic components. In an advantageous variant, the emitter is increased by a temperature of

at least 0.1 degrees Celsius, and, in an even more advantageous manner, by at least 1 degree Celsius, by at least 10 degrees Celsius, or by at least 50 degrees Celsius.

In an advantageous variant, a defined part of a measurement is considered as a measurement sequence. This means that measurements can consist of one or more measurement sequences between which the contact between the sensor and the skin is not interrupted. To accurately determine substances, it may be necessary to perform several measurements with their respective measurement sequences one after the other. The measurement sequences can be designed so that a sequence is only valid for the detection of one substance and, for example, only certain emitters are switched on one after the other for a specific duration with a selected light intensity and in a specific order. The measurement sequence can be designed differently for each substance. An advantageous variant is to use a measurement sequence that can measure several substances.

When performing multiple measurement sequences or even comprehensive measurements, bleaching effects may occur, which affect the accuracy of the concentration determination of substances. This effect may vary between substances. If the concentration of a substance is low at a certain depth of the skin area measured by the measuring device, the bleaching effect has a stronger impact on the signal-to-noise ratio and, in contrast to a higher concentration, also reduces the accuracy of the measurement more significantly or makes it impossible to detect the substance correctly. Another reason why it's hard to measure concentration is that substances are mostly found in certain layers of the skin or in the blood. So, if deeper layers of the skin or even blood vessels need to be analyzed, it might be necessary to improve the signal-to-noise ratio for the long light paths so that even low concentrations can be detected well.

Surprisingly, it was found that by specifically adjusting and/or combining the switch-on time and/or light intensity and/or the frequency of switching on certain emitters within a measurement sequence, as well as the order in which the emitters are switched on within a measurement sequence, the bleaching effect has no negative or only a slight negative effect on the detection of substances. If the targeted adjustment of a measurement sequence influences the accuracy of the concentration determination of another substance to be detected in a subsequent measurement sequence, the adjusted measurement sequence is preferably performed as the last sequence of a measurement. In an advantageous variant, targeted bleaching can also be used to precisely determine substances that decompose under the influence of certain wavelengths. In this case, at least one light path is measured multiple times, i.e. at least once before the bleaching sequence is activated and then again after the bleaching sequence. In an advantageous variant, this is also done once or several times in between. During the bleaching sequence, in an advantageous

variant, the partial decomposition of a specific substance in the skin is achieved using emitters of a suitable wavelength.

Most substances are distributed unevenly in the human body. This applies not only to differences in concentration within a skin area, but also to comparisons between different skin areas of the human body. In a preferred embodiment, the switch-on time of the emitters, their light intensity, and the sequence and frequency of switching on the emitters can therefore be set individually for each user and each skin area.

An individual determination of the influencing factors is carried out in an advantageous variant by first determining the extent to which a skin area or a person deviates from an empirically determined standard setting. Therefore, within a measurement, it is advantageous for the first measurement sequence to correspond to this standard setting. In the preferred variant, the ratio of the amount of light detectable at the detector between light paths of different lengths is determined by analyzing the individual light paths, and the deviation from the empirical standard is determined. In a preferred variant, all emitters and detectors of the measuring device are used in this measurement sequence. In accordance with the preceding definitions, the light path is understood here to be, for example, the distance between the emitter and the detector or the most probable path that a photon travels from the emitter to the detector. In an advantageous variant, a second measurement sequence is performed, in which the influencing factors are individually adjusted to the measurement area or the person depending on the deviation. This can be the same for all substances to be detected. However, it is also possible that the adjustment is different for each substance and that each substance must be detected using its own measurement sequence, in which, for example, only certain emitters are switched on. The order of the substance-related measurement sequences is then determined, for example, with a view to minimizing the bleaching effect.

In an advantageous variant, the measurement is controlled via an application that runs on a smartphone or smartwatch, for example. Once the application has received the individualized settings, it prompts the user to re-establish skin contact with the sensor. The follow-up measurement with the individualized measurement sequences starts automatically as soon as the application registers that skin contact has been re-established. In a preferred variant, the application can determine the individualized settings itself. By individualizing the measurement with regard to the measurement sequences it contains, an advantageous variant allows each user to obtain a measurement that is optimized for the correct concentration determination. It is possible that the computing effort required for individualization does not take place on the measuring device itself, but on an external server. In a preferred variant, the measuring device,

e.g. with the aid of a special application, sends the spectral data of the standard measurement sequence to a server and receives from the server the settings for the individually tailored measurement sequences, which were determined there, e.g. with the aid of AI. The data can be sent to the external server via the Internet, for example, from the measuring device itself. In an alternative, advantageous variant, the measuring device transmits data to the server by transferring it to an application. The application can be run on a smartphone, smartwatch, or other device with Internet access. The data can be sent via a mobile network. Alternatively, the data can be transferred to the server via Wi-Fi or LAN or other communication channels that are currently available or will be available in the future.

In a particularly preferred variant, the measuring device sends the data via WiFi or Bluetooth, e.g. to a mobile device (e.g. smartphone or tablet), which then sends it via mobile communications (e.g. 4G, 5G) over the Internet to the external server or uses an existing WiFi network to send the data. In a preferred embodiment, the data is encrypted before being sent. In another preferred embodiment, the server sends the settings for the individually tailored measurement sequences back to an application on the mobile device in encrypted form using the same method. In an advantageous configuration, the server always sends the settings only to the device that sent the data to it.

In a preferred variant, the individualization of the measurement can also be used to compensate for the influence of certain skin characteristics on the measurement result. This applies, for example, to skin type, skin spots, wrinkles, scars, or skin roughness.

In another preferred variant, the correct detection of the concentration of a substance is improved by changing the number of repetitions of at least parts of the individual measurement procedure within a measurement. In an advantageous variant, a standard setting is first selected, which comprises, for example, 1, 2, 3, 4, 5 or more repetitions of the measurement procedure. In an advantageous embodiment, the concentration of the substance is then calculated for each individual measurement procedure and the deviation of the individual results from each other is determined. If the deviation is too large, the user is prompted to perform another measurement with a certain number of measurement procedures. As experts know, measurement errors can sometimes be reduced by taking more measurements, i.e., more measurements lead to a lower standard deviation of the overall measurement result obtained from all partial measurements. For this reason, the number of measurement procedures or even the number of measurements could be increased from the outset in order to ensure a correct result. However, the advantage of the aforementioned procedure is that no more measurement sequences or complete measurements need to be performed than is necessary for the individual case. The number of measurement

sequences required within a measurement may vary between individuals. The aforementioned advantageous procedure therefore saves the user time. However, the aforementioned advantageous procedure also reduces measurement errors that can arise from bleaching due to an excessive number of measurements. In an advantageous variant, the number of measurements performed is calculated so that a sufficient number of measurements is achieved to attain the desired accuracy, while at the same time avoiding bleaching.

In an advantageous variant, at least one number of repeated measurements per light path is performed, which exceeds 1, 2, 4, 8, 16, 32, or, in the most advantageous variant, 64. In an advantageous variant, the number of repetitions per light path is limited to a value such that it does not exceed 2, 4, 8, 16, 32, 64, 128, 256, or 1024. Since almost all substances in skin and tissue are distributed inhomogeneously, the concentration can vary from a measuring point to another measuring point. In a preferred embodiment of the invention, the size of the sensor and the placement of the emitters and detectors are therefore selected such that the sensor size can detect a representative section of the inhomogeneous distribution, so that the same measurement results are obtained when the sensor is brought into contact with the skin again, provided that the concentration of the substance has not changed for physiological reasons.

For everyday use, it is highly advantageous to select an appropriately sized sensor/sensor surface, because in repeated measurements, the measured concentration is virtually unaffected by inhomogeneous distribution, so that within the error tolerance of the measurement, a change in the measurement result can be traced back to physiological changes. In an advantageous variant, the measuring arrangement has therefore a mounting area for optoelectronic components of at least 100 mm^2. In an alternative advantageous variant, the measuring arrangement has therefore a mounting area for optoelectronic components of at least 225 mm^2. In an alternative advantageous variant, the measuring arrangement has therefore a mounting area for optoelectronic components of at least 400 mm^2. The size of the mounting area for optoelectronic components is defined as the area of the smallest circle or smallest square in which the emitter and detector chips projected onto the circuit board of the measuring device all fit. In an advantageous variant, the area of the smallest circle or smallest square takes into account the necessary wiring for controlling the emitter and detector chips and/or the necessary contact areas on the circuit board for attaching the emitter and detector chips. Surprisingly, it was found that, with a certain size of the sensor area and by specifically designing the above-mentioned measurement sequence adjustment in conjunction with the choice of the time for the first repeated measurement, the dynamics of the change in a substance concentration can already be determined. This means that the future values of the substance concentration can be predicted in advantageous variants of the invention.

In an advantageous variant, the sensor surface that comes into contact with the skin during a measurement should be between 0.5 cm^2 and 10 cm^2. In a preferred embodiment, the sensor surface has a size of max. 1 cm^2, in a further preferred embodiment a size of at least 1.5 cm^2, in an equally preferred embodiment of at least 2 cm^2, in a more preferred embodiment of at least 2.25 cm^2 and in more preferred embodiments of at least 4 cm^2. The size of the sensor area (3a) of the measuring device is therefore, in a preferred embodiment, for example, max. 10 mm x 10 mm, in a further preferred embodiment of at least 12 mm x 12 mm, in a highly preferred technical embodiment of at least 15 mm x 15 mm, and in a particularly highly preferred technical embodiment of at least 20 mm x 20 mm. Depending on the detection task, it can also be at least 25 mm x 25 mm. Fig. 1a shows an example of what is meant by the size of the sensor area (3a). For special applications, the preferred sensor area may also be max. 8 mm x 8 mm, and in a particularly preferred design it may be max. 6 mm x 6 mm or max. 25 mm x 25 mm. It is clear to the skilled person that the sensor area does not have to be square. It may, for example, be rectangular, round or approximately round, but it may also have any other shape.

Measurement of substances

It was found that the measuring device described above, when designed appropriately, enables the differentiated analysis of different substances. This includes, for example, the measurement of carotenoid concentrations in human tissue and blood, whereby a distinction can be made between the concentrations of lutein, zeaxanthin, ß-cryptoxanthin, α-carotene, ß-carotene, and lycopene. When measuring humans, it is important to measure carotenoids individually because, for example, the absorption of ß-carotene and lutein interfere with each other. For any transmission of information to the user, for example the communication of measurement results, this information should preferably be displayed as a numerical value and/or as a graphic and/or as text information, e.g. in conjunction with corresponding advices, on the display of the measuring device or a device that communicates with the measuring device and/or can be read aloud to the user as audio information and/or presented as a video. Signaling to the user may also take place in other known ways. This also applies to other text passages in which communication with the user is addressed. This includes, among other things, the use of symbols and colours, light signals, or other signals that can be perceived by the human senses. It is particularly advantageous to use a signal that is visible, audible, tactile, olfactory, or gustatory. Direct transmission of information to the brain or nervous system would also be conceivable as soon as the technology is sufficiently mature.

With regard to nutrition, a connection to a device that influences the appetite center would be particularly advantageous as soon as this is technically possible. Indirect communication is also possible, for example, by objects in the user's environment exhibiting certain automatic behavior. Examples of this are:

- Refrigerator doors or cupboard doors that open or lock
- A fruit bowl that turns the best fruit toward the user or turns away or covers the less desirable fruit
- A food processor with recipes that prioritizes particularly suitable recipes
- A shopping application that suggests particularly suitable recipes. This range of functions can also be implemented as an online shop or additional service for such a shop, for example.
- As an alternative to influencing food in one of the above ways, medications or dietary supplements can also be processed, e.g., by automatically dispensing them in individual doses from a dispenser.
- Beverage, smoothie, or other food vending machines that automatically add ingredients or substances based on the calculated recommendations are also conceivable.
- It is also conceivable to give the user small electric shocks if he/she behaves contrary to the recommendations.
- Indirect communication is also conceivable, e.g., to the user's partner or a family member or a trusted person in his/her circle of friends or a trusted medical professional such as his/her family doctor or nutritionist in one of the ways mentioned above.

The above variants can be understood as indirect signals to the user. They can also be understood as support systems for behavioral change.

In an advantageous variant, the communication, signaling, and/or behavior change support methods or their components can be integrated into all variants of the device that communicate a result or recommendation or other information to the user or to a person associated to the user.

Individual metabolism

Surprisingly, spectroscopic measurements have shown that, with a favorable design, the device described here can be used to determine the individual metabolism of food. In order to determine the physiologically determined individual metabolism from the concentration measurement of substances that are also contained in a food, additional information is recorded by the user and processed using information technology in an advantageous variant.

In a preferred variant, it is collected from the user information which, independently of the metabolism or at least partially independently of the metabolism, may influence the measured concentration of a substance in the body. In a preferred embodiment, the information may include, for example, one or more of the following: lifestyle or living habits such as smoking, alcohol consumption, sleep duration, time spent in the sun, use of solariums, intensity, frequency, and duration of physical activity, e.g., through sports, private and professional stress. Information that is considered useful to record includes, for example, the way in which food is consumed by the user, e.g., raw, cooked, boiled, pureed, or whether fruits and vegetables were consumed as a smoothie with oil, etc. In a preferred embodiment, the strength of their influence on the concentration determination is determined, for example, by comparing the measurement results of a large number of users under the aforementioned aspects in order to determine, for example, with the aid of artificial intelligence, an average influence on the concentration determination. In a preferred variant, general scientific knowledge about metabolic processes in the human body is also taken into account.

If the individual metabolism of a specific substance is to be determined for a specific user, in a preferred embodiment, the user is first asked to enter the amount of food or substance consumed, e.g., in grams, into the application that communicates with the measuring device. In a preferred embodiment, this can be done, for example, by manual entry, voice input, or uploading a photo of the amount consumed. Scanning codes on packaging is also an advantageous embodiment. Transferring data from a scale is also an advantageous embodiment. In an advantageous variant, the amount of food consumed can be weighed and/or the change in body weight due to food intake can be determined, e.g., using a scale. The data can be stored and/or processed, e.g., in the application itself or by means of data transfer, e.g., to a server. In a preferred variant, the user is also prompted to enter as much of the above-mentioned additional information as possible.

In a preferred embodiment, after eating, the user is instructed to use the measuring device described here to take measurements on the skin to determine the concentration of this substance in the blood and tissue and to repeat these measurements at specific intervals, i.e. in a preferred variant, at intervals of max. 2 hours, max. 4 hours, max. 6 hours, max. 8 hours and max. 12 hours. In other preferred variants, the intervals between regular recommended measurements are max. 24 hours, max. 36 hours, max. 2 days, max. 4 days, max. 1 week, max. 2 weeks, and more than 2 weeks. In a preferred embodiment, a series of several measurements is performed at intervals after food intake. It is preferable to take the substance again at some point between measurements. The measurement results from several of the intervals mentioned in the previous paragraphs can also be used to detect delayed accumulation in the tissue, for example.

In order to improve the measurement accuracy, in a preferred variant, several measurements are performed and evaluated in succession at the respective measurement time in order to improve the accuracy of the measurement, e.g., by averaging and/or outlier detection. In a further preferred variant, the measurement accuracy is improved by using the individual measurement sequences described above. In a preferred variant, at least 3, at least 5, or at least 10 consecutive repeated measurements are performed at the respective measurement times, wherein the measurement times have, for example, the intervals mentioned above. In further preferred variants, a maximum of 20 repeated measurements, a maximum of 30 repeated measurements, or more than 30 repeated measurements are performed at the respective measurement times in order to further improve the measurement accuracy, for example.

In a preferred variant, for example, for a specific user, based on information regarding the amount of the measured substance ingested and/or additional information provided by the user and/or the measurement results obtained at different measurement times and/or taking into account the average influence of the metabolism on the measurement result determined with the help of a large number of users, the individual metabolism of the substance for this specific user is calculated using various mathematical methods. In a preferred variant, the quantities, e.g., in grams, that the user should consume so that the substance accumulates in his body in a desired concentration can be calculated from this. In a preferred variant, the calculation is repeated whenever the data basis for the calculation changes, e.g. if the user stores additional and/or new information, e.g. via the application, or if new scientific findings on metabolic processes become available.

In a preferred solution, the calculations for the individual metabolism of a substance also take into account whether substances that inhibit the absorption of another substance have been ingested at the same time. In an advantageous variant, a user-specific model is created, which allows at least a rough, and in an advantageous variant a good, prediction of which foods affect the concentrations of at least one desired substance in the user's tissue.

The following sections describe advantageous designs in which information obtained by measuring one or more substances in the user's body with the described device and their temporal course determined from several measurements and, if necessary, with the addition of further information, is used to determine information that is useful for the user. In an advantageous variant, this information can be a behavioral recommendation and/or a nutritional recommendation. In a further preferred variant, a comparison of measurement results from different measurement times is used to determine whether there is an individual saturation curve for repeated intake of a substance and which gradient exists between intake and the measured

concentration in the tissue and blood. The result is improved predictability, and thus, a better prognosis of the individual metabolism of substances in food is made. In a preferred solution, in conjunction with the calculated individual metabolism, a comparison is made between the concentrations of two or more substances if their ratio is relevant to health. An example of this is the desired ratio of omega-3 fatty acids to omega-6 fatty acids, or the effect of foods in terms of their glycemic load, or, in general, the reduction of health risks when certain food components are present in sufficient quantities in the body.

The results of the concentration determination of the various substances, whether as a result of joint measurement or individual measurements of the various substances of this substance class, are stored, in a preferred variant, on the measuring device and/or transmitted via the Internet to an external server, stored and calculated with each other in such a way that an individual degree of mutual interference in his/her absorption or metabolism, e.g., of carotenoids, can be determined for the user.

Two substances, e.g., two carotenoids, but also more than two substances, may be involved in the mutual interference in metabolism. In their mutual influence, they can significantly influence the absorption or metabolism of certain other substances. This functional relationship applies not only to carotenoids, but also to other substances in the diet.

In a preferred variant, the individual degree of the respective disorder is determined, for example, by first comparing the measured concentrations with health recommendations for the concentration in the human body. If deficits or excessive concentrations are detected, in an advantageous embodiment, for example, the concentrations of the substances that interfere with each other's absorption and metabolism are first compared with each other and evaluated mathematically. In an advantageous embodiment, the individual degree of mutual interference can be determined from this. These can be carotenoids, for example. In a preferred embodiment, a calculation formula is used, which incorporates the target health values for the substances under consideration. The result of the formula can be an indicator of the balance of the individual's diet, and, in particular, of the carotenoid diet or of the intake of one of the other substances mentioned above. In an advantageous variant, this method can also be applied analogously to other substances in the diet that interfere with each other's metabolism.

With the help of this indicator, individuals can be compared with each other in a preferred configuration, despite taking into account their individual metabolism. In a preferred embodiment, this comparison is displayed to the user in the form of a graph on his/her mobile device, which receives the measurement results from the server, for example. This information helps him/her to assess where he/she stands in comparison with a reference group. It is generally

known that such comparisons motivate people to make behavioral changes that minimize their risks of disease.

A change in the composition of the fruits and vegetables consumed may be sufficient, due to individual metabolism, to improve the ratio of mutually inhibiting substances, e.g., two carotenoids, without having to change the total amount of fruits and vegetables consumed. In an advantageous variant, such a change in diet is determined from the measured values and user input and suggested to the user. In a preferred variant, the user of the measuring device can, for example, be informed, together with the display of the result, of which types of fruits and vegetables he/she should consume, as an alternative, so that, with the same total amount of fruits and vegetables, a better ratio of concentrations, for example of carotenoids, is achieved.

The various pieces of information that can be provided to the user of the measuring device in addition to the measurement result, and how this can be done, are discussed in more detail below.

In another preferred variant, the user may also be suggested a time separation for the intake of mutually interfering substances. For example, in a preferred variant, recipes containing vegetables or fruit with high concentrations of a particular carotenoid (e.g., carrots/beta carotene or tomatoes/lycopene) may be suggested for lunch, while for dinner or the next day's lunch, recipes containing only low concentrations of this carotenoid but high concentrations of the other carotenoid, e.g. lutein, are suggested. In an advantageous embodiment, these may alternatively be appropriate dietary supplements. In a preferred embodiment, the time separation between the intake of interfering substances is maintained over a period of at least 4 weeks, with the user being given appropriate recipe suggestions for the respective meals over the selected period. After consumption, in a preferred embodiment, several measurements are taken to determine the concentration of, for example, beta-carotene and lycopene using the measuring device claimed herein. In a preferred embodiment, there is a definable time interval between the measurements. In preferred embodiments, this is max. 2 hours, max. 4 hours, max. 8 hours, or max. 12 hours. The measurement results are stored and the concentration levels for both substances, e.g., beta-carotene and lycopene, are determined over a period of at least 4 weeks to determine the effect of the time-delayed intake. In an advantageous variant, the concentration curve is displayed to the user, e.g., in a graph and output via an application. Depending on the result, in a preferred variant, the amount of food or dietary supplement containing the two substances can be increased and/or the time interval between consumption can be changed in order to bring the concentration of the two substances, e.g., beta-carotene and lycopene, to a level that has the greatest possible health benefit. In another preferred variant, the time interval between the consumption of food

and/or dietary supplements containing substances that interfere with each other's metabolism can be extended, for example, to more than 12 hours, and, in further variants, for example, to more than 24 hours, more than 36 hours, or more than 48 hours.

In view of the different health effects of certain substances, e.g., carotenoids, individuals have different preferences regarding the compensation of deficiencies through the consumption of appropriate foods/dietary supplements. For example, users may want to increase the concentration of a certain substance because it influences the development of a certain disease, regardless of whether this reduces the intake of other substances. This applies, for example, to macular degeneration, where sufficient lutein and zeaxanthin must be consumed in order to adequately treat the condition. An advantageous variant of the system can therefore be set up so that the recommendations issued take clinical pictures into account or the individually adjustable targets for substance concentrations can be specified.

In a preferred variant, the support provided to the user, such as the selection of fruits and vegetables containing the substances, the amount of fruits and vegetables to be consumed, and suggestions for appropriate recipes and/or dietary supplements, is generated using algorithms. In a preferred variant, the number of concentration measurements required to determine the actual amounts metabolized and the time intervals between them are also calculated using these algorithms. In a preferred variant, this algorithm also uses comparable data from other users, which has been transmitted to an external server, for example with the help of an application, and stored there anonymously in order to perform this calculation. In an advantageous variant, certain forms of artificial intelligence (AI) are used for the algorithms in order to be able to make these suggestions to the user.

In a preferred variant, a forecast is made based on the amounts of fruits and vegetables or dietary supplements consumed and the measurement results, and communicated to the user, showing him/her how high the concentrations will be at a point in the future. Based on the data processed, alternative forecasts can be calculated by adjusting the amount consumed and the time of delayed intake of interfering substances.

Measurement of the water content of skin and tissue

In a preferred variant of the measuring device described above, it was surprisingly found that the water content in the skin or tissue can be measured non-invasively when the measuring device comes into contact with the skin. Surprisingly, in a preferred embodiment, it was found that it is possible to determine, for example, when a person should drink in order to enable optimal cognitive performance or to prevent negative effects on other bodily functions (e.g., bowel

movements) and/or organs (e.g., kidneys). In an alternative advantageous variant, the effect of moisturizers for skin tightening can be tested.

Measurement of body fat percentage and BMI

In a preferred variant, it was surprisingly found that the body fat percentage can be measured with the measuring device described above. The measurement can be taken at different points on the body. In a preferred embodiment, the measurement is taken on the inside of the hand in the area of the palm. With the help of this measurement, it is possible, for example, to detect the effect of diets at a very early stage. This is a great advantage for the user, as it allows him/her to check the quality of a diet before any weight loss is visible on the scales. Noticeable success with a diet increases motivation to continue, while in the opposite case, the diet does not need to be continued. Based on the measurement results, users can also be supported in preparing their meals, for example. This is discussed in more detail elsewhere in this document.

In an advantageous variant, the measurement can output a value that correlates with the BMI. This allows the following statement to be made, for example: The measured fat percentage corresponds to an average person with a BMI of X, where X stands for the numerical value of the comparison group. The body mass index (BMI) is a common measure for classifying a person's body weight in relation to his/her height. It allows a person's body weight to be classified into the following categories: underweight, normal weight, overweight, extremely overweight (obese), and severely obese. A disadvantage of the BMI is that it does not distinguish between fat and muscle mass.

Surprisingly, in a preferred embodiment, it was found that the measuring device described here can be used to take measurements on the palm of the hand, the results of which correlate with BMI, for example, and take muscle mass and body weight into account more accurately than fat. This makes it possible for the first time to quickly and easily determine fat storage, which is important for weight management, because people who are on a diet, for example, want to lose fat and not muscle mass. In a preferred embodiment, this new BMI determination is called "BMI 2.0".

In the preferred embodiment, the basis for the spectroscopic determination of BMI are algorithms developed, for example, on the basis of neural networks with the aid of AI. Fig. 45 shows, for example, a correlation of $R = 0.61$ between the traditionally calculated BMI (kg/m^2 = body weight (in kg) divided by height (in meters) (squared) and the BMI predicted by spectroscopic measurement. A well-known disadvantage of BMI is that high muscle mass leads to a high BMI. For this reason, BMI is not an ideal indicator for identifying an energy-rich diet.

Measuring the proportion of fatty tissue in the subcutaneous and muscle tissue using a non-invasive optical method does not have this disadvantage in its advantageous design. An advantageous measuring device according to the invention can therefore be used very advantageously for observing the effects of energy intake and energy consumption in the body.
Surprisingly, in another preferred variant, it was found that AI can be used to generate algorithms that can separately determine visceral fat (in cm^2) and skeletal muscle mass (in kg/m^2) when optical measurement data is collected using the measuring device claimed here, e.g., on the palm of the hand.

Measurement of glucose

In a preferred variant of the measuring device described above, it was surprisingly found that the glucose concentration in the blood can be measured non-invasively when the measuring device comes into contact with the skin.
In a further preferred variant, it was surprisingly found that the glucose concentration can also be measured in tissue, e.g., in the intercellular fluid of the subcutaneous fatty tissue.
Surprisingly, the glucose concentration in the blood and in the tissue can be determined by measuring it on the palm of the hand. Surprisingly, it was found that, in an advantageous embodiment, the glucose measurement can be used to predict the development of inflammations, e.g., skin inflammations. In a preferred solution, the rise and fall of glucose levels are determined over a certain period of time by measurements before and after meals in order to record the minimum and maximum individual glucose levels, including the time between the occurrence of the minimum and maximum glucose values and/or the progression between the minimum and maximum glucose values. Using this data and the corresponding data from other users, the user is assigned a risk class for the development of inflammation, e.g., skin inflammation, with the help of AI methods. Additional criteria such as age and gender can be taken into account.
To improve the accuracy of the measurement, in a preferred variant, several consecutive repeated measurements are performed before and immediately after meals. In a preferred variant, at least 2, 3, 4, or 8 repeated measurements are performed. In another preferred variant, at least 2 measurements, at least 4 measurements, at least 8 measurements, or at least 12 measurements, are performed immediately after meals at specific intervals. In an equally preferred variant, the interval between measurements is max. 1 minute, max. 2 minutes, max. 4 minutes, max. 6 minutes, max. 8 minutes, or max. 10 minutes. In a preferred embodiment, the period over which the rise and fall of the values before and after meals are tracked by measurements is, for example, at least one day. In a further preferred embodiment, this period is, for example, at least

2 days. In a more preferred embodiment, the period is, for example, at least 3 days. In an even more preferred embodiment, the period is, for example, at least 1 week, and in the most preferred embodiment, the period is, for example, at least 2 weeks, in order to determine the average rise and fall of the glucose values of the person taking the measurements. In an advantageous variant, measures for reducing the maximum fluctuations in glucose levels are determined for each risk class to which a user can be assigned. Taking into account the above-described method for determining individual metabolism, the measures in the advantageous variant include, for example, suggestions for foods to be consumed or the components of food intake. These can be calculated and output using an algorithm based on his/her glycemic index and/or the time and/or the frequency of food intake during a day. In an advantageous variant, suggestions for the number and timing of meals are determined from the time and result value of the glucose measurement. The implementation of the suggestions by the person taking the measurements is checked, for example, based on subsequent glucose measurements. The differences in glucose values determined in this way can, for example, lead to a reassignment to a lower risk class. In this way, the risk of inflammation can be gradually reduced.

Measurement of glucose, C-reactive protein, cortisol, alpha-linolenic acid, and prognosis for the development of inflammation

In a preferred embodiment of the measuring device described above, it was found that one or more of the substance concentrations of C-reactive protein, cortisol, and alpha-linolenic acid can be measured non-invasively with the measuring device if the sensor is in direct contact with the skin at least temporarily during the measurement.

In another preferred embodiment, the measurements of glucose, C-reactive protein, cortisol, and alpha-linolenic acid are taken in the area of the palm of the hand.

In another preferred embodiment, it was surprisingly found that, for example, when glucose and C-reactive protein are measured simultaneously, the assignment to a risk class for the occurrence of future inflammations, e.g., skin inflammations, can be made more accurately in accordance with the method described in the chapter "Measurement of glucose." In another preferred embodiment, it was surprisingly found that, for example, when glucose, C-reactive protein and cortisol, in accordance with the method described in the chapter "Measurement of glucose," it is not only possible to assign a risk class for the occurrence of future inflammation, e.g., skin inflammation, but also to make an approximate prognosis of the time or period of occurrence and severity of the inflammation. In a further preferred embodiment, it was surprisingly found that, for example, when glucose, C-reactive protein, and alpha-linolenic acid, in accordance with the

method described in the chapter "Measurement of glucose," it is possible to assign a risk class for the occurrence of future inflammation, e.g., skin inflammation, and to predict the time or period of occurrence and severity of the inflammation more accurately.

In the preferred variants described above for improving classification into a risk class and predicting the time/period of occurrence and severity of inflammation, the respective measurements for the individual substances are either carried out in quick succession or the corresponding optical data are collected together as part of a joint measurement. In an alternative preferred embodiment, the measurement methods described in this chapter are only performed non-invasively, optically, for some of the substances. Another part of the measurements is performed by other means.

In a further preferred variant, the measurements of the various substances can also be collected in close succession using different measurement methods, e.g., within a maximum of one month, within a maximum of one week, preferably within a maximum of one day, or even better within a maximum of one hour. As described above, in this case too, the individual measurement results and the corresponding data from other users form the basis for the application of artificial intelligence methods to predict the development and severity of inflammation at a point in the future.

Measurement of AGE and glucose

In a preferred embodiment of the measuring device described above, it was found that the concentration of advanced glycation end products (AGEs) can be measured non-invasively when the measuring device comes into contact with the skin. In an advantageous embodiment, the device is designed so that not only photons emitted by the emitters, but also photons that arise from fluorescence properties in the sample to be measured after the sample has been excited to fluorescence by light, can be detected by the detectors. Surprisingly, in a preferred variant, it was found that the future concentration of AGEs can be predicted when AGEs and glucose are measured simultaneously. In a preferred variant, measurements are taken at intervals of, for example, a maximum of one week, a maximum of two weeks, a maximum of three weeks, a maximum of four weeks, a maximum of two months, or more than two months. In preferred variants, at least 2 such measurements, at least 4 such measurements, at least 8 such measurements, or more than 10 such measurements are performed at the aforementioned intervals. In a preferred variant, these measurements can, for example, be performed directly after one another. In further preferred variants, these measurements can, for example, be performed at intervals of max. 10 minutes, at intervals of 10 to 30 minutes, at intervals of 30 to

60 minutes, at intervals of 60 to 90 minutes or at intervals of 90 to 120 minutes. In further preferred variants, the measurements can, for example, be performed before each meal and after each meal, immediately after getting up and shortly before going to bed. In a preferred variant, the concentrations of AGEs and glucose generated during the measurements are offset against each other to determine the influence of the current glucose concentration on the change in the AGE concentration.

In a preferred variant, part of the data set is used to predict the other part of the data set in order to optimize the calculation method. The calculation method can be modified by comparing the prediction with the actual measured results until a satisfactory prediction of the measured values is achieved. In an advantageous variant, this is done automatically by algorithms. In a particularly advantageous variant, this is done by AI methods such as neural networks.

In a preferred variant, a prediction quality is determined for the results. This is communicated to the user. The prediction quality indicates, for example, the probability that a predicted value will correspond to a value at a specific point in time in the future. These can be AGE values, for example. In an advantageous variant, the result of each new measurement is compared with the result of the predicted value. In a preferred variant, the prediction of a value is optimized taking into account another measured value. For example, the prediction of an AGE value is optimized by taking into account a glucose measurement value corresponding to the same time. In a preferred variant, the temporal progression of the measured values and the predicted values is displayed in a common graph. This can be done, for example, for AGE values. As described above, in a preferred variant, suggestions are made to the user on how to influence the current glucose value by changing his/her diet and lifestyle (e.g., nutritional components, time of food intake, physical activity) in order to ensure that the measured AGE values do not exceed health-relevant threshold values.

Weight management – measurement of glucose, body fat percentage, and water content of skin and tissue

For successful nutrition and weight management, it is useful to monitor the glucose concentration in the blood or in the intercellular fluid of the tissue. Body fat is not broken down, or only partially broken down, if sufficient energy in the form of glucose is available in the blood. Since glucose and insulin rise to similar levels after a meal and insulin blocks lipolysis, fat is not burned or metabolized. As a result, at least some of the fat consumed with the meal is stored in the fat cells. This leads to weight gain and simultaneous expansion of the existing fat cells.

If there is little glucose in the blood because insulin has previously transported the glucose to the body's cells for energy or because calorie intake has been stopped, the body first breaks down its glycogen reserves. Glycogen is a form of carbohydrate that is stored in the muscles and liver (approx. 300-400g). When energy is obtained from glycogen, water is released and flushed out of the body. This leads to a measurable weight loss on the scales, but has nothing to do with successful weight management and the reduction of excess pounds. Despite exercise, emptying the glycogen stores reduces the breakdown of fat reserves in the body. Weight loss through fat burning is reduced accordingly.

In a preferred embodiment, it was surprisingly found that, for example, when measuring blood sugar, water, and fat levels simultaneously (see previous chapter), an individual corridor can be determined within which a decrease in body weight (net weight loss) occurs without the weight reduction later determined on the scale being distorted by water loss. This is of great importance to the user, as he/she has not previously been able to distinguish between water loss and actual weight reduction.

Furthermore, the weight of the stomach and intestinal contents varies, which makes determining body weight an inaccurate starting point for a diet aimed at reducing body fat. In an advantageous variant, a non-invasive optical measurement using one of the embodiments of the invention is used to monitor the progress of a diet.

At the same time, in a preferred embodiment, a corridor can be determined for the point in time at which it is expedient and effective to initiate fat burning through physical activity, such as exercise. This means that the user is informed when to start a sporting activity so that the greatest reduction in body fat is achieved through exercise.

In a preferred embodiment, the individual corridor for fat burning described above is determined, for example, by means of a specific mathematical calculation using blood sugar values, which are collected, for example, in accordance with the procedure described in the chapter "Glucose measurement." In a preferred variant, the calculation takes into account the use of water content and/or body fat percentage, which are determined, for example, together with the glucose measurement in joint measurements. Within the corridor, further mathematical methods, e.g. based on AI, can be used to identify areas where, for example, net weight loss is particularly beneficial. In a preferred embodiment, the individual ranges can be identified, for example, using special indicators that describe the ratio between the individual measured values in relation to each other.

Surprisingly, in a preferred embodiment, it has been found that by measuring the above-mentioned three substances (blood sugar, water content, body fat percentage) using an algorithm,

it is possible to predict the weight reduction that will actually occur later. In a preferred embodiment, the prediction is particularly accurate if, in addition to the three substances mentioned above, the length of time spent in the corridor is also determined, because the longer the body is in this individual corridor, the greater the net weight loss. In an advantageous variant, the determination of future net weight loss becomes even more accurate if, for example, the length of time spent in the areas for different weight loss is determined and included in the calculation.

Since body fat percentage changes more slowly than blood sugar and water content, it was surprisingly discovered, in a preferred embodiment, that the ratio of fat to blood sugar and water content can be used to retrospectively calculate the period of time during which the body was in the individual weight loss corridor. To this end, the measured values stored in the measuring device or on an external medium (e.g., a server that receives the data via an application over the Internet) are analyzed. Preferably, the retrospective calculation of the period is carried out, for example, by including one or more measurements that were previously taken within the corridor. The possibility of retrospective calculation is an advantageous variant and represents a considerable customer benefit, as it does not require continuous determination and/or continuous analysis of the three substances and the time spent in the corridor in order to predict future net weight reduction.

In a preferred variant, repeated measurements are performed at intervals of max. 3 hours. In further preferred variants, they are performed at intervals of max. 2 hours, at intervals of max. 1 hour, at intervals of max. 30 minutes, at intervals of max. 20 minutes, at intervals of max. 10 minutes, or at intervals of 1 minute. If this measurement interval is repeated on several days or over a longer period of time, the net weight loss can be extrapolated for different periods of time. In a preferred variant, the net weight loss resulting from the user maintaining his/her current behavior can be extrapolated for a period of up to 1, 2, 3, or 4 weeks, for example. In further preferred variants, this can be extrapolated for a period of up to 2, 3, 4, 5, or 6 months, in further preferred variants for a period of 7, 8, 9, 10, or 11 months, and in equally preferred variants for a period of up to 1, 2, 3, or more years, or analogously for other points in time and time spans.

Compared to the state of the art, this represents a significant benefit for customers, as physiological conditions make weight loss quantifiable before it becomes visible on the scales. This is an objective weight loss that does not depend, for example, on the accuracy of the scale or the resolution of the measurement result on the scale. This is a significant advantage because the customer no longer needs an expensive personal scale that can display weight differences in

the gram range with a very low measurement error in order to notice motivating weight loss at an early stage.

In a similarly preferred embodiment, it was found that it is also possible to determine the corridor by measuring blood sugar, water content, and body fat percentage at different times. However, it has been found that this method only allows the corridor to be determined with lower accuracy. The advantage of this embodiment is that the measuring device can be designed to be more cost-effective.

Sharp drops in glucose levels

It is well known that blood sugar levels rise and then fall in the first two hours after a meal. Scientific studies show (e.g., Postprandial glycaemic dips predict appetite and energy intake in healthy individuals**.** in**:** Nat Metab. 2021 April 01; 3(4): 523–529. doi:10.1038/s42255-021-00383-x), some people experience a sharp drop in blood sugar levels 2-4 hours after a peak in sugar levels, before the level rises again. People affected by this have a stronger feeling of hunger and consume an average of 300 calories more per day than people whose blood sugar levels do not drop as sharply. This behavior can lead to weight gain of 10 kg within a year. For sustainable weight management, it is therefore beneficial to inform individuals whether they belong to the group with sharply falling sugar levels and therefore consume more calories than others. To identify this group of people, an advantageous variant of the invention is used, which includes a measurement procedure and/or visualization of blood sugar levels optimized for this question. A preferred method for identifying people with sharply falling sugar levels is, for example, as follows:

before performing a glucose measurement, users can specify the time that has elapsed since their last meal on the measurement application's user interface. Alternatively, the time at which the last or subsequent meals were consumed can be entered or recorded in another way. In a preferred embodiment, this can be done, for example, via a selection menu or by manually or verbally entering the time period, or by pressing a button on the application shortly before or after the meal. In addition, in another preferred embodiment, it is possible to document the components of the previous meal, for example by entering them, selecting them, or taking a digital photograph. In a preferred variant, the measurement application controls the measurement with the measuring device described above. It can be located on a mobile device (e.g., smartphone, tablet) that uses the application to retrieve the data from the measuring device and to forward it to a central server for calculation and/or data storage. The data transfer can take place via the Internet, to which the mobile device can connect automatically, e.g., by dialing into

an existing WiFi network or by sending data via mobile communications. The measurement data stored on the server for a preferred number of users is analyzed for sugar levels that drop over time. With the help of AI, for example, risk levels are defined for users with rapidly falling blood sugar levels. Each user is assigned one of these levels. Since the assignment to a level also depends on the number of blood sugar measurements stored for the user, the assignment may change over time. At the same time, the probability of correct assignment increases with more measurements. In a beneficial variant, the user is informed of the probability of correct assignment. In an alternative variant, the assignment is not to risk levels, but is continuous.

If the user has stored information about the components of his/her meal or digital photos of his/her meals in the application, the components of a meal or the photographed meals that have contributed most to the predicted drop in sugar levels are also displayed when assigning a risk level.

Measurement of alpha-linolenic acid, arachidonic acid, linoleic acid

In a preferred embodiment, the measuring device described here can be used to measure the concentration of one or more of the following substances: alpha-linolenic acid (omega 3), arachidonic acid (omega 6), and/or linoleic acid (omega 6). In a further preferred embodiment, the acids are detected simultaneously within a measurement, which may consist of several measurement sequences.

In an additional preferred embodiment, the respective acid concentration is measured at different depths of the skin down to the blood. In a preferred embodiment, the determination of the different depth concentrations for the individual acids is carried out simultaneously during a measurement, which may have several measurement sequences. This is based on the targeted analysis of data originating from emitter-detector pairs with light paths corresponding to the relevant depth.

Measurement of carotenoids

With the help of the measuring device described here, it is possible to measure the concentration of carotenoids in the human body in an advantageous configuration. This is already described in US patent 11,085,876 B2 for the MSRRS method. If the MSRRS method is used in conjunction with the properties of the measuring device described here, the concentration of the various carotenoids can be determined more accurately than with the MSRRS method alone. In a preferred embodiment, the measuring device can detect the concentration of alpha-carotene, beta-carotene, lutein, gamma-carotene, beta-cryptoxanthin, zeaxanthin, and lycopene. In a

further preferred variant, the aforementioned carotenoids can be measured individually and/or jointly in the blood and in the skin (tissue) with the aid of appropriate algorithms, and the results can be displayed individually and/or jointly on the display of an output device.

In another preferred embodiment, when measuring carotenoids in the blood on the same day, e.g., after a few hours, the contribution of food intake to the increase in carotenoid levels, and thus, to the increase in antioxidant levels in the body, can be determined, while the accumulation of carotenoids in the skin or tissue cannot be measured on the same day, but often only after several weeks, for example.

In a preferred embodiment, for measurements used to determine the carotenoid concentration, which are performed, for example, on the palm of the human hand, the measurement inaccuracy in the concentration determination is reduced by calculating the carotenoid concentrations taking into account the measurement results of C-reactive protein and/or cortisol, which are or were performed simultaneously and/or at different times. In a preferred embodiment, better repeatability of the carotenoid measurement is achieved by calculating the concentration of the carotenoid measurement taking into account the measurement results of C-reactive protein and/or cortisol.

In a preferred embodiment, in the case of dietary and behavioral changes aimed at improving carotenoid levels, the increase in carotenoid concentration can be detected earlier if, for example, C-reactive protein and/or cortisol are measured simultaneously and taken into account in the carotenoid concentration calculation.

Surprisingly, a preferred variant also showed that the deviation between the predicted carotenoid concentration and the carotenoid concentrations actually measured later is smaller if, for example, the measurement results of the simultaneously performed measurement of C-reactive protein and/or cortisol are taken into account when determining the trend. With regard to the number of measurements required for trend calculation, the time intervals between the individual measurement times and the time differences between the measurements, and the conditions described for calculating the future concentration of fatty acids, apply analogously in a preferred embodiment.

In a preferred variant, the aforementioned substances can also be measured using the transmitted light method during spectroscopic measurement. In contrast to reflection spectroscopy, the emitters and detectors are not located on a common plane in this method, so that measurement is only possible at certain points on the body (e.g., fingertips, earlobes). In an advantageous variant, the user can determine the optimal food for him/her, taking into account his/her individual metabolism, by measuring his/her blood. In a preferred variant, liquids and dietary supplements

containing, for example, carotenoids or antioxidants are also considered as a food intake in this context. If, for example, the user determines that certain foods have no or only a minimal effect on the carotenoid concentration in the blood, he/she can immediately replace them with others and thus quickly optimize his/her diet. An advantageous variant of digital and automated nutrition and behavior counseling is based on algorithms. In an advantageous variant, the algorithms use the results of the concentration determination of one or more biomarkers, e.g., carotenoids.

In an advantageous variant, the algorithms calculate individual dietary recommendations. Preferably, these lead to an increase in the concentration of at least one biomarker in the user. Nutritional recommendations may preferably include recipes, methods of food preparation, times of food intake, and meal options in restaurants. Preferably, the recommendations are supplemented by suggestions for changes to the user's lifestyle.

In a preferred embodiment, measurements are taken on the user's body to determine the individual metabolism of one or more biomarkers, which are used to determine the influence of at least one first meal and/or food intake and/or behavior on the concentration level of the biomarker.

In a preferred embodiment, measurements are taken on the user's body to determine the individual metabolism of one or more biomarkers, whereby the influence of at least one second meal and/or food intake and/or behavior on the concentration level of the biomarker is determined. The biomarker may preferably be a single biomarker or several biomarkers, for example one or more carotenoids. In an advantageous method, mathematical methods are used to determine whether one of the two meals/behaviors increases the concentration of the biomarker more than the other. In a further preferred variant, the first meal/behavioral pattern represents the reference normal with which the second meal/behavioral pattern is compared. In a preferred variant, the reference normal can be determined at any time. In a preferred variant, the reference normal can also be determined after the second meal/behavioral pattern. In a preferred variant, non-invasive measurements are performed to determine the concentration of the biomarker. Preferably, when using a spectroscopic system, e.g., the measuring instrument described here, only raw data from specific light paths can be evaluated for concentration determination, whereby, for example, individual light paths can be weighted in the evaluation. In a preferred variant, mathematical algorithms are used to evaluate the measurement data collected by measurement and to determine the concentration of the biomarker or biomarkers.

In a preferred embodiment, the algorithms can be developed with the aid of artificial intelligence. In a preferred variant, the first meal/behavior can be a meal/behavior that the user

selects himself because, for example, he particularly likes and/or eats it more often than other meals and/or because it is a typical or frequently performed behavior for him. In a preferred variant, the second meal/behavior may be, for example, suggestions from the automated nutrition and behavior counseling service. In a preferred embodiment, these may be meals/behaviors that the user determines and carries out independently of the suggestions. In a preferred embodiment, measurements are taken on the user's body before and after the first meal/behavior. In a preferred embodiment, measurements are taken on the user's body before and after the second meal/behavior. In a preferred embodiment, the measurements may be one or more measurement sections, each measurement section comprising one or more individual measurements. Preferably, the accuracy of the concentration determination can be increased by the number of measurement sections and individual measurements.

In a preferred variant, at least 1 measurement is taken shortly before the first and shortly before the second meal/behavior. In equally preferred variants, at least 2, at least 4, at least 6, or more than 6 measurements are taken to determine the concentration of one or more biomarkers. In preferred variants, measurements to determine the concentration of one or more biomarkers are taken a maximum of 15 minutes or a maximum of 30 minutes or a maximum of 1, 2, 3, 4, 5 or more than 5 hours after the first meal/behavior. In preferred variants, measurements to determine the concentration of one or more biomarkers are performed no later than 15 minutes or no later than 30 minutes or no later than 1, 2, 3, 4, 5 or more than 5 hours after the second meal/behaviour. In a preferred variant, the number of measurements performed at one of the aforementioned measurement times may correspond to the number of measurements performed before the meal/behavior.

In a preferred embodiment, the user may be asked not to consume any food other than the first and/or second meal during the measurement period nor to drink any liquids containing the biomarkers which the concentration of is to be determined. Preferably, for the first meal/behavior, the substance concentration levels determined by individual measurements are calculated using mathematical methods, separated into measurements taken before and after the meal.

Preferably, for the second meal/behavior, the substance concentration levels determined by individual measurements are calculated using mathematical methods, separated into measurements before and after the meal. Preferably, the mathematical calculation can be performed by calculating, for example, an arithmetic mean or a linear regression or a nonlinear regression.

Preferably, for the first meal/behavior, the calculation results before the meal/behavior are compared with the calculation results after the meal/behavior and evaluated mathematically. Preferably, the evaluation determines whether the substance concentration of one or more biomarkers after the first meal/behavior is higher than before the first meal/behavior. Preferably, this result is referred to as the evaluation result. Preferably, for the second meal/behavior, the calculation results before the meal/behavior are compared with the calculation results after the meal/behavior and mathematically evaluated to determine whether the determined substance concentrations differ in their magnitude. In a preferred embodiment, the evaluation determines whether the substance concentration of one or more biomarkers after the second meal/behavior is higher than before the second meal/behavior. Preferably, this result is referred to as the evaluation result. In a preferred variant, the evaluation results of the first and second meal/behavior are compared with each other and it is mathematically determined whether the first meal/behavior or the second meal/behavior increases the substance concentration of one or more biomarkers more strongly. In a preferred embodiment, when determining whether the first meal/behavior or the second meal/behavior has increased the substance concentration more, the level of the substance concentration before the two meals is also taken into account. In a preferred embodiment, this consideration can compensate for the influence that the level of a substance concentration has on the increase in the substance concentration caused by a meal/behavior.

In a preferred embodiment, the system includes a component that models the influence of the user's behavior on a user's biomarker. In a preferred embodiment, the modeling is performed using a mathematical model. Preferably, this consists of several mathematical formulas. Preferably, the model is implemented in software. In an advantageous variant, the model is implemented and/or created using artificial intelligence software methods. In a preferred embodiment, the system includes a component that models the influence of the intake of certain foods on a user's biomarker. In a preferred embodiment, parameters of this model are optimized over time to bring the model into better agreement with reality. Preferably, this improves the usability of the model for prediction and/or planning purposes. In a preferred embodiment, the model is used to predict the development of biomarkers depending on the user's behavior and/or consumption of specific foods. In a preferred embodiment, the model is used to determine which action and/or dietary recommendations have a desirable effect on the user's biomarkers and/or key figures and/or goals. In a preferred embodiment, the model is used to create a plan based on actions and/or food intake. In a preferred variant, the plan is created automatically. In an alternative version, the plan is created by the user and the model shows the user the effects. In an

alternative version, the plan is created interactively. Preferably, the plan is then created partly with automatically generated suggestions and partly through manual entries and/or manual requests for alternative automatic suggestions.

In the preferred version, the model uses data from other users. In the preferred version, the model is initialized with data from other users. Preferably, the model can thus be used for planning or forecasting purposes even before the user's measurement data is available. Preferably, the model takes into account ingredients for recipes. Preferably, a model is created for individual ingredients for their effects on biomarkers and/or substance concentrations that can be measured on the user. Preferably, the model also takes into account the preparation of the ingredients and/or their interaction. Preferably, the ingredients of food consumed are stored. Preferably, the time of consumption is stored. Preferably, the temporal development of at least one parameter is stored. This parameter is preferably a value that can be determined by measurement. Preferably, the model for predicting the parameter is refined based on the temporal course of the consumption of certain foods and the temporal course of the parameter.

Preferably, models are created that apply individually to a user. Preferably, models are created that apply to specific user groups. Preferably, user groups are formed according to whether the users in a group can be well represented by a specific model. Preferably, the comparison of user-specific models allows information to be transferred from one user to another. Preferably, recipes that were beneficial for one user can be suggested to another user with a similar model. Preferably, the model allows to establish a forecast and/or plan that enables the optimization of several biomarkers and/or measured values and/or key figures.

Preferably, the model allows the development of measurements such as carotenoid concentration to be predicted and displayed based on the recipes planned for consumption in a future period using known information such as current measurements and recently consumed food. Preferably, the model is customized for each user. For example, the model of a user who is particularly good at absorbing carotenoids in these recipes provides a higher carotenoid concentration forecast than an average user would receive. In an advantageous variant, the model also has cross-user components. These components are learned for all users or for specific user groups. Due to the larger number of users, these models can learn faster in an advantageous design and have information on a larger number of ingredients and/or recipes.

In an advantageous variant, cross-user models are combined with user-specific models in order to combine the advantages of individual modeling with those of cross-user modeling. In an advantageous design, this is achieved by learning the deviations from a cross-user model for an individual user. In an advantageous variant, AI algorithms or neural networks are used. In an

advantageous embodiment, model parameters are stored for an individual user. In an advantageous embodiment, there are model parameters that characterize how large a user's storage capacity is for certain substances. In an advantageous embodiment, there is a model parameter that records how full the storage capacity is for a storage location. Preferably, the filled level is substance-specific. Preferably, multiple storage locations are modeled for substances. Preferably, one storage location is the digestive system, in particular the stomach and intestines. Preferably, another storage location is the blood. Preferably, another storage location is the fatty tissue. Preferably, another storage location is the liver. Preferably, not only the storage of fat in fatty tissue is considered. Preferably, the storage of carotenoids in adipose tissue is also considered. Preferably, another storage location is muscle tissue. Preferably, another storage location is tissue fluid. Preferably, one storage location is the skin. In an advantageous embodiment, there are model parameters that characterize how large the maximum absorption rate of a user is for certain substances. In an advantageous embodiment, there are model parameters that characterize how high a user's consumption of certain substances is. Preferably, consumption is recorded and/or stored depending on the situation. In an advantageous embodiment, there are model parameters that characterize how certain substances interact in a user, preferably, how strongly certain substances interfere with each other's absorption. In an advantageous embodiment, there are model parameters that characterize the influence of a user's food preparation. Preferably, it is determined whether a user shows certain deviations from average users when cooking his/her own meals. Preferably, it is determined whether the user uses more or less oil in the preparation process. Preferably, it is determined whether the user uses longer or shorter cooking times in the preparation process.

Preferably, the user is given feedback based on the determined model parameters. Preferably, he/she receives information about the model created for him/her. Preferably, explanations for key figure developments can be derived from the model. Preferably, recommendations for action are created for the user. Example: use less oil when cooking to save calories. Preferably, these recommendations for action are no longer general, as is often the case in the state of the art, but individual and based on data. Preferably, the influence of a change in behavior through the model is quantifiable. The results achieved in relation to the first meal/behavior (comparison normal) are, in a preferred variant, the reference value for evaluating all future meals.

Example of comparing a meal/behavior with the comparison normal

In a preferred variant, the user informs the application that he/she would like to check how his/her next food intake/behavior affects the concentration of one or more biomarkers, e.g., the

concentration of carotenoids, in the body, e.g., in the blood. In a preferred variant, this can be done, for example, by pressing a button. In another preferred embodiment, the user can also specify the exact or approximate time at which the meal is to be eaten and/or the behavior is to be performed. In a preferred embodiment, this can be done, for example, by an application displaying a timer on which the user can set the time until the meal/behavior. In another preferred embodiment, the user can also communicate the time verbally by using the microphone of the device on which the application is installed. Depending on how much time remains until the meal/behavior, the application prompts the user in a preferred manner to perform a certain number of measurements before the meal/behavior in order to determine the current level before the meal/behavior. When the user begins eating, he/she informs the application, in a preferred variant, that the meal is now starting. In a preferred embodiment, this information can be used to determine more accurately the time at which the carotenoids appear or arrive in the blood. In a preferred variant, the user provides additional information to the application. In a preferred variant, this may be one or more pieces of information about the food intake of the dish. In another preferred design, the user can enter the information, for example, in writing via the keyboard or verbally via the microphone of the device on which the application is stored. Preferably, the information may include one or more of the following: information about the main ingredients of the meal, information about the respective quantities of the ingredients, information about whether the food is eaten raw, cooked, or baked, and information about whether the food is consumed with oil. In another preferred embodiment, the information about the meal and its ingredients can be provided using photos and/or videos. Preferably, the user uses, for example, the camera of the device on which the application is installed (e.g., a tablet or smartphone) to take the photos and/or videos. Preferably, the user uses a separate camera that forwards the recordings to the device with the application. Preferably, these photos and/or videos can be evaluated, e.g., using image recognition algorithms, and the ingredients of the food and their respective quantities can be determined. In a preferred variant, the photos and/or videos are automatically saved. Preferably, the storage takes place on the display device and/or an external server.

In another preferred variant, the user has the option of evaluating the meal after eating according to various predefined and/or personal criteria. In a preferred variant, the evaluation can take the form of symbols, e.g., stars, and/or in writing, and/or by recording verbal statements. Preferably, the data is stored on the device on which the application is stored. In a preferred variant, the data is stored on a separate server. In a preferred variant, this is done with the help of the application. In a preferred variant, measurements are taken on the user's body after the meal. Preferably, the

user takes the measurements himself/herself. In another preferred variant, the measurements are performed by a third person. Preferably, the time for performing the corresponding measurements is controlled by the application. Preferably, the application gives the user an acoustic, optical, or tactile indication when a measurement is to be performed. In a preferred variant, the time for performing the individual measurement or measurements is determined using an algorithm. Depending on the nutritional composition of the meal, the algorithm preferably calculates the time period during which metabolism takes place. Preferably, the algorithm calculates when the substance concentration of one or more biomarkers contained in the food arrives in the body, for example in the blood, and/or can be measured. In order to expand the database for calculating the time at which the substance concentration arrives in the body, e.g., in the blood, the algorithm preferably uses not only the user's measurement data, but also corresponding measurement data from other users. In a preferred variant, the algorithm can also use measurement data and/or information that was not collected with the measurement system and originates, for example, from publications.

In a preferred embodiment, data and/or measurement data from the user and data and/or measurement data not originating from the user are treated differently by the algorithm. In a preferred embodiment, the data and/or measurement data from the user can, for example, be weighted in the user-specific calculation for the metabolism process and/or the arrival of the substance concentration of one or more biomarkers in the body. In a preferred embodiment, the algorithm can make a more accurate prediction for the user as to when the user should take measurements after a meal as the amount of user-specific data and/or measurement data increases. In a preferred embodiment, the algorithm uses the data provided to it to determine when a substance concentration, e.g., that of carotenoids, will increase in the user's body, e.g., in the blood. In a preferred embodiment, the algorithm uses the data provided to it to calculate when a substance concentration, e.g., that of carotenoids, in the user's body, e.g., in the blood, will reach its maximum concentration level over time. In a preferred embodiment, the algorithm makes it possible to calculate from the data provided to it how long a substance concentration, e.g. that of carotenoids, remains at its peak in the user's body, e.g. in the blood. In a preferred embodiment, the algorithm uses the data provided to it to calculate when and/or how strongly a substance concentration, e.g., that of carotenoids, in the user's body, e.g., in the blood, begins to decline after reaching its peak. In a preferred embodiment, the algorithm uses the data provided to it to calculate when a substance concentration, e.g. that of carotenoids, in the user's body, e.g. in the blood, has reached a level at which it remains after it has reached its peak and begins to decline. In a preferred embodiment, the algorithm uses the data provided to it to calculate the

time span that elapses without additional food intake of one or more biomarkers, from the arrival of the substance concentration to the rise and fall of the substance concentration. In a preferred embodiment, the number of measurements that the user performs after eating can be gradually reduced based on the aforementioned calculations.

In a preferred embodiment, the information, for example the presentation of the measurement results, the presentation of the calculation results, the presentation of photos or videos or other previously described information, can be displayed on the screen of the device on which the application is installed. In a preferred embodiment, the presentation can also be made on other devices. In a preferred embodiment, the user can determine where and/or in what form the results are to be displayed. In a preferred variant, the user can, for example, choose between graphical and/or tabular display, whether the respective meals should have images and/or text descriptions, and whether the difference between the reference normal and meal 2 should be presented as a qualitative or quantitative result. In a preferred variant, arrows can be used in a simplified display to indicate how meal 2 compares to the reference normal. In a preferred variant, an upward arrow can mean that meal 2 improves the concentration of the substance in the body, e.g., in the user's blood, more than the reference normal.

In a preferred embodiment, the angle of an upward arrow can indicate the strength of the higher substance concentration in comparison to the reference normal. In a preferred embodiment , a downward arrow can indicate the opposite. In a preferred embodiment, a horizontal arrow can indicate that no clear difference between the reference normal and meal 2 could be determined. Preferably, the result can also be represented analogously using the symbols "+", "-", "~", whereby several plus or minus signs can indicate the degree of difference and the symbol "~" is used if no clear difference could be determined. In a further preferred variant, the change in the substance concentration of the reference normal before and after the meal/behavior and/or the analogous change in meal 2 can be output as an absolute value or as a percentage difference. In a preferred variant, the percentage difference between the change in the reference normal and the change in meal 2 can be displayed. In a preferred variant, the user can be presented with a time-differentiated display of this data based on stored data. In a preferred variant, the information includes the date of storage. In a preferred embodiment, further information can be provided to the user. In a preferred embodiment, the following information can be provided, for example: which meal/food did the user consume and when, which meals were suggested by the automated nutrition and behavior counseling service, how much did the user enjoy these meals, which meals does the user recommend for future consumption, what costs are associated with the meals/behaviors, which health-relevant components do meals contain, to what extent have

meals/behaviors increased the concentration of biomarkers, e.g., carotenoids, in the body, e.g., in the user's blood, which of the stored data has the user shared with third parties, e.g., via social networks.

Initialization – Creating a user profile in the application

As previously described in various sections, the measuring device disclosed herein and the methods for performing the measurement enable the determination of physiological conditions of an individual or the measurement of the concentration of substances in the human body. In order to fully fulfill the measuring device's task of promoting the user's health and well-being, the user is also provided with behavioral suggestions, recommendations, assistance, or support in writing, acoustically, or as a video based on the measurement results, which help him/her improve his/her measurement results and his/her well-being or comfort. In another advantageous variant, general behavioral suggestions, recommendations, assistance, or support can also be presented to the user without prior measurement. In an advantageous variant, this can be done by the user verbally describing a problem, e.g., in colloquial language, e.g., in complete sentences, to the application that communicates with the measuring device after activating a corresponding button in the application. With the help of speech recognition and AI, the behavioral suggestions, recommendations, help, etc. stored in the application's resources are then analyzed and suitable suggestions, recommendations, help, etc. are provided to the user. In an advantageous embodiment, the user may be advised, in the course of presenting the general behavioral suggestions, recommendations, etc., to perform corresponding measurements with the disclosed measuring device in order to validate and adapt the suggestions to the individual condition of the user. In a further advantageous variant, the user may also be advised to carry out additional or exclusively validating measurements with other measuring devices and to store the results, for example, in the application that communicates with the measuring device disclosed herein. In an advantageous embodiment, the general or user-specific behavioral suggestions, recommendations, etc. may also involve establishing, initiating, and maintaining contact with experts or institutions that provide counseling and/or physical and/or mental assistance or support, using additional aids if necessary. In a preferred variant, the user can specify which additional information, support, assistance, etc. he/she wishes to receive and in what context. In another advantageous variant, the user can communicate certain preferences, likes, requirements, or needs to the technical system, e.g., the application, by entering them, which, alone or together with the measurement results, contribute to behavior suggestions, recommendations, assistance, support, or aids being defined or used in a very targeted manner in order to promote and

maintain the user's health and well-being in the long term. In an advantageous embodiment, the user can specify his preferences, likes, needs or requirements via input fields, the content of which is organised, for example, in a kind of tree structure containing superordinate and subordinate subject areas or terms. The preferences, likes, needs or requirements can be entered in writing and/or selected by clicking or marking, e.g. checkboxes. This may present a semantic problem for the user, making it difficult to find the right place for the entry in the tree structure. For example, in the context of nutrition, the term "tomato" belongs in the category "vegetables" or "red vegetables." However, if a user assigns "tomatoes" to the category "fruit," he/she will not find this term in the tree structure under "fruit" in order to store his/her preference for "tomatoes," for example. To solve this problem, the term or the category "tomato" can be included under both "fruit" and "vegetables." This means that a category or term can appear in more than one branch of the tree structure. As soon as the user has made an entry/selection, this entry/selection is automatically transferred to the other branches of the tree structure in which the category or term also appears. The same applies if the user changes or deletes his/her preference.
In another advantageous embodiment, preferences, likes, needs, etc. can also be entered verbally. To do this, the user can, for example, press a button in the application and express his/her preference verbally, e.g., in colloquial language, e.g., in complete sentences. With the help of AI and speech recognition, the application searches for the corresponding category or creates it if it does not yet exist, enters the written input in the input window, or activates the corresponding selection field. In another preferred variant, the user is asked to confirm the entry in order to rule out any errors in speech recognition and assignment. As with manual entry, the confirmed preference is automatically transferred to the other branches of the tree structure where the same category or term occurs or is expected to occur in the future. In an advantageous solution, the user can, for example within the application, make basic settings that permanently apply certain requirements to all future recommendations, help, support, etc. that are given to him/her. In another advantageous variant, he/she can specify requirements for recommendations, help, and support that only apply for a certain period of time, e.g., for the moment, one or more days, weeks, or months. In a further preferred variant, permanent basic settings and temporary settings can be based on the principle of exclusion and/or inclusion. The basic settings also include, for example, sociodemographic data of the user such as age, gender, weight, height, etc. If, for example, the user is offered dietary suggestions, e.g., in the form of recipes or dishes offered in restaurants, he or she can permanently specify exclusions or preferences in the basic settings. For example, he/she can enter his/her wheat allergy in a category called "Allergies," or he/she can enter "vegan" in the category "Nutritional principles/dietary style," or he/she can enter garlic and

onions in a category called "General aversion to certain ingredients or components of the dish." On the other hand, he/she can also provide information about specific preferences. For example, he/she could enter spaghetti as a filling side dish in a "Preferences" category. All suggestions made to him/her must then not contain wheat, meat or fish, any products made from animals or animal extracts, garlic or onions. Recipes or dishes with spaghetti as a filling side dish should be suggested.

If the user has a particular appetite on a certain day, e.g., for a specific ingredient in a recipe or dish, he/she can specify inclusions so that the suggestions must contain one or more desired foods, e.g., carrots and/or spinach. In a beneficial variant, this requirement can be limited to a specific period. In a preferred variant, a time-limited requirement can also contradict one or more basic settings, which are then suspended for this period. For example, a vegan could enter the preference "fish up to 100 g" as an exception for a particular meal. Despite selecting the "vegan" category in the basic settings, he/she would then only be suggested recipes or dishes that all contain up to 100 g of fish but otherwise meet the "vegan" category. In another preferred version, exclusions can be limited quantitatively so that, for example, only recipe suggestions or dishes that contain more than 10 g of wheat are excluded. Similarly, the user can specify that he/she only wants to be suggested recipes or dishes that contain a minimum amount, e.g., 100 g of carrots and/or 50 g of spinach. In another preferred variant, the user can, for example, rate the suggestions made to him/her after he/she has implemented them or, in the case of recipes, cooked them and eaten the dish. The rating can be given on an ordinal, interval, or ratio scale of satisfaction, ranging from "completely unacceptable" or "do not suggest again" to "highly acceptable." In another preferred variant, the rating is saved and taken into account for future suggestions. In another preferred variant, the user can set in the application, for example, whether he/she wants to receive suggestions or only suggestions that he/she has given a certain rating in the past or which the rating of falls within a certain range. Surprisingly, it has been found that the aforementioned options can improve the well-being of users in the long term. The above-mentioned additional information, recommendations, assistance, etc., which can be provided, initiated, or maintained without measurement or on the basis of a measurement carried out with the measuring device claimed here or other measuring devices and, for example, provided via a special application in an advantageous variant, relate to or contain, for example, the following aspects. Several or parts of the aspects mentioned may apply:

- Provision of the history of recommendations, assistance, etc., and/or measurement results of individual or multiple measurement parameters, e.g., in the form of a list of the

corresponding recommendations, assistance, etc., and/or individual measurement values with time stamps or as a graphical representation of the progress over time.

- Determination and storage of user preferences, e.g., in the application that communicates with the measuring device, e.g., regarding nutrition, health, sports and exercise, leisure activities, or professional requirements.
- Display of health limits for the concentration of individual measurement parameters or combinations of measurement parameters, evaluation of preferences that the user can set for certain measurement parameters.
- Determination and display of the fulfillment value resulting from the preferences when the user implements recommendations, e.g., selects or consumes individual foods or complete meals.
- Presentation of trend statements for the development of individual measured values or combinations of several measured values, e.g. based on measurement results.
- Comparison of the measurement results achieved with, for example, mean values or medians of reference groups (divided, for example, by age and/or gender and/or education and/or occupation) at regional level (e.g., the user's hometown or state), national level (the user's country), international level (e.g., continent, worldwide). Summary of all results in weekly, monthly, or annual reports.
- Option to forward results and/or recommendations, help, etc., e.g., automatically or after confirmation by the user, to user groups in social networks, to followers in social networks, to individuals, e.g., family doctor, friends, family members, to national or international institutions, e.g., hospital, statistics offices, Ministry of Health, WHO.
- Option for the user to send explanatory voice messages to selected persons or institutions via the measuring device application, together with the measurement results and/or recommendations, assistance, etc.
- Access to certain databases, e.g. with the help of search algorithms provided, in order to provide the user with information, e.g. on health-related topics, e.g. recipes, scientific publications, experience reports from affected persons, e.g. through digital entry of search queries or verbally expressed queries.
- Option for the user to receive a reminder e-mail or WhatsApp message at freely definable intervals, e.g. if a new measurement is advisable based on existing measurement results or other information.

- Information about the availability of experts in the user's vicinity, for example on health and nutrition-related issues or on legal issues that may arise, for example, from nutrition or the purchase of food or visits to restaurants.
- Information about one or more institutions from the following list: from the fields of health and nutrition, e.g., health authorities, ministries, consumer advice centers, including possible contact persons.
- Automatic appointment scheduling, e.g., with doctors, nutritionists, health experts. Advantageous if measurement results exceed certain limits or other information indicates changes that may affect the user's current or future well-being.
- Automated provision of one or more pieces of up-to-date information from the following list: opening hours and unavailability due to vacation or illness of, for example, doctors, health and/or nutrition experts, or experts for legal questions that may arise, for example, from nutrition or the purchase of food or visits to restaurants.
- Automated reminders to perform and adhere to one or more of the following activities: sports activities, relaxation exercises or rest periods, initiating a measurement, appointments, e.g., with a doctor or counseling center.
- Provision of personalized advice on how to improve measurement results, taking into account one or more of the following parameters: the user's preferences, likes, dietary habits, measurement history, and regional and seasonal availability of food.
- Provision of information, e.g., on the location and opening hours of shopping facilities for products such as food, e.g., in grocery stores, at weekly markets, in farm shops in the vicinity of the user. In an advantageous variant, taking into account one or more of the following parameters: quality (e.g., organic products), cost, distance, accessibility, and parking facilities, e.g., for cars or bicycles.
- Provision of information about dining options from one or more of the following categories: restaurants, fast food restaurants, snack bars, food delivery chains and their offerings.
- Provision of, for example, a database in which restaurants can post their current dishes in written form, e.g., with all ingredients, and as photos, which the application can then access when selecting user-related suggestions.
- Option to integrate photos taken by users of their food in the restaurant into the aforementioned database. Image analysis of these photos with regard to the ingredients, e.g. including calculation of the respective ingredient quantities (e.g. in grams), the calorific value, vitamins, and other ingredient-specific properties of the dish. Indication

of the cost of the dish and evaluation of the quality of the food by the user who may have uploaded the photo to the database with comments. Photos can be uploaded to the database via the application, which communicates with the measuring device.

- Automated ordering of products and/or services that the user needs, such as ingredients for recipes that the user selects for his/her meals and which are delivered to his/her home.
- Automated monitoring of the user's food supplies, e.g., with regard to their expiration date or availability, e.g., by quantifying the food consumed to date.
- Provision of up-to-date information about products that are relevant to the user, e.g. regarding special offers from stores in the user's vicinity. The products may be food, for example.
- Option to store external data, e.g., personal health data such as lab reports and/or measurement results from other measuring methods.
- Provision of information regarding recreation and leisure activities, e.g. if the measurement result indicates physical or mental exhaustion or high psychological and/or physical stress. This may include, for example, the presentation of current vacation offers, such as last-minute deals for package tours, vacant vacation apartments, available rooms in hotels, private rooms, campsites, including all travel options, e.g., by plane, car, train, bicycle, or hiking. The term "automated," e.g., in connection with provision, reminders, orders, or monitoring, is understood in the context of this disclosure to mean an action that the user does not have to trigger in a current situation through his/her own actions, but which the system, e.g., an application, triggers automatically with the help of a corresponding algorithm. In a preferred embodiment, the user must have previously authorized this "automated action" to the system, e.g., through the application. In an equally preferred variant, the system can always suggest these actions to the user when certain conditions are met, whereby, in such case, the user must then approve the execution of the action in each case.

It is clear to the skilled person that the aforementioned aspects can also be combined in order to provide the user with special measures or offers tailored to his/her preferences and needs, and to check the effectiveness of these offers, e.g. with the help of subsequent measurements, and, if necessary, to propose them again with appropriate adjustments.

In order to calculate certain values, to generate individual advice on how to improve measurement results, or to provide additional information, additional information may be required on a case-by-case basis, which can be requested via the application, for example. This

includes, for example, age, gender, height, weight, occupation, location of the user, but also data on certain diseases that influence the measurement results or their interpretation, such as diabetes. Therefore, in an advantageous design, the application provides input options for several of these parameters. In a preferred variant, the additional information also includes information previously required in connection with the determination of individual metabolism. This includes, for example, lifestyle or living habits such as smoking, alcohol consumption, sleep duration, current exposure to the sun, use of solariums, intensity, frequency, and duration of physical activity, e.g., through sports. The applicable data protection regulations in this context can be taken into account on a country-specific basis during use. In a preferred solution, the user can enter this information, if desired, once when configuring the application that the measuring device uses to perform its tasks. This process can take place immediately after downloading the application for use with the measuring device from the app store. In another preferred solution, this can also be done later. The user can change, add, or delete the necessary entries at any time. The user can enter such data, for example, in the application, which displays the necessary keyboard or activates the voice assistant so that the user can provide the data verbally. The application can, for example, be stored on a device that communicates with the measuring device and sends measurement data and other information to a central server, where it is evaluated and stored.

If a measuring device is used by several people, e.g., other family members, it must be possible to assign the measurement to a specific person. This can be done, for example, by creating user profiles that can be selected before each measurement. In addition to the name chosen by the user (alias), the personal information described above can also be stored in the user profile. In the preferred version, the measuring device automatically identifies the user based on measured optical characteristics that allow the user to be distinguished from other users. In the preferred version, the sensor reports which user has been recognized, so that subsequent correction is possible. In an advantageous variant, the system reports when user recognition was not possible, and, if necessary, offers a selection of possible matching users. In general, the more frequently a person takes measurements, the more accurately physiological conditions and changes can be recorded, allowing more targeted advice to be given, e.g. via the application. In an advantageous variant, the user can therefore select in his/her user profile a function that prompts the application to perform a measurement. This setting can be tailored to the individual user and adapted to his/her preferences.

This is particularly advantageous when analyzing whether a user belongs to the group of people with rapidly falling blood sugar levels, because in the advantageous variant, the user is then

prompted to take measurements at specific times and at a specific interval, which makes the detection of rapidly falling values most likely. To select the time at which a measurement is to be taken, the application can, in a preferred embodiment, be based on the analysis of previous measurements as well as on times at which the user typically performs certain actions, e.g., eats meals. In another preferred variant, the user can also store the typical times for eating meals in his/her user profile, for example. In the preferred variant, user activities can be linked to the measurement. For example, the user can take a measurement after each meal. This allows the user to tell the system when he/she has eaten, if the system knows this connection. If there are enough and/or sufficiently recent measurement results in an assigned database that determine a characteristic of the user, the application can, in an advantageous variant, prevent the measurement of further data. This can be done by omitting parts of the measurement sequence. This can be done through communication or by not communicating. For example, if the user has been assigned to the group with rapidly falling blood sugar levels, he/she will no longer be prompted by this application feature to take measurements to clarify this aspect. The request to perform a measurement can be made directly via the application when the application is open. If the application is not open on the smartphone, for example, the server can send this message to the user via SMS, email, or social networks. Alternatively, a push notification can be generated.

In a preferred variant, the measurement results and/or additional information provided are appropriately visualized, processed, and enriched with supporting information so that they can be used by the person taking the measurement without special knowledge and implemented in everyday activities. In a preferred variant, this can be achieved, for example, by providing the aforementioned results and/or additional information in varying degrees of detail and allowing the user to select the level of detail as required. In a particularly preferred variant, the user of the measuring device is also informed of what the measured value of a particular substance would be, for example, certain carotenoids, or of how much fruits and vegetables would need to be consumed daily if the user were to change certain behaviors. In an advantageous variant, one or more of the average influences determined in connection with individual metabolism, such as smoking, alcohol consumption, sleep duration, exposure to the sun, etc., are used for this purpose.

In a preferred variant, the user can contribute to the measuring device being able to measure additional parameters in the future, e.g., biomarkers in blood and tissue. To do this, the user can, for example, select in the application a function that allows him/her to enter measurements determined using other measuring methods. If the user receives the measurement result from the other measurement method immediately after the measurement has been performed, he/she can

perform a measurement with the measuring device described here in a timely manner. In a preferred embodiment, it does not matter which biomarker is measured with the measuring device described here. In a preferred embodiment, such a measurement records optical raw data over a wide spectral range, even if only a specific part is used to determine the biomarker for the specific measurement. Together with the optical raw data, the measured values entered by the user and determined using other measurement methods can be transmitted to a server, for example, and stored as reference values together with the optical raw data. The external measurement values entered by the user may also be qualitative data, for example, data relating to the user's current state of health. If the external data consists, for example, of laboratory values from a blood sample, the user usually receives the values a few days after the blood sample was taken. In a convenient variant, the application offers the option of entering the results retrospectively. However, if the user has taken a measurement with his/her own measuring device shortly after the blood sample was taken and informs the measurement application that he/she will enter the blood measurement results retrospectively after receiving them, this data can be assigned to the raw optical data on the server, e.g., based on its time stamp. In this way, the blood measurement data entered retrospectively can also be used as reference values for the development of algorithms for measuring new biomarkers. If the user agrees, additional user-specific information such as age, gender, height, and weight can be used for the algorithm development.

Once a sufficient number of reference values are available because other users have also transmitted corresponding values, an AI-based analysis of the corresponding optical measurements can be performed on the server, for example, which attempts to determine the biomarker spectroscopically. If it is possible to develop an algorithm that enables the spectroscopic measurement of the reference value or biomarker, a new measurement function can be made available, e.g., through an automatic update of the measurement application. This can be done free of charge for users, e.g. to motivate them to enter this data, while all other users have to pay for this new measurement function.

Support for users in terms of health-conscious nutrition

In a preferred embodiment, based on the measurements performed with the measuring device described here, it is recommended to the user, for example, to consume substances or foods that help to stabilize and/or increase or improve the concentrations of certain substances (e.g., carotenoids) present in the blood and/or tissue and/or the measured physiological conditions of the user.

In a particularly preferred variant, the user is recommended the quantities of certain foods that still need to be consumed. Fig. 17 shows, for example, information regarding the amount of fruits and vegetables, e.g. in grams, that the user should still consume on the day of measurement in order to comply with recommendations, e.g. from the WHO or government institutions, recognized associations or professional associations, e.g. the "German Nutrition Society" (Deutsche Gesellschaft für Ernährung), or his/her own guidelines. The user's own guidelines can be stored in the application, for example. In a particularly preferred version, the user is given detailed information regarding the quantities of individual types of fruits and vegetables that he/she should consume in order to achieve the target value resulting from a preference selected by the user or recommended by relevant institutions or individuals.

In another preferred version, the user is also informed of the time frame within which he/she can achieve the target value if he/she follows the recommendation for fruit and vegetable consumption. In a preferred embodiment, the determination of the time period is based on previously collected knowledge about the user's metabolic process and/or on data collected, for example, from comparable users and/or on results obtained in scientific studies.

In another preferred variant, the user is specifically recommended foods or recipes containing ingredients for which the measuring device has also identified deficits in relation to target values. These may include, for example, omega-3 and omega-6 fatty acids or certain vitamins. In an alternative variant, the identified deficits may also have been determined using other measuring devices. The user can then report these deficiencies himself/herself, e.g., to the application. In another preferred variant, the substances or foods recommended for consumption and their quantities are based, for example, on the user's preferences regarding the time period within which the concentrations and/or physiological states measured in the user should change.

In another preferred variant, the user can, for example, specify categories of rates of change in the measuring device's application. Main categories can be, for example, "rapid change" or "moderate change." In the case of a rapid change, the amount of a substance recommended for consumption is higher or, for example, the reduction is greater than in the case of a moderate change.

In another preferred variant, the recommendations for substances or foods and the respective quantities to be consumed are based, for example, on generally accepted and/or scientifically proven target levels of these substances in human blood or tissue and/or on consumption levels recommended by recognized institutions and/or they are based, for example, on the average concentrations of these substances measured with the measuring device in a comparison group relevant to the user and/or on target values defined by the user himself/herself. A combination of

the above-mentioned target value sources is also possible. In a preferred variant, there may also be several intermediate stages for achieving target values that compensate for the identified deficit. The intermediate stages can, for example, act as motivational aids, because the user experiences a sense of achievement when he/she reaches each intermediate stage. In a preferred variant, the user determines which target values are used for comparison.

In another particularly preferred variant, the user is not only suggested individual substances and/or foods, but also complete recipes for a day's food intake. In another preferred variant, the user can also be given suggestions that relate to his/her entire lifestyle or his/her current lifestyle. This also includes dietary habits, e.g., switching to a vegetarian or vegan lifestyle, or suggestions for improving work-life balance, e.g., by reorganizing the user's work environment and/or working hours, or suggestions for actively organizing leisure time, e.g., by joining sports clubs or associations such as the volunteer fire department. In a preferred solution, the user can also be suggested several substances and/or foods or several complete recipes from which he/she can select the one he/she wants. In another preferred solution, the user is always suggested new recipes until he/she decides on one. Alternatively, dietary supplements are suggested in an advantageous variant. In another particularly preferred variant, the quantities of substances and/or foods suggested for daily consumption based on the detected substance concentrations are distributed across three main meals: breakfast, lunch, and dinner. In another preferred variant, the amount is distributed not only across the three main meals, but also across one or more additional snacks that can be consumed, for example, after a meal or between meals. In another preferred variant, dishes offered in a restaurant located within a maximum distance from the user's location, as selected by the user, can also be suggested. In another preferred variant, at least one measurement of a biomarker or substance is used to determine which substances and/or foods are recommended for consumption and in what quantities. The measurement may be, for example, the measurement of glucose concentration. In a further preferred variant, the suggestion may also relate to the time of day at which the substances and/or foods are to be consumed.

With certain substances, one substance may interfere with the absorption and/or metabolism of another substance. An example of this is beta-carotene and lutein. If a user has a deficiency in both substances, he/she faces the problem that simultaneous intake of both substances is less efficient. In an advantageous design are given recommendations whereby substances that interfere with each other are recommended at sufficient intervals between intakes. In an advantageous variant, recommended recipes are selected so that a suitable time interval is maintained. In a preferred embodiment, several and, in a preferred variant, all substances mentioned in this description, of which the concentrations have been measured in the user's

blood and tissue and which are stored accordingly in the user-specific database, are taken into account in the generation of suggestions for individual foods, recipe suggestions for meals, or dishes offered in restaurants. In an advantageous embodiment, substances that are produced exclusively or primarily by the human body itself are taken into account by determining dietary recommendations that provide the body with the raw materials necessary for its own production. Therefore, in an advantageous embodiment, the quantities of the relevant substances contained in recipes/restaurant dishes are recorded and specified with sufficient accuracy. In a preferred variant, the respective quantities of these substances, e.g., carotenoids in kale, can be determined, for example, by referring to information from the Internet or by targeted research in special databases, whereby AI (artificial intelligence) is used for the necessary search algorithms or for formulating the search criteria.

The analysis of the ingredients of a meal consumed by a user can also be carried out using an image analysis software. Thus, the user can photograph his/her meal to enter the ingredients. The software uses image recognition to identify the food components, e.g., potatoes, peas, carrots, determines and quantifies their ingredients, stores the result, e.g., in a database that can be accessed by the measuring device's application and displayed on a display device, e.g., a smartphone/tablet. In a preferred version, not only the information itself is made available to the user, but the search algorithms or research strategies are made available as well, so that he/she can repeatedly determine the content that interests him/her himself/herself in order to keep the information that interests him/her up to date. In an advantageous design, the user can store any other type of parameters that are important for his/her well-being and that he/she receives from third parties, for example, in the application. These can then be taken into account when determining individual preferences, selecting substances, or determining suggestions for recipes or dishes. These parameters are also taken into account when evaluating the substances, recipes, or dishes selected by the user from the suggestions. In another preferred variant, the respective quantity of a substance can be determined using a database created by the user, which the measuring device application has access to and in which the results of previous Internet searches have been stored.

If it is not possible to compensate for measured deficits, e.g. due to physiological dependencies, by changing behavior or diet, the measures suggested to the user follow a preferred variant of a deficit compensation hierarchy specified in the application. This hierarchy can be based, for example, on the general medical knowledge that applies to most people. In another preferred variant, the hierarchy is based on the preferences specified by the user.

In a particularly preferred variant, the suggestions also include information on general, health, economic, social, or environmental aspects, such as CO_2 balance, or the effort and costs involved in procuring substances, food, or ingredients for the recipes, or the price of a dish listed on a restaurant menu. In an advantageous variant, delivery costs for food or restaurant meals are also specified. For example, when determining the carbon footprint, a distinction can be made between the means of transport (e.g., bicycle, car, scooter) used for delivery. In other equally preferred variants, the proposals quantify the total effort required by the user to implement the proposals. This includes, for example, the time required for purchasing and preparing food or cooking the recipes. In a preferred version, the effort required for shopping at the stores or grocery stores suggested by the application or for visiting the restaurants suggested by the application is calculated. If the user decides to go to other stores or restaurants, this effort can also be calculated.

The effort can be represented in different units, e.g., time in minutes, money in dollars, psychological stress as a stress value on an ordinal or interval scale. For an overall assessment, the individual efforts can be converted into a monetary unit, e.g., dollars.

In addition, in a further preferred variant, the ecological footprint is also quantified, which results, for example, from the production of the food, its transport and storage at the point of sale, the journey to the point of sale or delivery by a delivery service, as well as the energy required to prepare the food and the possible disposal of food leftovers. In a preferred variant, the ecological footprint data is also included in the evaluation of the suggested recipes or restaurant dishes and presented to the user as a separate indicator, e.g., in the overview table for the selected dishes of a day. In another preferred variant, the ecological footprint is part of a larger/more comprehensive indicator.

In a preferred variant, the system includes a planning aid. Preferably, this supports the user in planning his/her diet. Preferably, the planning aid can save and display plans. Preferably, the user can enter planned events. Preferably, the planned events are food intakes. Preferably, the planned events are the intake of dietary supplements and/or medication. Preferably, the system can forecast the achievement of goals and/or key figures based on the planned events. Preferably, the planning aid determines suggestions for planned events. Preferably, the user can accept or reject these. Preferably, an alternative suggestion is created if a suggestion is rejected. Preferably, the planning aid takes the set goals into account when determining suggestions. Preferably, the planning aid uses optimization algorithms for this purpose.

Key figures, e.g., nutritional quality

In a preferred variant, the system calculates one or more key figures. In an advantageous variant, a key figure is a number that indicates how well a goal is being achieved. In an advantageous variant, the key figures describe the achievement of nutritional goals. In a particularly advantageous variant, key figures are formed with regard to one or more of the following categories: nutrition, health, fitness, exercise, cosmetics, medication dosage. In a particularly advantageous variant, key figures are formed with regard to one or more of the following aspects: weight management, antioxidant supply, inflammation parameters, nutrients, fatty acids, fruit consumption, vegetable consumption, vegetarian diet, vegan diet, dietary diversity, avoidance of unhealthy foods, allergen avoidance, sugar avoidance, salt reduction, alcohol consumption, drug consumption.

A useful indicator can be obtained from the ratio of target to target achievement. Target achievement is advantageously measured using a measuring device, preferably the measuring device described in this text. In a useful variant, quantities of different units can also be compared. For example, a key figure for nutritional quality can be formed from the ratio of the amount of fruit and/or vegetables consumed by a person or recommended for consumption to the concentration of a biomarker, e.g., antioxidants, and/or, e.g., carotenoids, measured in a person's body. In an advantageous variant, one or more time periods for one or more targets can be specified, in which these targets are to be achieved. In an alternative advantageous variant, one or more speeds for one or more targets can be specified, at which these targets are to be achieved. In an advantageous variant, the speeds can be specified in stages. In a particularly advantageous embodiment, these levels are based on the user's workload and/or the level of commitment required. Examples include moderate or drastic changes in diet, or gradual changes in diet.

In an advantageous variant, the achievement of the goal is not measured directly, but estimated by measuring a substance concentration, from the result of which a statement about the achievement of the goal can be derived. For example, goals for the consumption of fruits and vegetables are usually specified by health organizations or governments in units of quantity of fruits and vegetables to be consumed, e.g., in grams. The variable used to check whether the target has been achieved is preferably the carotenoid concentration in the user's body. In a particularly advantageous design, the measurement variable used to achieve the target for the user's well-being or health is a more relevant value than the target value. For example, when consuming vegetables, the amount consumed is less relevant than the amount of nutrients from the vegetables that is absorbed into the blood.

In a preferred variant, the user receives suggestions for recipes and/or dishes and/or dietary supplements. Preferably, the suggestions take into account one or more key figures. Preferably, the temporal progression of the key figures is taken into account. Preferably, the user is shown a predicted key figure development.

In preferred variants, the target value is determined by a national authority, an international authority, a medical institution, or traditional dietary practices. In a preferred variant, this target value is the value specified by the German Nutrition Society (Deutsche Gesellschaft für Ernährung). In another preferred variant, the recommendation distinguishes between fruits and vegetables. In another preferred variant, the user himself/herself determines the target value to be achieved. In a preferred variant, the user receives information on the contribution a dish and/or recipe makes to the achievement of one or more targets. In a preferred variant, the proportion of a target achieved by a dish and/or recipe over a specific period of time is displayed. In a preferred variant, targets can be divided into sub-targets. Sub-targets for individual meals are particularly preferred. For example, breakfast, lunch, dinner, snacks, drinks. In a preferred variant, the contribution of dietary supplements to target achievement can be taken into account.

In a preferred variant, a meal and/or snack and/or drink and/or dietary supplement can compensate for the deficit of another meal within a period of time.

In a preferred variant, priorities can be set if there are several goals. The background is illustrated by the following example: if the measurement of the biomarker representing the consumption of fruits and vegetables shows that the concentration of the biomarker in the user's body does not correspond to the target value of, for example, 650 grams of fruits and vegetables, the user must change his/her dietary habits. The cause may be insufficient intake of fruits and vegetables, but it may also be due to individual metabolism, meaning that the relevant biomarker, e.g. carotenoids, has only been partially absorbed by the body. However, it may also be due to the poor quality or lack of freshness of the fruits and vegetables consumed. The advantage of a definable target achievement speed is illustrated by the following example : the greater the deficit determined by measurement in relation to the target value, the more the user must change his/her dietary habits. If the required dietary change is too great, many users fail. To make the change easier and prevent failure, users can try to achieve the target value gradually by eating just a little more fruits and vegetables each day than they have done previously. This means that the additional amount consumed is less than the daily deficit determined by measurement. Over a longer period of time, however, even with smaller additional amounts of fruits and vegetables, the difference becomes smaller and smaller until the amount determined by measurement finally corresponds to the target value.

In a preferred variant, one or more measurements are used to estimate the extent to which the user has achieved one or more goals. Preferably, the user receives this information. In an alternative preferred variant, one or more measurements are used to estimate how far the user is from achieving one or more goals. Preferably, the user receives this information. In a preferred variant, the achievement of a goal can be expressed as a percentage. If a target value is exceeded, this can be documented in a preferred variant by assigning an additional symbol, e.g., by assigning stars. The more stars, the greater the excess achievement. However, the excess achievement can also be expressed as a percentage, for example.

Fig. 18 shows an example of labeling with "3 stars" as a sign of overachievement. The degree of achievement is less than, for example, 100% if fruits and vegetables still need to be consumed or if less than 650 grams were consumed by the user. In the preferred version, it is not recommended to eat additional fruits and vegetables, but rather to replace other foods. In a preferred variant, the user can specify a gradual increase in the daily amount of fruits and vegetables as a target for achieving the target value. This preference can be defined as a "slow" improvement towards achieving the target value.

In another preferred variant, the user can set a target of consuming the amount of fruits and vegetables determined by the measurement. This preference can be defined as a "moderate" improvement to achieve the target value. In another preferred variant, the user can set a target of consuming more than the amount of fruits and vegetables currently determined by measurement, e.g., double the amount or more than double the amount. This preference can be defined as a "fast" improvement to achieve the target value. In another preferred variant, the "fast" improvement should mean that the daily amount of fruits and vegetables is above the measured value but below twice the amount. In another preferred variant, the "fast" improvement means that the daily amount of fruits and vegetables is above the target value.

In a preferred variant, there is more than one category for the speed at which the target value should be achieved. In a preferred variant, there are no fixed categories for the speed at which the target value should be achieved. In a preferred embodiment, the application determines and evaluates how well the selected recipes or dishes correspond to the goals set by the user and/or the recommendations suggested from a medical point of view or by experts or institutions. Figure 17b shows an example of how the target value is selected. Figure 17c shows an example of how the speed at which the target is to be achieved or the speed of behavioral change is determined.

In a preferred variant, the individual metabolism can be taken into account when evaluating the amount of fruits and vegetables contained in recipes or dishes. If the user's priority target for

speed is, for example, 250 grams, the amount of fruits and vegetables contained in recipes or dishes can be multiplied by an individual metabolism factor for the respective types of fruits and vegetables. The resulting corrected gram amount can then be used as the basis for the recipes or dishes automatically suggested to the user.

In a preferred variant, the corrected gram amount can be displayed in the application, for example.

In another preferred variant, in which recipes or dishes are not automatically suggested to the user, but rather the user searches for and selects recipes or dishes himself/herself, the corrected gram amount can be used as the basis for determining the degree to which the selected recipes or dishes meet the requirements. This means that the corrected gram count is used to assess how well the selected recipe or dish meets the speed target chosen by the user. The degree of fulfillment is displayed to the user. In a preferred variant, in cases in which there can be automatically suggested an insufficient number of recipes or dishes that achieve the corrected gram amount of fruits and vegetables, and, therefore, recipes or dishes that do not quite meet the selected speed target must also be suggested, the degree of fulfillment for each recipe or dish is also displayed.

History of degree of fulfillment

In another preferred variant, the user can also be shown a timeline of information about his/her diet. This can be one or more values from the following list: degree of fulfillment of nutritional quality, target values, specific actual values, measurement results, nutrient values. In an advantageous variant, current values and/or time-averaged values can be displayed. Fig. 22 shows an example of the display of a value history. In an advantageous variant, historical and/or future values can be displayed. In a further preferred variant, the observation period of the history is at least 14 or 30 days or approximately one month, whereby the amount of fruits and vegetables consumed or selected in recipes/dishes and the amount of fruits and vegetables that has been determined by measurement and still needs to be consumed in order to achieve the target value are displayed graphically, for example in a joint X-Y diagram. In a preferred variant, the observation period may also be longer or shorter than 30 days. In preferred embodiments, it is between 30 and 60 days, between 60 and 90 days, between 90 and 180 days, between 180 days and one year, or more than one year.

In other preferred embodiments, the observation period is between 20 and 30 days, between 10 and 30 days, between 5 and 30 days, or between 1 and 5 days. In a particularly preferred embodiment, the user determines the length of the observation period. In a preferred variant, the

selected or consumed amount of fruits and vegetables is displayed as a bar chart, for example, and the measured value for the amount still to be consumed is displayed as a curve on the bar.

In a preferred variant, the X-axis of an X-Y diagram represents time, e.g. in days, while the Y-axis represents the amount of fruits and vegetables, e.g. in grams. In a preferred variant, the amounts of fruits and vegetables contained in recipes or dishes are displayed as bars, for example. In another preferred variant, the values measured by the measuring device for the additional quantities of fruits and vegetables to be consumed are represented as lines in the same diagram. In a preferred variant, the target value/setpoint for the daily quantity of fruits and vegetables is entered and named, e.g., as a dashed horizontal line over the entire observation period of the graph. In a preferred variant, the height of the bars indicates the amounts of fruits and vegetables contained in recipes or meals. If the target value/desired value is plotted as a dotted line, it is immediately apparent whether the meals eaten on a given day exceed or fall short of the desired value. In another preferred variant, the X-axis intersects the Y-axis at the target value selected by the user or at a target value that can be preset in the application. Bars pointing downwards from the intersection indicate that the meals on that day did not reach the target value in total. Bars pointing upwards from the intersection indicate that the target value has been exceeded.

In a preferred variant, the two bar directions also differ in colour. It is clear to the skilled person that any other form of representation can be chosen for the history of the "nutritional quality" instead of bars and lines. These include, for example, line-dot lines, dot diagrams, or combinations of line, column, and dot diagrams. In a preferred variant, the amount of fruits and vegetables contained in the selected recipes or dishes of the day is also entered as a digital numerical value in the graph. In a preferred variant, the measured value for the amount of fruits and vegetables that the user still has to consume or has consumed is also entered as a numerical value for each measurement.

In a preferred embodiment, the value is a negative number if the amount of fruits and vegetables contained in recipes or dishes is less than the target value. If the amount exceeds the target value, the value is positive.

In another preferred variant, the area below the target value in the history graph can be colour-coded to differ from the area above the target value.

In another preferred variant, the graphical representation of the "nutritional quality" history is supported by multimedia. This can be done, for example, through images, videos, or spoken text. This could include photos of the meal or the fruits and vegetables it contains and/or videos of the meal being prepared and/or comments on the meal or the fruit and vegetable content that the user

has previously stored, for example in a database that communicates with the application that displays the history graph. In a preferred variant, the comments can be entered in writing via a keyboard or recorded as a voice message or recorded as a voice recording and output as a written comment. In a preferred variant, the multimedia support is activated, for example, by the user clicking on his/her display device for the value or the day about which he/she would like to learn more. In another preferred variant, there may be a special button that activates the output. In another preferred variant, the request for additional information can also be expressed verbally after, for example, a corresponding activation button has been pressed.

In another preferred variant, the diagram showing the history of the "nutritional quality" also contains a statistical statement on the trend that emerges from all the individual daily results. The diagram can, for example, show the average value for falling below or exceeding the daily target values for fruits and vegetables over a selected period of time and/or the average value for compliance, with the priority for the speed of behavioral change being also able to be displayed. In a preferred variant, any other measure of the central tendency can also be used, such as the median of all individual results. In another preferred variant, the central tendency can also be expressed as a written comment. In yet another preferred variant, the description of the central tendency can also be provided exclusively or additionally via images, video, or as a voice output. In another preferred variant, this can also be expressed using colours, for example. For example, there can be, below the history graph, a colored area that contains the written comment. Green shades can symbolize the achievement of user goals, yellow can indicate that the goal was narrowly missed, and red can indicate that the goal was clearly not achieved.

In another preferred variant, the history of the "nutritional quality" shows, for example, the start of the period under review and the date of the last measurement or the last selected recipes or dishes, and/or the current date on which the history was called up. In another preferred variant, the target values for the two nutritional quality goals mentioned above are also specified. This refers, for example, to the target value of 650 grams of fruits and vegetables and the speed at which the target is to be achieved, i.e., the amount of fruits and vegetables that corresponds to this speed.

Fig. 22 shows an example of the display of the nutritional quality history over 30 days. The X-axis intersects the Y-axis at the value 0. The first day of recording is August 2, 2022. It is labeled "Start" in the graph. The last measurement or selection of dishes was made 16 days later. The date on which the nutritional quality history was accessed or displayed in the application, for example, is August 20, 2022 in the example. It is labeled "Today" in the graph. The priority selected by the user for the speed of behavior change is indicated in a separate field below the

graph. The user has selected the priority "moderate." The amounts of fruits and vegetables contained in the recipes or meals are shown as vertical bars, and the measurement results for the amount still to be consumed are shown as a continuous line. The target daily fruit and vegetable consumption to be achieved by the user is represented by a dashed horizontal line that intersects the Y-axis at the value 650 g. The target value is also written at the edge of the graph ("DGE recommendation 650 g/day"). Over the 16-day measurement period, the user has exceeded the priority for the speed of behavior change (selected as "moderate") on average, while the biomarker measurement shows that the equivalent of 650 g of fruits and vegetables has not yet been accumulated in the body. Both are shown in writing in a separate field below the graph.
It is clear that the "moderate" priority of 10 days on which the amount of fruits and vegetables consumed exceeds the target value of 650 g on average is not sufficient for a concentration of the biomarker corresponding to the value of 650 g of fruits and vegetables to build up in the user's body under the influence of the individual metabolism. For the user, this is also an indication of the quality of his/her metabolism.

Weight management indicator

In a preferred version, the application contains an additional indicator that informs the user whether the selected recipes or the food consumed correspond to his/her preferences for weight loss, weight gain, or maintaining his/her current body weight (within freely definable limits). In a preferred version, this key figure is referred to as "weight management." In another preferred version, the user can specify in the application whether he/she wants to maintain his/her weight, reduce it, or increase it. He/she can set goals for weight loss or weight gain. In a preferred variant, the user can select the category "moderate" in the application, for example, where he/she should consume 250 kcal/day less than his/her average energy consumption or, in the case of weight gain, 250 kcal/day more. However, he/she can also select the "strong" category, for example, in which he/she should consume 500 kcal/day less or more than his/her calorie requirement. The application evaluates the dishes selected by the user based on these goals. An example of an evaluation result can be seen in Fig. 18.
In a preferred variant, the category "moderate" for weight loss and weight gain refers to falling below/exceeding the average energy consumption by a value between 50 kcal/day and 350 kcal/day, and the category "strong" to falling below/exceeding 350 kcal to 600 kcal. In a preferred variant, there are more than two categories for weight loss and weight gain. In another preferred variant, there are different numbers of categories for weight loss and weight gain. In a

further preferred variant, the target values for weight loss and weight gain differ in each category.

In another preferred variant, there are no predefined categories.

In another preferred variant is specified as the target value a fixed value, which, from a medical point of view, best promotes the long-term well-being of the user. The user can adjust the target values at any time according to his/her own preferences. In another preferred variant, the user can also formulate a dynamic target for weight loss or weight gain, whereby the weight change becomes greater or smaller on a time axis in a definable number of days. In another preferred variant, the user can define the target values for weight gain and weight loss himself/herself in the application. It is clear to the expert that energy consumption can also be expressed in kilojoules (kJ).

Fig. 17a shows an example of how the user of the measuring device can set his/her weight management preferences in the application that communicates with the measuring device. In this example, he/she can choose between five categories. In the example, he has chosen a moderate reduction in body weight. The goal is for the caloric value of the selected meals per day to be 250 kcal less than his average daily energy consumption. The user can select the appropriate category in the application by, for example, checking a box, clicking a button, or making an entry in a field. In this example, he has entered an "X" in the "Moderately reduce body weight" field. To calculate the key figure, the application determines the calorie content in kcal for all suggested recipes or restaurant offers that a user selects for a day and compares the total with the average calorie requirement or average energy consumption of that user per day. In a preferred variant, the average calorie requirement or average energy consumption is determined using a recognized calculation method. The following calculation methods can be used, for example: Harris-Benedict method, Mifflin and St. Jeor method, method according to WHO and the Food Agricultural Organization of the United Nations. Since the calculation methods do not determine exactly the same calorie requirement, the user can specify which calculation method should be used in a preferred variant. In another preferred variant, the application makes a suggestion that the user can accept or reject.

In another preferred variant, several or all methods are used for calculation, for example by using a measure of central tendency (e.g., mean, median) to determine the user's daily calorie requirement/consumption from the calculated results. In another preferred variant, the consumption of kcal during the consumption and metabolism of food is also taken into account when determining the calorie requirement or average energy consumption.

Fig. 19a shows an example of a result page for the calculation of individual average energy consumption per day. The calculation is based on data entered by the user (e.g., gender, age, weight, activities). In this example, the daily energy consumption in kcal was determined as the average of four calculation formulas. In this example, it is 2049.69 kcal. In a preferred variant, it is shown in a separate field at the bottom of the figure. The label for the field could be, for example: "Average of the various calculations for daily energy consumption in kcal." In a preferred variant, the calculation results for "basal metabolic rate," "energy expenditure," and "energy consumption" of the four calculation methods are displayed side by side in blocks. In a preferred embodiment, however, the user can also select one of the four calculation methods for calculating his/her energy consumption, for example, by checking a box, clicking a button, or making an entry in a field. In this example, he/she must enter an "X" in the corresponding field. The value is then displayed as the result in the field indicated above. The explanatory text is adjusted according to the selected calculation formula. If the user does not make a selection, the preferred variant uses the average value from all four calculation methods.
In the preferred variant, information from other sensors, such as a motion sensor and/or sensors for body temperature and/or sensors for ambient temperatures and/or sensors for perspiration, is included in the determination of the body's energy consumption. In another preferred variant, the key figure expresses the degree of achievement of the target selected by the user, analogous to the nutritional quality. In this case, the average calorie requirement or energy consumption of the user is compared with the actual calorie intake resulting from the calorific value of the recipes or restaurant meals selected for one day. The result is expressed as a degree of achievement, e.g. in percent. In a preferred variant, exceeding a target value in weight management is displayed in a manner analogous to nutritional quality: the more stars, the greater the target value is exceeded. An example is shown in Fig. 18. The meals selected by the user exceed the target for moderate weight loss. The degree of achievement is 100% and three stars have been awarded for exceeding the target.

Weight management history

In another preferred variant, the user is also shown a history of the degree of achievement of his/her weight management. An example of this is shown in Fig. 19. In this case, the history is displayed in the form of an X-Y diagram, with the time on the X-axis and the energy content of the recipes or meals for a day on the Y-axis. The X-axis intersects the Y-axis at zero. Values in the negative range indicate that the amount of kcal consumed through meals is lower than the user's average energy requirement. Positive values and bars that rise above the intersection

indicate that the energy consumed through meals has exceeded the energy requirement. In a preferred variant, the X-axis intersects the Y-axis at the value 0.00, so that positive values represent weight gain and negative values represent weight loss, i.e., bars representing weight gain go up and bars representing weight loss go down. A reverse direction of the Y-axis is also possible. It is clear to those skilled in the art, analogous to nutritional quality, that the history of weight management can be displayed in different colours and backgrounds, that exact numerical values can be included, that the display can be graphical and multimedia-based and supported by comments/statements from experts or friends, that the time frame of the history can vary, and that aspects mentioned in relation to nutritional quality also apply analogously to weight management.

Fig. 19 shows an example of how weight management history can be displayed in relation to the ratio of kcal intake from selected meals to a user's daily energy requirement. The figure shows that the user selected recipes or dishes from a restaurant on 10 days and consumed an average of 456 kcal/day less than his/her average energy requirement. This is shown below the graph in a separate field as "current average -456". His/her self-set target of -250 kcal/day was thus exceeded. In Fig. 18, 3 stars were therefore also awarded for weight management. The X-axis in Fig. 19 shows the observation period in days and the Y-axis shows the reduction or increase in kcal compared to the user's daily energy requirement. The X-axis intersects the Y-axis at the value 0. The user's goal of reducing kilocalorie intake by 250 kcal per day is also shown in the graph as a continuous dotted line over the entire observation period of 30 days. The date when the history was started and the date when the history is displayed are also entered. This is shown in a separate field below the graph and labeled "Start 08/02/2022" or "Today 08/20/2022." Below the graph, there is also a written comment on the average achievement of the goal. In this example, it reads: "On average, your kcal reduction is much better than your 4-week goal."

Healthy Food Ratio

In a preferred version, the application contains an additional key figure, which in the preferred version is called "Healthy Food Ratio." This refers to the following:

The energy (calories) consumed in food in the form of carbohydrates, fats and proteins is used by the body to maintain bodily functions (breathing, heartbeat, brain activity, etc.). Energy is mainly produced by the supply of oxygen through the combustion of fatty acids and carbohydrates (aerobic metabolism). This produces free radicals. If these are present in excess, oxidative stress occurs, which is considered a contributing factor to a variety of diseases. Because the antioxidants (vitamins, carotenoids, etc.) contained in fruits and vegetables can neutralize free

radicals, it is important to provide the body with adequate amounts of fruits and vegetables. Therefore, the ratio of fruits and vegetables to the calorific value of meals, expressed in kilocalories (kcal) or kilojoules (kJ), reveals the long-term health effects of the diet. It is therefore an important criterion for evaluating the dishes selected by the user or suggested to him/her.

Based on all meals in a day for which recipes or restaurant dishes are suggested, it indicates how many calories (kcal) are contained in one gram of fruit + vegetables (grams/kcal). In a preferred variant, additional parameters can be taken into account, such as the method of preparation, for example, the temperature at which dishes are prepared, because lower temperatures preserve the vitamins in fruits and vegetables. In a preferred variant, the Healthy Food Relation (or Ratio) achieves a percentage value of 100% if 1 kcal is allocated to 1 gram of fruits and vegetables, i.e. the ratio between the two reaches the value 1.

In a preferred variant, the ratio of 1 also represents the target that the user should achieve in his/her diet. In another preferred solution, the target can also be greater or less than 1.0. In further preferred solutions, the target lies between 0.8 and 1.0, between 0.6 and 0.8, between 0.4 and 0.6, or between 0.2 and 0.4. In other preferred solutions, the target is between 1.0 and 1.2, between 1.2 and 1.4, between 1.4 and 1.6, or between 1.6 and 2.0. In a preferred variant, the target value is not a constant value but can change over a period of time. In a preferred variant, the target value increases over the observation period. In another preferred variant, the target value decreases over the observation period. In a preferred variant, the user can, for example, specify in the application itself which target he/she wants to achieve with regard to the "Healthy Food Relation" indicator. In accordance with the above-mentioned target values, the value can be between 0.2 and 2.0. In another preferred variant, a target value is set that best promotes the long-term well-being of the user from a medical point of view. The user can adjust the target value at any time according to his/her preferences. In another preferred variant, a target value is set that starts at a low value and increases gradually. The user can adjust the target value at any time according to his/her preferences. The same applies to the "Healthy Food Relation" indicator as to nutritional quality and weight management in relation to exceeding targets: in a preferred variant, the indicator shows a value of 100%, with additional stars indicating exceeding the target. The more stars, the higher the degree of exceeding the target. In Fig. 18, for example, the degree of achievement is 63.1%. In a preferred variant, the user is also shown the history of the Healthy Food Relation in the application.

Healthy Food Relation history

In another preferred embodiment, the history is displayed, for example, as a bar chart, with the time on the X-axis and the ratio of grams of fruits and vegetables to the caloric value in kcal of the recipes or restaurant meals selected for the day on the Y-axis. The intersection of the X-axis and the Y-axis is at 0.00 grams/kcal. In another preferred embodiment, the intersection of the X-axis and the Y-axis is at the target value that the user should achieve. If the target value for the ratio of grams of fruits and vegetables to kcal is 1.00, for example, then the intersection is at 1.00. If the intersection of the X-axis and the Y-axis corresponds to the target value, then in a preferred variant, the bars start at the target value and go up for values greater than the target value and down for values less than the target value. In a preferred variant, the bars indicating a gram/kcal ratio less than the target are colored differently from the bars indicating a gram/kcal ratio greater than the target.

In another preferred variant, the bars indicating a ratio smaller than the target have a first colour, e.g., a bluish colour, while the bars indicating a ratio greater than the target have a second colour, e.g., a greenish colour. In a preferred variant, in addition to the bars, the values for each bar are displayed, e.g., as a digital value above the bar. It is clear to those skilled in the art that any other form of representation can be chosen for the "Healthy Food Relation" instead of the bar chart. These include, for example, line charts, scatter plots, or combinations of line and bar charts. In another preferred variant, the observation period is the same as that already mentioned for other key figures. In a particularly preferred variant, the user determines the size of the observation period. In another preferred variant, the area of the diagram that shows a gram/kcal ratio of <1 is distinguished in colour from the area of the diagram that shows a gram/kcal ratio of >=1 during this observation period. In an equally preferred variant, the area with a ratio of <1 has a first colour, e.g., a reddish colour, while the area with a ratio of ≥1 has a second colour, e.g., a bluish colour. In another preferred variant, the graphical representation of the "Healthy Food Relation" is supported by multimedia in ways already mentioned for other key figures. In a further preferred variant, an average fulfillment of the Healthy Food Relation is calculated for the period under review and displayed in the application. This can be done in ways already mentioned for other key figures.

Fig. 23 shows an example of how the history of the "Healthy Food Relation" can be displayed. In this display, the time in days is shown on the X-axis. In this example, the observation period is 30 days. The dotted line in the graph shows the target value that the user should achieve, although any other display can of course be used for the target value. In this example, it is 1.00. The start of the observation period, in this example August 2, 2022, and the day on which the graph is presented, in this example August 20, 2022, are indicated in separate fields below the

graph. The graph shows that the user did not select recipes or dishes from a restaurant on all days of the observation period. The last selection was made on the 16th day of the observation period. In this example, the 16th day is two days before the date on which the graph is presented. This does not necessarily have to be the case, as the user can view the graphs at any other time. The graph clearly shows that the user has fallen well short of his/her target of 1.0 for the fruit/vegetable consumption to calorie (kcal) ratio of the selected meals. The average is 0.6. It is displayed in a separate field below the graph and labeled "current average 0.6." A corresponding evaluation comment can also be found below the graph. In this case, it reads: "On average, the ratio of fruit and vegetable consumption to the caloric value (kcal) of your meals is significantly worse than your target value."

ORAC value

Another key figure that can be used to evaluate suggested foods, recipes, or dishes offered in restaurants is the ORAC value. ORAC stands for "Oxygen Radical Absorbance Capacity," which is the ability to capture oxygen radicals. The value indicates how many free radicals can be neutralized per gram of juice or fruit, thus describing a chemical property of the food measured. In a preferred variant, the ORAC value is determined for the foods, recipes, or meals offered in restaurants that the application suggests for consumption on a given day. In a preferred variant, the values are taken from publicly accessible databases or from databases to which access is granted.

In a preferred variant, nutritional components that are not available are not taken into account when calculating the ORAC value for nutritional components of the recipe or dish. In another preferred embodiment, the user is informed of how many ingredients in a recipe or dish for which the ORAC value cannot be determined and how this affects the determination of the ORAC value of the recipe or dish. For this purpose, confidence classes can be defined, for example, and the assignment to these confidence classes is made by comparing the weight (in grams) of the non-ORAC-rated ingredients to the weight of the rated ingredients of a recipe or dish.

In a preferred variant, this value is not displayed together with all other key figures in a common overview in the application, but is only made available to interested users as additional information. In Figure 18, the ORAC value is therefore only shown in the upper part of the graphic and not in the lower part, where the fulfilment of the various targets is shown. In another preferred variant, this also applies to the history of the ORAC values. In another preferred variant, the ORAC value is displayed together with all other key figures in a common overview

in the application. In another preferred variant, this also applies to the history of the ORAC values. In another preferred variant, the recommended intake for users is assumed to be 7,000 µmol TE per day. In a further preferred variant, the recommended intake for users is assumed to be 5,000 µmol TE per day. In a preferred variant, users can specify themselves how many µmol TE their selected recipes or dishes should contain for a period of one day.

History of ORAC values

In a preferred variant, the user is also offered a history of ORAC values over a period of time selected by the user. The same applies to the display of the history as described above in connection with the history of other key figures (e.g., nutritional quality). This applies, for example, to the observation period, the graphical representation of the values per day, the colour coding, the type of target value display, the representation as a diagram, the fulfilment of the target values over the observation period, etc. Figure 24 shows an example of the history of ORAC values as a bar chart. The observation period is 30 days. On the X-axis are shown in the form of bars the days in the course of which the user selected recipes or meals. The Y-axis shows the ORAC values associated with the recipes/meals for these days. The X-axis intersects the Y-axis at the value 0. The target value, in this example 7,000 µmol TE, is represented as a dotted line over the entire observation period of 30 days and entered in words and numbers in the graph at the height of the dotted line. In a field below the graph, the ORAC average value is entered as "Current average per day 13,816" for the 10 days in the course of which the user selected recipes or meals. Also below the graph, in a separate field, is the assessment of the target exceedance. It is labeled "On average, the target value of 7,000 µmol TE/day was significantly exceeded." In the adjacent field, the exceedance percentage is entered as "Plus 197%." The start date of the observation period is noted below the graph as "Start 08/02/2023." The date on which the ORAC value history was accessed is shown in a separate field below the graph as "Today 08/20/2023."

User interface for selecting and evaluating suggestions from the application

Figure 18 shows an example of the user interface of an application that communicates with the measuring device and presents the user with recipe suggestions or restaurant offers for breakfast, main courses, and snacks for one day on a technical system with a screen. The recipe suggestions or dishes from restaurants in the vicinity can be retrieved in a preferred solution, e.g., from a website or a database to which the application has access. The technical system can be, for example, a smartphone, a tablet, or a computer screen. In a useful application, the same application can be used, for example, to control the measuring device by establishing a

connection to the measuring device via Wi-Fi, Bluetooth, or USB connectivity, to initiate a measurement, to transfer data between the measuring device and the technical system, to display the progress of the measurement visually and/or acoustically. E.g., the data collected during the measurement is forwarded via the Internet to an external server using a network in the vicinity or via mobile data transfer, e.g. G4 or G5, e.g. the calculation result for the concentration of the measured substance returned by the server is received and displayed on the screen of the technical system, and, e.g., error messages regarding measurement and/or data transfer and/or errors in the determination/calculation of the concentration are output. In a further advantageous application, the application is, for example, a separate application that, however, allows the user to access his/her measurement results. In an advantageous variant, the measuring device is a non-invasive measuring device which advantageously functions on the basis of optical principles, as described above. In an advantageous variant, this measuring device can be used to detect several body substances or their concentrations, which can be processed by the application. In an advantageous variant, new dietary suggestions are presented automatically at intervals determined by the user. This individualization of the presentation rhythm allows the user to consider the suggestions at his/her own pace. In an advantageous embodiment, the user can request an individual time for the presentation of new suggestions, e.g., by briefly clicking or tapping the screen interface. In an advantageous embodiment, the recipes or dishes of a restaurant are described in writing and additionally explained by one or more images, for example. In Fig. 18, for example, the "Meal" column contains a brief description of the dish. In an advantageous embodiment, the complete recipe can be displayed on the screen and/or printed out via a connected printer.

In a useful feature, the application allows users to display/print individual ingredients for a dish, or, in the case of recipes, the quantity of each ingredient for a freely selectable number of people, the type and duration of preparation, how long uneaten portions of the dish can be stored in the refrigerator, display/print a shopping list, add to the list of ingredients, order the ingredients from a shop or delivery service and have them delivered, rate the dishes individually after consumption, add the dishes to a favorites list, prioritize the dishes on the favorites list according to specific criteria, and repeat the automatic presentation after a freely selectable period of time. For dishes offered in restaurants, either a table can be reserved automatically for a specific day and time, or the dish can be ordered via a delivery service for a specific day and time.

In an advantageous embodiment, without having to view the ingredients in detail, the user is informed, for each suggested recipe/dish, for example, whether it is a vegetarian or vegan option, of which quantities (e.g., in grams) of vegetables, fruit, fish, meat, of how much time is needed

for preparation, of the caloric value (e.g., in kcal) and of the ORAC value of the recipe/dish, and whether consuming all of the dishes suggested for that day will affect the user's body weight. Figure 18 shows examples of columns in which the respective quantities are listed for each recipe or dish in a restaurant, for example, the calorie content in kcal is shown in the column " " ("Calories"). In a useful version, the user can specify for which meals, such as breakfast, main meals, or snacks, he/she would like to receive suggestions. This can be done, for example, by marking individual or all meals on the screen, e.g., with a cross or a check mark. In Fig. 18, for example, there is no cross next to the snack category, so no recipe or restaurant dish is suggested for this meal. In a useful variation, the user can tell the application which dishes he/she does not want to see any more suggestions for, e.g. by entering the number of a suggested recipe or restaurant dish in the "Selection" column. When the corresponding column is tapped or clicked, the application opens an editor where the recipe number can be entered.

Fig. 18 shows an example where the "Selection" column contains recipe numbers, meaning that no new suggestions are made for the breakfast and main course categories. The "Daily balance" row shows the total amount of vegetables, fruit, fish, or meat contained in the meals for that day. This row also shows the ORAC value of all meals in µmol TE and how much less the user is consuming compared to his/her average daily energy consumption of 759 kcal with this selection. The value "-759 kcal" is therefore shown in the last column of the "Daily balance row." The column "Effect on your body weight" therefore also shows the entry "You are losing weight.". In a preferred variant, there may be a second area below the suggestions for recipes or meals for a day, which automatically displays the evaluation of all suggestions or selected recipes/restaurant meals.

In another preferred variant, the suggestions are evaluated as described in detail above, e.g., taking into account the user's measurement results, his/her preferences, and the determined individual metabolism of ingredients contained in the recipes/dishes. In Fig. 18, for example, the individual key figures "weight management," "nutritional quality," and "healthy food relation" are assigned to the following categories: "How well do the meals match your selected preferences" and "How well do the meals support your long-term well-being" With regard to the combined, synergistic effect of all key figures, the "Overall fulfilment level", in this example, shows the total result for the user for the day as 87.7%. In a preferred variant, the highest "overall fulfillment level" is 100%. In a preferred variant, the value may exceed 100% if the target is exceeded. In another preferred variant, 100% is displayed when the target is exceeded, but stars are also awarded to indicate the degree of overfulfilment. The more stars, the greater the overfulfilment. In another preferred variant, the "total degree of fulfilment" is not displayed as a

percentage, but as an ascending numerical value, with a larger number indicating a higher degree of fulfillment.

In a preferred variant, different mathematical methods or algorithms can be used to calculate the "total degree of fulfillment" key figure. These include, for example, mean or median calculations and methods in which the key figures are weighted in the calculation, but complex mathematical methods are also possible for determining the "total degree of fulfillment" key figure. In a preferred variant, the field in which the respective results are displayed numerically can be colour-coded so that the colour indicates the meaning of the numerical value. In a preferred variant, the traffic light colours red, green, and yellow are used for characterization, with green colours indicating a positive evaluation result, red colours indicating a negative evaluation result, and yellow colours indicating a critical but not yet negative evaluation result. In another preferred variant, lighter or darker shades of green, red, and yellow indicate gradations within the evaluation result. For example, a dark shade of green can stand for a particularly positive evaluation result, a light shade of green for a moderately positive result, and a very light shade of green for a result that is just barely positive. In another preferred variant, the user can save the current selection of recipes/restaurant dishes.

In an equally preferred variant, this can be done in the user interface by pressing a button. In Fig. 18, it is the "Save daily balance" button, which can be located in an area below the "Suggestions for meals for one day," for example. In a preferred variant, the user can then request recipe/meal suggestions for another day. In a preferred variant, the user must press another button to do this. In Fig. 18, it is the "Restart monitoring" button. In a preferred variant, he/she then enters the respective date in a date field by selecting it from a drop-down menu or by entering it directly via an editor, e.g., in a separate field. Fig. 18 shows, in a preferred embodiment, that the meals have been selected for August 20, 2022, in this example. In a preferred variant, the application alerts the user that if meals are selected for a future date, the currently available measurement results will be used to evaluate the recipes/meals. This means that the evaluation result may be different if the measurement results change before the date on which the user cooks the recipes or eats the restaurant meals. In a preferred variant, the user can select and specify his/her daily meals for a period of up to one week, and, in further preferred variants, for a period of up to two weeks, up to three weeks, or up to four weeks. In another preferred variant, the ratings of the selected recipes or dishes offered in restaurants are displayed for several days or weeks, for example in an overview graphic or table, which contains all the information contained in graphic 18 for each day. In another preferred variant, the results of each new measurement are automatically applied to all daily selections of recipes/dishes that are after the measurement time.

This ensures that the evaluation results contained in the overview graphic always correspond to the user's current status. In a particularly preferred variant, any changes in the evaluation results are marked accordingly so that, for example, the user can reselect the recipes/dishes for specific days contained in an overview graphic. In a further preferred variant, the user can decide whether evaluation results should be updated based on new measured values.

History, e.g., overall degree of fulfilment

In an advantageous design, a history for a key figure can be specified. In a further advantageous design, a forecast can be created and displayed. In an advantageous design, clarity for the user can be increased by combining key figures into an overview key figure. In an advantageous design, there are several overview key figures, preferably one key figure for the user's interest category. In an advantageous design, overview key figures can in turn be combined into one key figure. A key figure that combines all other key figures can be called, for example, "Overall degree of fulfillment."

In a preferred variant, key figures can be displayed as bar charts. In an advantageous design, the bars of key figures can differ in colour depending on their height. In a preferred variant, the bar for a value up to 50% has, for example, the colour 1, the bar for a value up to 75% has, for example, the colour 2, and the bar for a value above 75% has, for example, the colour 3. In a preferred variant, the recipes or dishes selected for that day are also displayed for each daily result. In a preferred variant, the numbers of the dishes shown in Fig. 18 are displayed in the order breakfast, main course, snack. If the user has selected, for example, one breakfast, two main courses, and one snack on a given day, a total of four numbers are displayed, separated from each other by a vertical line. In a preferred variant, this block of numbers is located below the bars when the X-axis meets the Y-axis at 0% and the values of the Y-axis are ascending. In a preferred variant, the dish can be displayed visually and/or via audio or video on the display device, e.g., a tablet or smartphone that communicates with the application and on which the graphics are output, by tapping on the respective number. This may be, for example, photos of the meal or videos of the meal being prepared, or a list of ingredients or comments that the user has previously stored, e.g., in a database that communicates with the application that presents the graphics to the user.

In another preferred variant, the request for additional information on a recipe or dish number or all dishes/recipes for a day can also be expressed verbally after, for example, a corresponding activation button has been pressed. In a further preferred variant, an average fulfillment of the "overall fulfillment level" is calculated for the period under review and displayed in the

application. The average fulfillment can, for example, be described in words and/or output as a numerical value and/or explained in a multimedia format, e.g., through images, videos, spoken text, e.g., at the user's request. In a particularly preferred variant, any other measure of a trend can be used instead of the average fulfillment to show how the development of a degree of fulfillment and/or a key figure is to be assessed over the observation period. Fig. 21 shows an example of the history of the "overall degree of fulfillment." This is a bar chart showing the history over the 30-day observation period. The X-axis shows the individual days of the observation period and the Y-axis shows the degree of fulfillment in relation to all of its targets. The maximum value of the degree of fulfillment achieved on any given day is 97%, and the lowest value is 53%. Overall, results are available for a period of 16 days. However, the user only selected meals/recipes on 10 days, and only selected or consumed four meals on four of those days. On average, the user has achieved 76.1% of his/her goals with the selected meals since August 2, 2022. This value is displayed in a separate field below the graph as "current average 76.1%". The start of the recording of the degree of fulfillment is also displayed in a separate field below the graph as "Start 08/02/2022".

History of measured values using the example of carotenoids

For several or preferably all substances that can be measured with the measuring device, a history of all measurement results/measurement values can be output over a definable observation period in an advantageous variant. This can be done individually for each substance or for more than one substance, e.g., in a common graph. The history of the measurement results is shown in Fig. 20 using the example of carotenoids, which can be measured in the skin and blood. The measured values of carotenoids can, for example, be used as an equivalent for the amount of fruits and vegetables to be consumed. The measured values can be displayed in a preferred variant over a viewing period selected by the user in a graph on the tablet or smartphone with which the application that controls the measurement communicates.

For the display example of the carotenoid history, all previously described details for displaying histories apply analogously, provided that their application is useful and possible for displaying carotenoids.

In another preferred variant, additional areas of the measured value are marked in the graph, e.g., by different lines, for example areas that are considered critical and/or within the target range by experts, physicians, government institutions, or the user himself/herself. In a preferred variant, the carotenoid measurement value, which indicates, for example, the carotenoid concentration in skin, tissue, or blood, is plotted in arbitrary units ranging, for example, from zero to 12. In

another preferred variant, the carotenoid measurement values are displayed, e.g., in nmol/g skin or another unit typically used in medical applications. In a preferred variant, two carotenoid measurement values can be displayed in the graph, with one value representing the concentration in skin and tissue and the other one representing the concentration in blood. For example, one value can be displayed as a bar and the other one as a line. The advantage of this distinction is that changes in blood behavior are visible within hours, while changes in concentration in skin and tissue only become visible over longer periods of time. Both pieces of information are very helpful to the user because they allow him/her to learn more quickly which behaviors help him/her to achieve his/her self-set goals. In a preferred variant, the graph showing the history of the measured values can also contain a curve showing the trend of the measured values, which, for example, shows the expected future development of the measured values over a certain period of time. In an advantageous variant, the measured values are carotenoids or other substance concentrations that can be measured by the sensor. In another preferred variant, for example, an average value and/or a trend value for one or more measured values contained in the graph can also be output. In a similarly preferred embodiment, this can be a number and/or a written assessment. In a preferred variant, both are located in separate fields below the graph, for example.

In a preferred embodiment, additional explanatory information can be provided to the user on the display device, which may be a tablet or smartphone, for example, and on which the application controls the measurement and sends the spectral measurement values for evaluation to an external server, for example, by clicking on the separate fields, e.g., in the form of images, speech, or videos. Fig. 20 shows an example of the history of carotenoid measurements. This example of a bar chart contains 10 measurements spread over a period of 18 days, with time plotted on the X-axis and the measured carotenoid values on the Y-axis. In a preferred embodiment, the individual measurements are also displayed as numbers above the respective bar. In addition, in a preferred variant is marked an area above a limit, where the user should reduce or discontinue dietary supplements. In this example, the observation period for the history covers a period of 32 days. The average of the 10 measured values is 5.25. In a preferred variant, the following is noted in a separate field as an evaluation of the average value: "Your average carotenoid value is only slightly above the average – but the values show an upward trend".

The start date for recording carotenoid values is specified as 02.08.2022, and the date for viewing the history is specified as "Today, 20.08.2022".

Sensor and housing Measuring instrument

A complete sensor for detecting, for example, biomarkers or physiological states, advantageously consists of a plurality of previously described emitters (1) and detectors (2), which, in a preferred embodiment, are located on a common printed circuit board and are arranged in enclosed spaces in such a way that it is obtained a sensor (20) which is as compact and small as possible and which measures the biomarkers or physiological states with high measuring accuracy and repeatability. An example of such a sensor is shown in Figs. 36 and 36a. For clarity, only the position of the detectors (2) is indicated in Fig. 36 and only the position of the emitters is indicated in Fig. 36a. The emitters and detectors are each located in recesses (5b) made of a material that is virtually impervious to photons. In order to be able to see the detectors and emitters, the transparent parts of the sensor surface elements (3), which in a preferred embodiment are located in the recesses to protect the sensor from moisture, for example, are not shown in these figures.

It is clear that the recesses have different geometric dimensions and that there are different numbers of emitters and detectors in the respective recesses. In a preferred embodiment, for example, in this sensor example, there are up to 12 emitters in one recess of the unit (5b). An emitter that can emit photons in three different wavelength ranges is counted as three emitters. This emitter is designated by (1.3). The numbering (1.1) means that it is an emitter that emits photons in one wavelength range.

In a preferred variant, the emitters and detectors are each located in their own separate recesses so that during the measurement process, when the hand is placed on the sensor, the emitted photons must pass through the skin in order to be detected by the detector. The recesses in the four corners of the sensor are an exception. As shown in Figures 36 and 36a, these recesses contain either an emitter that emits photons of one wavelength range (1.1) or photons of three wavelength ranges (1.3) and one detector (2) in each case. One reason for this arrangement is that it saves space, as each additional recess increases the sensor geometry because a web made of the unit material (5b) is required between each recess. Another advantage is that this arrangement allows the light reflected by the sample to be detected. In a preferred variant, information about the skin type, structure, or roughness of the skin can be collected in this way. In a measurement sequence in which the LEDs are switched on one after the other, the light paths between an emitter and a detector located in a common recess can be ignored in an alternative variant.

In a preferred embodiment, Fig. 36a shows that the sensor can have, for example, more than 4 or 8 or 9 emitters (1.3) that emit photons in three separate wavelength ranges and 28 emitters (1.1)

that emit photons in only one wavelength range. In an advantageous variant, a temperature sensor (40) is mounted in a recess.

In a preferred embodiment, Fig. 36 shows, as an example, that there are several detectors on the sensor. Four or more, in particular eight or more single-channel detectors (2) are advantageous. In an advantageous embodiment, the sensor additionally comprises at least one multi-channel detector (2.4). Single-channel means that the detector can detect photons over a wavelength range. In an advantageous variant, this is a broad wavelength range, so that the detector can detect light emitted by several emitters with different wavelength characteristics. Multi-channel means that the detector has, for example, 3, 4, 8, or more different wavelength ranges in which photons can be detected. In an advantageous embodiment, a value for the light intensity measured in this range is output for each wavelength range.

Fig. 35 and Fig. 35a show an example of the housing of a measuring device (30) with an integrated sensor (20) for measuring biomarkers and/or physiological conditions of the user. In a preferred version, the measuring device has various signal displays (S1a, S1b, S1c) and/or a positioning aid (P) for a correct positioning of the hand during measurement. In a preferred embodiment, the positioning aid is removable.

In a preferred variant, the measuring device has, for example, a WiFi function and/or WiFi signal strength indicator (S1a) as a signal display. This can, for example, indicate the transmission of data packets, e.g., to a smartphone, by flashing. In an advantageous variant, the device includes a display that, for example, shows the progress of the measurement (S1b) and/or a status display (S1c). In an advantageous variant, a display shows information about the power supply. This can include the charge status of a battery or rechargeable battery, information about whether charging is in progress, and/or information about whether power is available from an external power source.

In a preferred embodiment, the sensor (20) with its emitters and detectors and the associated electronics can be installed in the housing (30) as a separate component. It consists of elements made of a material that is virtually impervious to photons (5) and transparent parts of the sensor surface elements (3) that are permeable to photons. The transparent parts of the sensor surface elements and at least some of the non-transparent parts can be joined together to form a unit 9 and be firmly connected. The sensor surface elements (3) are preferably located at points where the emitters and detectors are located, which are mounted on a common printed circuit board. As already shown in Fig. 9, the material (5) that is almost impenetrable to photons preferably extends to the printed circuit board. The thickness of the sensor surface element (3) is preferably dimensioned such that there are no collisions with the emitters and detectors located on the

printed circuit board. The unit (9) can preferably be a molded part. The unit (9) can preferably be bonded to the printed circuit board with adhesive tape and/or adhesive. The adhesive or adhesive tape is preferably almost impenetrable to photons. By bonding the unit (9) to the printed circuit board, the emitters and detectors are preferably located in spaces enclosed on all sides. When the measuring device is mounted in the housing, the sensor can be glued in place, e.g., with a bead of adhesive, or adhesive tape can be bonded to the housing inside the housing in such a way that no moisture can penetrate between the sensor and the housing. In a preferred variant, the measuring device (30) has a connection, e.g., a USB socket. In an advantageous variant, this allows a charger to be connected to charge the battery of the measuring device and/or a connection for transmitting the measurement data, e.g., to a smartphone. In another preferred embodiment, the measuring device has control elements. In an advantageous variant, one or more or all of the following control functions are available: switch on, switch off, start measurement, pair radio connection, restore factory settings. The following description covers further embodiments and methods. These can be combined with the other devices and methods described in this text.

Integration of the sensor into everyday objects, e.g., into a smartphone

In an advantageous embodiment of the invention, the sensor is integrated into an object that is regularly used by the user in everyday life. In an advantageous embodiment, this object has at least one further function. Integration into electronic devices is particularly advantageous. It is particularly advantageous in devices with a display or communication capability with devices with a display. Particularly suitable devices are smartphones, smartwatches, computers, computer peripherals, or add-on devices for the aforementioned devices. Integration into devices that already contain optical emitters or optical detectors is particularly advantageous. In an advantageous variant, the emitters used in the device for other applications can also be used for the sensor functionality according to the invention. In an advantageous variant, the detectors used in the device for other applications can also be used for the sensor functionality according to the invention. Integration into devices in which a camera is integrated is particularly advantageous. Integration into devices that have several cameras is particularly advantageous.

Fig. 25 shows a smartphone without a sensor arrangement. Fig. 26 shows a smartphone with a sensor arrangement. Fig. 27 shows a smartphone with a sensor arrangement and a scale for describing the arrangement. Fig. 25 shows the rear side of a smartphone (1001) with a camera arrangement (1002). The example of smartphone is equipped with four cameras (1003, 1004, 1005 and 1006). Arrangements with other numbers of cameras or a different arrangement of the cameras are also possible. Smartphones with such or similar camera arrangements on the rear

pertain to the present state of the art. In an alternative advantageous variant, cameras can also be used on the front of a smartphone. In an advantageous variant, the pixels of a display are used as emitters for the sensor instead of individual LEDs. One of the following display technologies can be used: LCD, OLED, QLED, HDR, Quantum Dot, AMOLED, NanoCell. Fig. 26 shows a smartphone with a sensor arrangement according to the invention. The smartphone also has the elements shown in Fig. 25, which, for the sake of clarity, are not shown in Fig. 26 and Fig. 27. The sensor arrangement (1007) shown as an example consists of the cameras (1003, 1004, 1005 and 1006), which are used as light detectors.

The arrangement also contains one or more additional light detectors. An additional light detector is shown as a white circle in the arrangement example. The arrangement example contains a large number of light emitters. These are shown as white rectangles. The emitters and light detectors are designed as shown in one of the other figures. Fig. 27 shows the arrangement from Fig. 26. The elements designated in (1001) to (1007) are also present in Fig. 27 and are not shown here for clarity. The scales (1008 and 1009) are not attached to the smartphone, but serve only to designate individual emitter positions. The division line at which the number (1008) is marked is the first division line along the X-axis. To the right of this is division line 2. To the right of this is division line 3, and so on.

The division line where the number (1009) is marked is the first division line along the Y-axis, i.e., Y-position 1. The division line above it is division line 2, and so on.

Emitters are referred to in the following description by their coordinates, which are specified as (X,Y) coordinates. For example, emitter (1010) is emitter (2,1). According to this naming convention, emitter (1011) is emitter (10,13). However, the emitters do not have to be placed exactly on grid positions. An arrangement in which other positions are also possible is shown in the example arrangement. In an advantageous embodiment, several emitters are present in the arrangement. In the example, 87 emitters and five detectors are shown. Four detectors are the cameras of the smartphone. However, other numbers of emitters and detectors are also possible.

In an advantageous design, there are different distances between the light emission location and the light detection location. In a typical arrangement, these locations are not points but areas. In an advantageous embodiment, these areas are limited by an opaque material of the contact surface (virtually impenetrable to photons) which delimits a transparent area (permeable to photons) of the contact surface. The contact surface is preferably the part of the outer shell of the smartphone which is located in the area of the cameras and light emitters. Typically, this area does not come into contact with objects when the smartphone is in use, but only when it is stored, e.g., in a pocket. The use of the cameras while the transparent surface in the camera area

is in contact with an object is a instance of use not intended in previous use, but which is preferably used in the embodiment according to the invention. Light detectors, cameras, or light emitters can act on the above-mentioned transparent areas. In the case of transparent light emitters, it is understood that the light emitters emit light through the transparent surface, which is bounded by non- material. This can be achieved for a transparent surface area by one or more light emitters. In an advantageous variant, the emitters can also emit several different wavelengths.

In the case of a camera, it can be seen that a camera is not a single light detector, but usually an array of many individual pixels, each of which represents a light detector. In an advantageous design, it is a colour camera that has pixel groups with different wavelength characteristics. RGB cameras are a common arrangement. These, typically, have a pixel group that is sensitive to light in the red range. In addition, there are, typically, pixel groups that are sensitive to light in the green range and pixel groups that are sensitive to light in the blue range. However, some cameras also have additional colour groups, which is often advantageous for the use according to the invention. In an advantageous variant, cameras have additional sensors for light intensity, in particular those used for the autofocus function. These often include light detectors sensitive to the infrared range and light detectors used for the autofocus process in the so-called phase comparison method. In an advantageous embodiment, several or even all of these pixels and sensors of the camera can be used for the sensor technology according to the invention. In summary, when referring to light detectors of the camera in the following, not only the pixels are meant, but also other light detectors integrated in the camera or used in conjunction with it. This includes, in particular, those of the autofocus. In an advantageous embodiment, cameras are equipped with additional devices. These include devices for changing the focus of the camera, devices for changing the aperture of the camera, and devices for compensating for camera movements. The latter are also referred to as image stabilizers, and reduce the occurrence of blurred images or videos. Although these devices and the light detectors described are primarily designed for creating images and videos, it is surprising that the devices mentioned can also be used advantageously for determining substances in, for example, human tissue. The following describes an advantageous method for doing this. The devices described are referred to as camera functions.

In order to accurately determine the optical properties of a sample, light passing through the sample is used in the preferred embodiment.

To determine the desired properties of the sample, light of different wavelengths is advantageously used. The effective wavelength range is determined, on the one hand, by the

light wavelength range that is emitted and, on the other hand, by the light wavelength range that is detected. In an advantageous approach, the effective wavelength range results from the combination of these light wavelength ranges. It should be noted that the ranges often do not have hard boundaries, but rather show a wavelength-dependent intensity that decreases toward the edges of the ranges. The effective wavelength range can therefore be adjusted particularly finely by combining light emitters of different wavelength ranges with light detectors of different wavelength ranges. Another advantageous application is the use of fluorescence in the sample. Here, the sample is irradiated with short-wave light to which at least some of the camera's light detectors are not sensitive, so that they essentially only receive light originating from fluorescent substances in the sample. In an advantageous design, the analysis of which wavelengths are absorbed as they pass through the sample is used to determine the substance concentrations in the sample. In an advantageous variant, fluorescence effects are also evaluated.

In practice, it has been shown that in the case of complex samples such as the skin or tissue of living beings or the analysis of foodstuffs such as fruit or packaged food, a further capability is highly advantageous. Such samples are often inhomogeneous. For example, they may consist of different layers. In a living organism, these would be the layers of skin and the underlying tissue. It may be of interest to analyze a substance that is only found in the blood but not in the upper layers of the skin. In the case of an orange, for example, it may be that you are not interested in the properties of the peel, but want to analyze substances in the flesh of the fruit. In the case of packaged food, you may not want to determine the properties of the packaging, but rather those of the packaged product.

For this reason, it is advantageous to influence how deeply the light penetrates the object to be analyzed. In an advantageous variant, measures are taken to ensure that the light penetrates deeply into the tissue to be analyzed. In an advantageous design, light is emitted in such a way that a large proportion of the emitted photons move in a direction that forms a minimum angle to the contact surface of the sample, which is close to 90 degrees.

Quantifying this statement, it is advantageous if some light emitters emit at least 25%, but preferably at least 50%, of the photons emitted by the light emitter and reaching a selected light detector at an angle to the contact surface of the sample that is greater than 20 degrees, preferably greater than 30 degrees, preferably greater than 45 degrees, and, preferably, greater than 60 degrees. Since the above statement refers to a pair consisting of an emitter and a light detector and only considers those photons that reach the light detector from the emitter, the nature of the sample to be analyzed also plays a role. In order to exclude this from the

consideration, it is preferable to assume an artificial sample that simulates the nature of a typical sample.

Another aspect that can influence whether the photons also pass through deep layers of the sample is the distance between the center of gravity of the contact surface of the light emission location and the center of gravity of the contact surface of the light detection location. Alternatively, this center of gravity can also be calculated by taking into account the light intensity that passes through the respective surface element. The further apart the light emission location and the light detection location are, the deeper the photons that reach the light detector, typically, penetrate into the sample.

However, even if photons are allowed to pass through the sample sufficiently deeply, this is often not enough to determine, for example, a material concentration at the desired depth. This is because the photons, typically, have to pass through flat layers of the sample in order to reach the deeper layers. The photons interact with the flatter layers of the sample, which influences the measurement signal. In an advantageous design, photons are therefore also emitted in such a way that they essentially only pass through flat layers of the sample. In this way, the optical properties of the flat layers of the sample can be determined. In an advantageous design, the influence of the flat layers of the sample on the photons that have passed deeper through the tissue, as explained above, can be determined. In an advantageous design, measured values of the flat layers can be algorithmically linked to measured values of the light that has passed through flat and deep layers, so that the optical properties of the deep layers are obtained as a result.

In order to carry out such compensation and to determine the optical properties of a sample as accurately as possible, it is advantageous to use a large number and variety of pairs of light emitters and light detectors. The totality of the volume elements that are traversed with a specified probability by one of the photons travelling from the light emitter to the light detector is referred to as the light path volume. In an advantageous design, the light path volumes of different pairs of emitters and detectors are differently shaped, and also reach different depths of a typical sample. In an advantageous variant, a large number of differently shaped light path volumes are possible, thus enabling a more accurate determination of the properties of the sample. This is particularly the case if the sample does not consist of defined layers, but, for example, has a gradual transition of properties depending on the depth, i.e., the distance of a volume element to be analyzed from the surface of the sample.

In an advantageous embodiment, the device also has light path volumes at different locations. In an advantageous embodiment, these can have identical and/or mirror-symmetrical light path

volume shapes. In an alternative embodiment, however, the shapes of the light path volumes can also be different. This design is particularly well suited for measuring samples with spatial inhomogeneity. This includes, in particular, samples in which the concentration of a substance varies not only as a function of the depth of a volume element in the sample, but also as a function of the location on the surface of the sample at which the measurement is taken.

The advantageous choice of the radiation characteristics of the light emitters plays an important role in the shape of the light path volumes, and, in particular, in the depth through which the light path volumes pass, and, in particular, in the radiation characteristics relative to the detector of a pair consisting of a light emitter and a light detector. If, for example, it is considered an emitter that emits light on average in a direction that is not perpendicular to the sample surface, the following advantageous case can be exploited. The emitter emits light in the direction of a detector A, so that a flat light path volume shape is formed in the pair consisting of the light emitter and detector A. In contrast, in the pair with a detector B that is not located in the direction of the light emission of the emitter, it is developed a light path volume shape that penetrates significantly deeper into the sample.

Therefore, in an advantageous design of a measuring system, arrangements are used which have the above-described property that emitters have a different radiation characteristic in the direction of one detector than in the direction of another detector. It should be noted at this point that properties such as directional characteristics, emission direction, and the distribution of the emission over different solid angles in the above text have mostly been explained using the emitter as an example. However, these properties also exist in equivalent form on the detector side. However, the detector side is somewhat more difficult to formulate linguistically. For example, the equivalent of the sentence "an emitter emits photons perpendicular to the contact surface" is "the detector is designed so that it can detect photons that arrive at the detector along a line perpendicular to the contact surface." However, it is explicitly pointed out here that the optical properties described using the example of emitters apply in the same way to detectors. Where an advantageous arrangement, design, or property of the emitters is described, it is hereby clarified that this text also describes and discloses the equivalent advantageous design for detectors. Insofar as the optical properties of the pair of light emitter and light detector are concerned and the targeted influencing of these properties has only been explained with regard to the light emitter, it must be taken into account that the light detector typically has a comparable influence to the light emitter. The properties of the pair are determined by the light emitter and the light detector. To shorten the text, a pair consisting of a light emitter and a light detector is

referred to below as an ED pair, its light path volume as ED-LW, and the shape of the ED-LW as ED-LWF.

This applies in particular to the light path volume shape and light penetration depth into the sample.

In an advantageous embodiment are provided materials with which the emission direction of light emitters or the direction from which detectors can receive photons can be influenced. In an advantageous embodiment, these are used to influence the light path volume shape and light penetration depth into the sample.

The above explanation illustrates the advantages of having a large number and/or variety of light path volume shapes available for determining the optical properties of a sample. Furthermore, the basic ways in which this diversity can be achieved have been explained. The following explains the advantages of the arrangement according to the invention for determining the optical properties of a sample. The arrangement shown in Figures 25 to 27 has many of the above-mentioned advantages, which are explained below. Advantageously, the arrangement has several light detectors, some in the form of cameras, and several light emitters. This results in a large number of ED pairs, and thus also in a large number of ED-LWF. Advantageously, the arrangement has emitters that have different emission direction characteristics. This results in a greater variety of ED-LWF. Advantageously, each of the light detectors of the camera can be used to form a separate ED pair with each emitter. Since, for example, the pixels of the camera are arranged next to each other, this results in different distances between the light emitter and the light detector, which leads to a greater variety of ED-LWF.

Advantageously, the light detectors of the camera have different reception directional characteristics. These result, for example, from the position of a pixel relative to the lens or to opaque components such as the aperture, the lens holder, or the edge of the camera opening. Again, this results in a greater variety of ED-LWF.

Advantageously, the arrangement produces ED-LWF due to the small distance between the camera pixels, which allows for a gradual gradation of the penetration depth. As a result, evaluation algorithms not only have data about a few discrete penetration depths at their disposal, but they have a gradation between the greatest and the smallest penetration depth as well. In an advantageous variant, it is achieved a similar order of magnitude of steps as there are pixels in a row or column of the camera.

Advantageously, the camera functions can be used to further increase the variety of ED-LWF. This is advantageously achieved by moving components of the camera functions into different mechanical positions. Advantageously, this influences the direction from which the light

detectors of the camera can receive light. In one advantageous manner, a lens is moved. In another advantageous manner, the detector chip is moved. In an alternative advantageous manner, the aperture is adjusted or a filter is placed upstream. In an advantageous manner, a measurement is performed in which at least one of the movable components of a camera function is in one position, and, afterwards, a second measurement is performed in which this movable component is in a second position. This results in multiple ED-LWFs for at least some of the ED pairs. In a further preferred variant are performed one or more additional measurements in which at least one component of a camera function is in a different state than in the previous measurements. In this context, measurement refers to the detection of brightness information by the light detectors, which may also be multiple pieces of light information resulting, for example, from an activation sequence of multiple light emitters or the use of multiple light detectors.

It is advantageous for the cameras to have a large number of light detectors. This results in a large number of measured values, so that the accuracy can be increased by mathematical methods. For example, noise components can be averaged out. Effects caused by inhomogeneities in the sample and leading to errors in the interpretation of the data can also be detected and reduced. However, the arrangement described also has advantages for the camera function and other functions of the smartphone. In an advantageous variant, at least some of the emitters are used to illuminate the object to be photographed. In an advantageous embodiment, there is made use of emitters which are mounted on different sides of the camera, so that the advantages of a ring light are obtained and no disturbing shadows are produced. In an advantageous embodiment, emitters of different colours are used to illuminate the photos. This increases the spectral resolution of the camera. This enables a more accurate determination of the colours in the image than is possible with the human eye. This allows the performing of many tasks that would otherwise require a multispectral camera. Examples include: verifying the authenticity of objects and detecting counterfeit products or money, contactless detection of the composition of substances or food, and accurate determination of colours and their appearance under different lighting conditions, e.g., in cosmetics.

Another advantageous feature is the detection of a surface roughness by comparing images taken when the light is incident from different directions. This can be used to detect wrinkles or skin imperfections in cosmetics. It can also be used to detect security features on banknotes or ID cards more reliably. Holograms in images can be made possible by illuminating them from different directions.

In an advantageous variant, LEDs from several of the following LED groups are activated for illumination from different directions: LEDs to the left of the camera, LEDs to the right of the

camera, LEDs below the camera, LEDs above the camera. In an advantageous embodiment, the emitters are used for signalling, e.g. for signalling the arrival of different messages by different colours or patterns on a smartphone lying on a table.

In an advantageous embodiment, the light emitters can be used to better detect the distance to photo subjects at close range, thereby enabling better autofocus. In an advantageous embodiment, objects can also be measured in three dimensions by illumination from different light emitters.

In advantageous designs, the colored light can be used for decorative or party purposes. In advantageous designs, the brightness of the lighting of photos can be increased because the light sources are distributed over a larger area and thus cause less damage when looking into them. Waste heat from the LEDs can also be dissipated more effectively over a larger area. This allows for greater overall brightness than with a single LED. In advantageous designs, the infrared light emitters can also be used to control devices with infrared receivers. Other data can also be exchanged optically, which can be done bidirectionally thanks to the cameras and light emitters. In an advantageous design, the light emitters can be used to determine the location and position of the smartphone in the room, for example by means of a camera fixed in the room. This function can be used to implement game controller functions, for example. In an advantageous design, UV light can be used for illumination in order to photograph fluorescent markings, for example on banknotes.

In an advantageous embodiment, smartphones can also use this arrangement as a distance sensor, reflex light barrier, or for improved gesture recognition.

In an advantageous embodiment, smartphones can use the arrangement both as a sensor designed to be brought into contact with a sample and as a multispectral sensor that analyzes a sample without contact. Since both types of application have advantages, a system that can implement both measurement methods is advantageous.

In an advantageous variant, transmitted light analyses can also be performed by using an external camera or light source or a second smartphone. In an alternative advantageous variant, a transmitted light analysis can be performed by means of an additional element, such as a sample vessel with a mirror on the side facing away from the sensor. A particularly advantageous variant results from combining this arrangement with the use of light emitters with approximately the same optical properties, such as the peak wavelength, which are designed so that the optical properties do not have to be the same for all light emitters, but can vary within a certain range. The advantage is that the arrangement can detect the variation in the peak wavelength of the light emitters by means of the cameras. In an advantageous embodiment, this can be done by the

colour sensor technology of the camera when measuring the sample. In an alternative advantageous variant, a test specimen is used. This can be, for example, a printed card or cardboard box held in front of the camera. In the case of the cardboard box, this can be the packaging of the smartphone, which helps to establish a defined distance to the optically active part of the test specimen. The part of the test specimen captured by the camera can be white or have colored areas, for example. By using the test specimen, the camera can determine which of the light emitters has which peak wavelength. In an advantageous variant, this information can be used to improve the quality of the evaluation of the measurement results.

In a particularly advantageous variant, the arrangement variants described above can be used to collect information about a person's food. Multispectral photos allow more accurate conclusions to be drawn about the composition of the food. More accurate distance detection and three-dimensional measurement of the volume of the food allow a better assessment of the quantities of food. Data on the quantity and type of food can be used to provide improved recommendations for the user. In an advantageous variant, the information can be used to facilitate or evaluate the selection of foods. In an alternative variant, the information can be used to identify the actual quantities and types of food consumed. In an advantageous variant, the user takes a photo of his/her plate of food. In an alternative advantageous variant, the smartphone is positioned so that it can recognize and measure the food on, for example, a fork or spoon. Fig. 28 shows a section of the arrangement of Figures 25 to 27.

The camera module (1012) with transparent cover (1013) and lens (1014) mounted in a lens holder (1021) is shown. The camera chip (1022) has numerous pixels. For simplicity, only 5 pixels are shown here. The pixel furthest to the left is labelled (1015). The pixel furthest to the right is labelled (1016). Several light emitters are shown, numbered (1018) to (1020), or not numbered at all.

The number (1017) denotes a surface made of at least partially transparent material, which in a preferred embodiment protects the light emitters from contact and contamination. It can fill the entire cavity in which the light emitter is located, or in an alternative preferred embodiment, it can be only a disc, so that the light emitter is partially surrounded by air, for example. The number (1023) refers to the material of the sample to be examined, which is brought into contact with the arrangement.

Figure 29 shows the same elements as in Fig. 28. Some of the designations have been omitted for clarity. The area within the sample (1023) that is the ED-LW is shown. The volume area of the light path ED-LW of the ED pair light emitter (1018) and light detector (1016) can be seen in Fig. 29.

The area through which photons traveling from the light emitter (1018) to the light detector (1016) flow with a significant intensity is bounded by the dashed lines (1024 and 1025). The sharply drawn boundary here should not obscure the fact that the area has naturally a soft transition in the number of photons. However, a soft boundary would have been difficult to represent in a black and white graphic. For this reason, a fixed boundary is used for the representation. The position of the light detector (1016) on the far right means that only photons arriving almost perpendicularly or from the left side of the image can be received. This means that the photons that make it from the light emitter to the light detector have a high average penetration depth into the sample (1023).

Figure 30 shows a comparable situation for the light detector (1015). Due to its position on the left edge, photons arriving flat from the right side of the image can be detected. The emitter (1018) also enables flat emission of photons due to its position on the right side of the emitter cavity. For these reasons, this arrangement results in a significantly flatter ED-LW. By moving the focus lens (1021), it is possible, in an advantageous embodiment, to change both the ED-LW from Fig. 29 and the ED-LW from Fig. 30 in order to increase the variety of ED-LWFs.

All variants and embodiments described in this disclosure can be combined with each other in any combination and connected to form advantageous systems or embodiments of devices. The application of all embodiments shown in the form of a process or method can be combined with the described methods to form various advantageous overall methods. The integration of the measuring device into a smartphone results in a particularly advantageous design, since the measuring function for body substances and biomarkers and the application for recommending nutrition and actions, which uses the measured values for the recommendation, can be integrated into one device. In an advantageous design, the costs for the sensor technology are minimized because the camera function of the smartphone can be used, thus replacing part of the necessary sensor hardware. In an advantageous variant, the functionality of the smartphone camera is increased at the same time, as it is given additional functions by the light emitters of the measuring device, such as a ring light function, 3D recognition, and multispectral measurement options. In a particularly advantageous variant, the expanded capabilities of the camera can in turn be used to estimate the composition and quantity of food from photos of food items and thus the substances they contain. In an advantageous variant, this information can in turn be fed into the recommendation system application, enabling more precise recording of the nutrients consumed.

Use of AI for the evaluation of spectroscopic measurement data

The accuracy of the optical measurement of biomarkers is determined by the spectroscopic measuring device and the way in which the optical measurement data is evaluated. An advantageous variant of a spectroscopic measuring device that has approximately the same sensor components and uses MSRRS measurement technology has been described previously in various parts of this disclosure. The following section now deals with advantageous methods for evaluating spectroscopic measurement data. A new method of using artificial intelligence (AI) is presented, with the help of which it is possible, for example, to use the differences required for the measuring device, e.g., in the peak wavelengths of approximately identical emitters and the fluctuations in the distances between emitter-detector pairs that are unavoidable in the series production of sensors, as additional information. The advantageous methods presented enable the development of algorithms that determine biomarkers with greater accuracy.

Definition of continuous filter kernels: continuous filter kernels are a learnable function that assigns a weight to the position of a data point (K. T. Schütt, P.-J. Kindermans, H. E. Sauceda, S. Chmiela, A. Tkatchenko, and K.-R. M̈uller, “Schnet: A continuous-filter convolutional neural network for modeling quantum interactions,” in Proceedings of the 31st International Conference on Neural Information Processing Systems, 2017, p. 992–1002. Hereinafter referred to as Lit.3). Contrary to previous methods, this method defines the position as an absolute position in the measuring range and not as a position relative to a data point. As a result, a continuous filter kernel represents a function $\psi: \mathbb{R}^n \rightarrow \mathbb{R}$, where n is the number of dimensions of the position of a data point. In an advantageous embodiment, the method uses continuous filter kernels to evaluate the information supplied by the sensor according to the invention. In an advantageous embodiment, continuous filter kernels are provided by an implicit neural representation, and, in an advantageous embodiment, a SIREN network (V. Sitzmann, J. N. P. Martel, A. W. Bergman, D. B. Lindell, and G. Wetzstein, "Implicit neural representations with periodic activation functions," in Proceedings of the 34th International Conference on Neural Information Processing Systems, 2020, hereinafter referred to as Lit.4), which has n input neurons and one output neuron.

In advantageous implementations, such continuous filter kernels are not trained separately, but are trained together with the rest of the model as part of end-to-end training. Fig. 31 shows an advantageous algorithm for evaluating the raw data supplied by the sensor. This is explained below.

In an advantageous embodiment, a level of continuous characteristics is used. The level of continuous characteristics (EkC) is defined as several continuous filter kernels. The input of the EkC is an arbitrary set of raw data points (I). In an advantageous embodiment, continuous filter

kernels assign a weight to a plurality of the raw data points based on the position of the raw data points using the function "ψ " of the continuous filter kernel (II). In an advantageous variant, this is done for all filter kernels. In an advantageous embodiment, this weighting is additionally multiplied by a measure of the local point density of the raw data. In an advantageous embodiment, this local point density is determined using the Parzen window method. In an advantageous embodiment, the weighting is applied to the raw data point. In an advantageous embodiment, this is done by multiplication. In an advantageous embodiment, this is done for the majority of the continuous kernels. In an advantageous embodiment, this is done for the majority of the raw data points.

Fig. 31 shows this step in the flowchart under (III). A weighted data point i in the continuous filter kernel k can be represented in a preferred embodiment as a weighted sum ($w_{i,k}$) by the formula $w_{i,k} := d_i \cdot \psi_k(p_i) \cdot \frac{1}{\rho(p_i)}$, where d_i is the value of the data point, $\psi_k(p_i)$ is the weighting of the continuous filter kernel k at the position p_i of the data point, and $\rho(p_i)$ is the local point density at the position p_i of the data point. In a preferred embodiment, the weighted raw data of a kernel is then reduced to a value (IV). In a preferred embodiment, this is performed for a plurality of kernels. In a preferred embodiment, a sum can be used for this reduction. In an alternative embodiment, a different reduction operation is used, preferably one of the following: median, mean, minimum, maximum, sum of squares.

The output of the EkC is referred to below as a latent vector of characteristics. The length of this vector is preferably not related to the amount of input data, but only to the number of continuous filter kernels used.

Components of the latent vector of characteristics correspond to a continuous filter kernel k. In an advantageous embodiment, the component is composed of the following formula: $v^k := \Sigma(w_{i,k}) = \Sigma\left(d_i \cdot \psi_k(p_i) \cdot \frac{1}{\rho(p_i)}\right)$. v is thus the result of step (IV).

Accordingly, the relationship between the input of the EkC and the output of the EkC can preferably be described as a function of the value and n-dimensional position of i data points to a k-dimensional latent vector of characteristics, formally $v: \mathbb{R}^i, \mathbb{R}^{i \times n} \rightarrow \mathbb{R}^k$.

Since the length of the latent vector of characteristics preferably depends only on k, the number of continuous filter kernels, the output of the EkC can act as a decoupling element from an input of any length. Fig. 31 shows in step (V) an algorithm component that reduces the output of the EkC to an output value.

This can be implemented in various ways.

In an advantageous variant, machine learning methods are used. In an alternative variant, an algorithm is used in which the output of the EkC is linked to an output value using classic algorithms and without learning methods. In an advantageous embodiment, this step is implemented by a multilayer perceptron. Fig. 31 shows the output of the determined value in step (VI). In an advantageous embodiment, this is a concentration of a substance in the sample. In an alternative advantageous embodiment, several substance concentrations are calculated from the output of the EkC in step (V). In this case, the output in step (VI) is several substance concentrations. In an advantageous alternative embodiment, steps (I) to (VI) or parts thereof are performed separately to determine multiple substance concentrations. The combination of steps (I) to (VI) is referred to below as a network of continuous characteristics (NkC).

A network of continuous characteristics (NkC) is preferably a combination of one or more EkCs and conventional elements of machine learning methods. In an advantageous embodiment, the input of the NkC is represented by an EkC.

Use of NkCs in combination with MSRRS sensors:

For the use of NkCs in combination with MSRRS sensors, the actual wavelengths of the emitters are preferably determined. Preferably, specifically introduced wavelength differences are detected. In an alternative advantageous variant are detected wavelength differences that were not introduced deliberately but are nevertheless present. In an advantageous variant, both deliberately introduced and unintentionally introduced wavelength differences are detected. In an advantageous variant, the wavelength characteristics of the detectors can be detected in an analog procedure similar to the wavelength of the emitters. In an alternative advantageous variant, the wavelength characteristics of the emitter-detector pair are used instead of the wavelength of the emitter. For the use of NkCs in combination with MSRRS sensors, it is preferable to determine the actual distances between the emitters and detectors of an emitter-detector pair for which a light intensity has been detected. Preferably, deliberately introduced distance differences are detected. In an alternative advantageous variant are detected distance differences that were not deliberately introduced but are nevertheless present. In an advantageous variant, both deliberately introduced and non-deliberately introduced distance differences are detected.

For the use of NkCs in combination with MSRRS sensors, it is preferable to determine key figures for the actual emission characteristics and/or detection characteristics between the emitters and detectors of an emitter-detector pair for which a light intensity has been detected. Preferably, deliberately introduced differences in key figures are detected. In an alternative advantageous variant are recorded key figure differences that were not introduced deliberately

but are nevertheless present. In an advantageous variant, both deliberately introduced and non-deliberately introduced key figure differences are recorded. In an advantageous embodiment, this can be achieved by deliberately measuring the sensors produced. In an alternative advantageous variant, the variation can be introduced through targeted production. In an advantageous variant, this eliminates the need to measure the sensors.

In an alternative advantageous variant, the variation can be derived from measurement data generated during use of the sensor by the user. In an advantageous variant are compared emitter-detector pairs in which the emitters and/or detectors belong to a group of approximately identical emitters or detectors. In this advantageous variant, the accuracy of the sensors placed on the market can thus be improved even after the start of sales. In an advantageous variant, the variation introduced provides additional information, enabling a more accurate concentration determination.

In an advantageous variant, one or more of the categories of information described above are linked to the data. It is particularly advantageous if at least one wavelength information and one emitter-detector distance information is available for each raw data point. In an advantageous embodiment, a raw data point corresponds to the light intensity measured when an emitter-detector pair is activated. In an advantageous embodiment, defective emitters and detectors, as well as otherwise unusable detectors and emitters, are identified. In an advantageous embodiment, all raw data points from emitter-detector pairs that are not detected as defective are now used as input for the NkC together with the respective raw data position. In an advantageous embodiment, the emitters and/or detectors that are not to be used are determined before the sensor is delivered. This allows production errors to be compensated for.

In an alternative advantageous embodiment, the emitters and/or detectors that are not to be used are determined after the sensor has been delivered to the customer. This allows defects in the sensor to be compensated for in an advantageous variant. This allows faulty measurements to be compensated for in an alternative advantageous variant. In an advantageous variant, emitters or detectors that did not have sufficient skin contact during the measurement are not used as input for the NkC. In an alternative advantageous variant, other interfering influences such as skin irregularities, tattoos, physiological peculiarities are defined as exclusion criteria for emitters and/or detectors.

In an alternative advantageous variant, individual or multiple raw data points, i.e., the measured light intensity of an emitter-detector pair, can also be excluded. In an advantageous variant, analysis of the measured raw data of the measurement to be evaluated determines whether a raw data point should be used as input for the NkC. In an alternative advantageous variant, an

analysis of the measured raw data from other measurements of the same sensor is used to determine whether a raw data point should be used as input for the NkC.

In an advantageous variant, production tests are used to determine whether a raw data point should be used as an input for the NkC. In an advantageous embodiment, the NkC is trained to calculate the concentration of a substance in the respective input on the basis of a data set of several measurements. In an advantageous embodiment, optimization methods are used for this purpose. In an advantageous embodiment, the data used in the training originate from several different sensors. In an advantageous embodiment, the data used in the training originate from several different samples.

Alternative variant of the invention

The following embodiments represent an alternative variant of the invention, which has been taken from the priority document.

This embodiment is similar in many respects to the one already described. Aspects of the following embodiments can be combined with aspects of the embodiment already described. Restrictions of the embodiment described below are not restrictions that must necessarily apply to the embodiment already explained.

Device and method for optimizing personal well-being

Description of the problem

It is generally known that nutrition has a significant influence on human well-being and health. A balanced diet with plenty of fruits and vegetables, for example, reduces the risk of developing typical lifestyle diseases such as cardiovascular disease or cancer. The antioxidants contained in fruits and vegetables play an important role in this, as they help to prevent the negative effects of oxidative stress by acting as radical scavengers. The World Health Organization and many national health ministries therefore recommend eating large amounts of fruits and vegetables every day. The German Nutrition Society (Deutsche Gesellschaft für Ernährung), for example, recommends eating 650 g per day. Carotenoids are substances with strong antioxidant properties and are considered to be the best marker for fruit and vegetable consumption (see study by the National Academy of Science (Studie National Academy of Science)).

Despite many recommendations and campaigns by health authorities, doctors, nutritionists, and other public and private institutions, the actual consumption of fruits and vegetables is usually well below these recommendations (see, for example, the National Consumption Study in Germany (Nationale Verzehrstudie Deutschland)). The associated health costs worldwide are correspondingly high. The question is therefore whether there are technical means by which behavioral change can be initiated and sustainably promoted among citizens.

The quality of nutrition and the amount of exercise play a decisive role in another problem, for example: obesity. In 2015, 2.2 billion people worldwide were overweighted. Between 1980 and 2015, the number of obese people (BMI > 30) doubled. Overweight and obesity are usually associated with secondary diseases such as type 2 diabetes mellitus, gout, atrial fibrillation, or coronary heart disease. In addition, there are a large number of people worldwide who are not considered overweighted in the medical sense but who struggle with excess weight for aesthetic

reasons and whose well-being suffers greatly as a result of subjectively perceived weight problems. Increasing stress at work, insufficient exercise, an unbalanced diet, and eating convenience food or fast food instead of cooking meals at home are some of the reasons for unwanted weight gain. Even desperate attempts to lose those extra pounds through dieting and exercise usually fail. This raises the question of whether there are technical means or technical support available to help people cope with this problem. According to the current state of technology, there are only solutions or technical devices that independently address individual aspects of these problems using different technical approaches:

Bathroom scales allow users to check their body weight and also measure their body fat percentage, pedometers count the number of steps taken each day as a measure of exercise and use this to determine calorie consumption, Smart watches and fitness watches also measure heart rate and oxygen saturation and inform the user when a heart rate is reached during training at which fat burning begins. Applications show the distance travelled while cycling and hiking, the associated elevation profiles, and calculate the calories burned. What is missing is a system that integrates these individual aspects so that various aspects of nutrition and lifestyle are taken into account and comprehensive health and well-being can be achieved in the long term.

The invention described here shows a technical system that estimates the physiological state of an individual by measuring various parameters and/or substances and, based on algorithms and collected data, determines recommendations for behavior, nutrition, medication, or other influencing factors.

Description

The system consists of at least one or more sensor components, one or more data processing devices and, in an advantageous variant, additionally, one or more display devices. In an advantageous variant, the system also includes at least one data storage device. The above-mentioned system components can be integrated into a single device. However, their functionality can also be divided among several devices. In particular with regard to data processing and display, systems with which users are already equipped are used in advantageous variants. These can be, for example, smartphones, smartwatches, computers, or similar devices. In particular, data processing functions can also be performed in the cloud. In an advantageous variant, data is stored on a server accessible via the Internet. In an advantageous variant, data from different users can be used to calculate recommendations for a user. In particular, statistical bases for optimizing the recommendations can thus be automatically incorporated.

In an advantageous embodiment, the system according to the invention can be designed as a stand-alone measuring device that is used exclusively for measuring certain parameters and/or substances and/or physiological states of humans. In a further preferred embodiment, the device according to the invention or parts of the device, such as the sensor components, can be integrated into other technical systems that have their own functionality and are used by the user in different contexts, for example, in cooking, hygiene, sports, communication, hiking, transportation, transportation with the aid of technical devices such as airplanes, cars, two-wheelers, or in the work process. The integration can be carried out, for example, in the following technical systems, objects, or materials: smartphones, smart watches, fitness trackers, pedometers, wristbands, compasses, altimeters, walking aids, clothing, gloves, computer mice, telephone handsets, armrests, handles, steering wheels, kitchen appliances, bathroom scales, kitchen scales, toilet seats, glasses, gear levers, dashboards, machines used for the production of goods. In an advantageous variant of the system, the measurements and/or measurement results and/or recommendations carried out with the system can not only be made available to the user of the system, but can also be digitally forwarded to third parties or handed over to third parties in analog form after being printed out. The group of third parties includes natural persons, legal entities, or institutions. Digital transmission can take place automatically or at the individual request of the user, the person authorized by the user, or at the individual request of the owner of the system.

Natural persons may include medical personnel such as doctors or alternative practitioners, but also nutritionists. For example, the person or institution receiving the data may supplement or comment on the measurement results and/or recommendations with their own data, store measurement results and/or recommendations and/or additions and/or comments on a medium, and/or transmit them to the person measured, e.g., digitally. In the case of comments or additions to the measurement results, this data may also be used to subsequently optimize the advices given to the individual user or to improve the advices given to an individual user based on a summary and/or analysis of comments or additions made by different persons.

The stored data may also be stored on a medium belonging to the measured person, which is presented, for example, during a visit to the doctor. This could be an electronic health card, for example. The storage does not have to take place immediately after digital transmission, but can be done later by downloading from a server that is accessible via the Internet, for example.

The institutions may be, for example, hospitals, health insurance companies, or public institutions such as health authorities, state or federal ministries, statistical offices, or, in the

context of a survey, the institution conducting the survey, which publishes the results in print or digital media or presents them in television programs.
The measurement results and/or recommendations may be forwarded to third parties in encrypted or unencrypted form and/or anonymized or pseudonymized.

Examples of parameters and body parts that can be measured with the system

In an advantageous embodiment, the measuring system can be used to measure body fat, water, blood sugar, and carotenoids in tissue and blood.
In a further technical embodiment, the invention enables the simultaneous or alternative measurement of cortisol, alpha-linolenic acid (omega-3 fatty acid), arachidonic acid (omega-6 fatty acid), linoleic acid (omega-6 fatty acid), riboflavin (vitamin B2), and C-reactive protein.
In a version that goes beyond the aforementioned versions, the invention enables the simultaneous or alternative measurement of telomeres or advanced glycation end products (AGE). In a further advantageous version, the measuring device can be used to detect malaria, for example by measuring plasmodia in the blood.
The measurement of parameters and/or substances with which the physiological condition of a person can be assessed is advantageously performed transcutaneously and can be carried out at different locations on the body. In a preferred variant, the measurement is performed at body locations that are not normally covered by clothing. In a further preferred variant, the measurement is performed at body locations with lower pigmentation. For example, this can be the inside of the hand in the area of the ball of the thumb or the sole of the foot of the person to be measured. Surprisingly, it was found that in a preferred embodiment, when measuring with the device, the body part to be measured does not need to be pretreated by washing, disinfecting, preheating, cooling, rubbing dry, removing calloused or dead skin layers, or vaporizing the uppermost skin layer in order to produce correct and repeatable measurement results.
Surprisingly, it was found that in a further preferred embodiment, the body part to be measured in the aforementioned sense can be pretreated in different ways and the type of pretreatment can be determined from the measurement results, for example.
Surprisingly, in a preferred embodiment, it was found that the measurement leads to accurate and repeatable measurement results if the measurement is not performed on body parts where there is a tattoo and/or a scar and/or a wound and/or an injury and/or a sebaceous gland and/or a sweat gland and/or a blood vessel and/oror contamination and/or moisture and/or sweat and/or blood and/or hair and/or moles and/or age spots and/or wrinkles and/or skin dimples and/or skin cream and/or sunscreen or sun milk and/or skin lotion and/or perfume.

Surprisingly, in a preferred embodiment, it was found that measurements taken at the aforementioned body locations yielded accurate and repeatable results, from which, for example, the respective measurement location can be determined.

Sensor components

In a preferred embodiment, an optical system that measures various parameters and/or substances and/or physiological states of the individual uses emitters and detectors as sensor components, which emit and detect photons in a wavelength range that is tuned to the respective parameters, substances, or physiological states. Depending on the parameter, substance, or physiological state and/or the number of parameters, substances, or physiological states to be measured, the systems have a different number of emitters and detectors. Together, they cover wavelength ranges that enable the measurement of the parameters and/or substances and/or physiological states. This means that the system comprises sensor components, e.g., emitters and detectors, which may be identical and/or non-identical, i.e., different, in their technical properties. The emitters may be, for example, LEDs, incandescent lamps, or, in general, components that emit photons in the same or different wavelengths. Detectors can be, for example, diodes, phototransistors or transistors, capacitors or, in general, components that can receive photons emitted or radiated by emitters and convert them into signals, for example, in order to measure parameters, substances and/or physiological states of the individual.

Identical sensor components

In an advantageous variant, the system comprises emitters in which identical emitters and/or emitters of the same type exhibit fluctuations in their optical properties. This applies, for example, to optical properties such as the emitted wavelength spectrum (lowest wavelength to highest wavelength), the peak wavelength, the center wavelength, the peak half-width, the full half-width (FWHM), the half half-width (HWHM), the radiation characteristics, the temperature dependence, the brightness (luminous intensity and radiance), and the current consumption. In an advantageous variant, the system comprises detectors in which identical detectors and/or detectors of the same type exhibit variations in their optical and/or electrical properties. This applies, for example, to the peak wavelength and center wavelength of the wavelength range in which the detectors receive photons, the amplification factor with which the received photons are converted into electrical signals, the signal response, the responsivity, and the signal-to-noise ratio. By variations of the same sensor components, i.e., variations of emitters or emitters of the same type and variations of the same detectors or detectors of the same type, we mean limited

differences in at least one optical and/or electrical property of the emitters and detectors among each other. In order for different values of a technical property to be considered fluctuations of the same sensor components or sensor components of the same type, the respective values must lie within the limits of a defined interval. The intervals may vary depending on the technical property.

In a particularly advantageous variant, the distribution of the values of the optical and/or electrical properties of identical sensor components in measuring devices produced in series is not the same for every measuring device produced. The distribution of the variation can be introduced into the measuring device in various ways. An advantageous method is to select sensor components and, when equipping the measuring device with emitters and detectors, to specifically use some components with higher values and some with lower values of the respective property. Alternatively, the variation in the optical properties of identical sensor components can be generated by forming a set of sensor components in which the value of the optical and/or electrical property lies within an interval. When equipping the measuring device with emitters and detectors, a random selection of a component from this set can be made for each equipping position, so that the variation is statistical in nature. The advantage of using identical emitters and/or detectors that exhibit variations in at least one property within certain limits is that, as a result of the variation, more information and/or gradients about the parameter to be measured or the substance to be measured or the physiological state to be measured are collected than in a device that does not exhibit these variations in identical emitters or detectors. The greater breadth of information obtained in this way increases the measuring accuracy of the measuring device.

Surprisingly, it was found that it is possible, in the production process, to transfer the higher measurement accuracy to all devices produced, to reduce the standard measurement error of the devices, and to calibrate the devices so that, for example, when measuring the same person, the measurement results of the devices deviate less from each other. For example, measurements can be taken on test specimens in the production process and the larger amount of data resulting from the variation of identical sensor components can be analyzed using AI. The result is, for example, device-specific algorithms for measuring the concentration of parameters, substances, or physiological states of humans. In addition, there are cost advantages, as the use of such sensor components means that lower requirements can be placed on the manufacture of the emitters and detectors or their selection after manufacture.

Description of the intervals of identical sensor components

Depending on the substances or physiological states to be measured, the measuring device must have emitters that can emit photons with specific wavelengths into the skin and detectors that can detect them. As soon as more than one emitter is required for the measuring range in order to determine the concentration of a substance or the physiological state, the emitters and the detectors suitable for detecting the photons can be assigned to wavelength intervals.

In this patent specification, the size of the interval (interval length) is defined as the value between the lower and upper limits of the interval. In a preferred embodiment, individual emitters or detectors can only belong to one interval. In another preferred solution, the limits of the intervals must not overlap.

In another preferred solution, the difference between the upper limit of one interval and the lower limit of another interval is up to 1 nm. In further preferred variants, the difference is up to 2 nm, up to 5 nm, up to 10 nm, up to 20 nm, up to 50 nm, up to 100 nm, up to 200 nm, up to 500 nm, up to 1000 nm. In a preferred solution, the measuring device may have emitters or detectors that cannot be assigned to an interval. These sensor components are considered to be non-identical sensor components. In another preferred solution, the measuring device may have several such emitters or detectors.

The wavelength range covered by all intervals with identical sensor components of a measuring device is defined as follows: When comparing all intervals of a measuring device with each other, the wavelength range covered by all intervals together is determined by the lowest lower limit and the highest upper limit of all intervals (see Fig. 14, 14a). In a preferred embodiment, this difference between the lowest lower value and the highest upper value of all intervals is up to 10 nm. In other preferred embodiments, it is up to 20 nm, up to 50 nm, up to 100 nm, up to 200 nm, up to 500 nm, up to 1000 nm, up to 1500 nm, or up to 3000 nm.

In a particularly preferred variant, for example, the intervals of a measuring device are distributed over frequency ranges of blue, green, red, and near-infrared (NIR) light.

Fig. 14 and Fig. 14a show examples of this for the technical property of the peak wavelengths and the half-value width of emitters. In a preferred variant, the interval lengths of the different intervals of a technical property can be identical, as shown in the example of the peak wavelength of emitters (see Fig. 14). The interval lengths for the different intervals in the blue, green, red, and NIR ranges of light are each 10 nm.

Intervals of the peak wavelength of identical emitters			
Frequency range	Lower interval limit	Upper interval limit	Interval length
Blue	460 nm	470 nm	10 nm
Green	530 nm	540 nm	10 nm

Red	650 nm	660 nm	10 nm
NIR	850 nm	860 nm	10 nm

In another preferred variant, there are differences in the interval lengths of a technical property, as shown for example by the half-width of emitters (see Fig. 14a).

Intervals of half-widths of identical emitters			
Frequency range	Lower interval limit	Upper interval limit	Interval length
Blue	454 nm	476 nm	22 nm
Green	520 nm	547 nm	27 nm
Red	640 nm	668 nm	28 nm
NIR	840 nm	870 nm	30 nm

In a particularly preferred variant, the measuring device may have intervals which the interval limits of are designed such that there are no gaps between the intervals over the entire frequency range covered, for example, by the emitters of a measuring device.

Figures 14 and 14a clearly show, using the example of emitters, that using identical sensor components that vary within certain limits generates more information because the bandwidth of the emitted light is greater. Measuring devices in which identical sensor components do not exhibit these fluctuations necessarily have a lower bandwidth for the emitted light. The range of information generated by the measurement is therefore smaller. In an advantageous embodiment, the accuracy of the measurement of a substance is influenced by the design of the intervals for identical sensor components which the technical properties of vary within an interval. The following principle applies:

the smaller the interval length and the greater the number of sensor components in an interval, the higher the spectral resolution when measuring the substance or a physiological state and the more accurate the determination of the corresponding concentration.

In a further preferred solution, individual emitters or detectors may belong to more than one interval. In a preferred solution, there may be overlaps between the upper limit of one interval and the lower limit of another interval. In another preferred variant, the overlap may be up to 2 nm, up to 5 nm, up to 10 nm, up to 20 nm, or up to 50 nm.

In a preferred variant, the overlaps do not have to be the same for the respective range; there may be combinations of different overlap widths.

In a further preferred variant, there are gaps between the intervals as well as intervals directly adjacent to an interval and overlaps between the intervals. This is illustrated by the example of

the peak wavelength of emitters for the wavelength range from 250 nm to 460 nm: An interval with an interval length of 50 nm covers the range from 250 nm to 300 nm, a directly adjacent interval with an interval length of 10 nm covers the range from 301 nm to 311 nm, another interval with an interval length of 50 nm covers the range from 320 nm to 370 nm, an overlapping interval with an interval length of 30 nm covers the range from 360 nm to 390 nm, and another interval with an interval length of 50 nm covers the range from 410 nm to 460 nm.

In a preferred embodiment, the wavelength range covered by all intervals of identical sensor components for a property is up to 50 nm. In further preferred variants, it is up to 100 nm, up to 200 nm, up to 400 nm, up to 600 nm, up to 800 nm or more than 800 nm. In another preferred variant, the wavelength range covered by all intervals of identical sensor components for a property begins between 200 nm and 250 nm. In further preferred variants, it begins between 250 nm and 350 nm, between 350 nm and 450 nm, between 450 nm and 550 nm, between 550 nm and 800 nm, or between 800 nm and 1400 nm.

In another preferred variant, the wavelength range covered by all intervals of sensor components with the same property ends at 2000 nm. In further preferred variants, it ends between 1500 nm and 2000 nm, between 1000 nm and 1500 nm, between 500 nm and 1000 nm, or between 200 nm and 500 nm.

Emitter

For the assignment of emitters to a group of identical emitters, for example, one of the following intervals is selected for the peak wavelength and/or the center wavelength of the emitters in an advantageous variant: 1 nm, 3 nm, 5 nm, 10 nm, 20 nm, 50 nm.

In an advantageous variant, there must be at least 2 emitters in each interval. In further advantageous variants, there must be at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, or at least 10 emitters in an interval. In a preferred variant, there are at least 2 emitters in an interval of which the peak wavelength and/or center wavelength differ by at least 0.5 nm. In further preferred embodiments, the difference is at least 1 nm, at least 2 nm, at least 4 nm, at least 8 nm, or at least 10 nm.

In an alternative advantageous variant, the difference in peak wavelength and/or center wavelength of the emitters described above occurs only in some of the measuring devices produced, preferably in at least 1%, particularly preferably in at least 10% and especially preferably in at least 90% of the measuring devices.

As the interval length for assigning emitters to a group of identical emitters, one of the following intervals is selected, for example, for the full half-width (FWHM) of the emitters in an

advantageous variant: 5 nm, 10 nm, 15 nm, 20 nm, 30 nm, 40 nm, 50 nm, 100 nm, 150 nm, 200 nm, 250 nm, 300 nm, 400 nm, 500 nm, 600 nm (see Fig. 14d).

Similarly, for the half half-width (HWHM) of the emitters, one of the following intervals is selected in an advantageous variant: 2 nm, 5 nm, 7 nm, 10 nm, 15 nm, 20 nm, 25 nm, 50 nm, 75 nm, 100 nm, 125 nm, 150 nm, 200 nm, 250 nm, 300 nm. In an advantageous variant, there must be at least 2 emitters for FWHM in each interval. In further advantageous variants, there must be at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, or at least 10 emitters in an interval. This also applies analogously to HWHM.

In a preferred variant, there are at least 2 emitters in an interval which the full half-width (FWHM) of differs by up to 1 nm. In further preferred embodiments, the difference is up to 2 nm, up to 4 nm, up to 8 nm, up to 10 nm, up to 20 nm, up to 40 nm, up to 50 nm, up to 100 nm, or up to 150 nm.

Similarly, for the half full width, at least two emitters must be located in an interval which the HWHM of differs by up to 0.5 nm. In further preferred embodiments, the difference is up to 1 nm, up to 2 nm, up to 4 nm, up to 5 nm, up to 10 nm, up to 20 nm, up to 25 nm, up to 50 nm, or up to 75 nm.

In an alternative advantageous variant, the difference in the half-width of the emitters described above only occurs in some of the measuring devices produced, preferably in up to 1%, particularly preferably in up to 10% and especially preferably in up to 90% of the measuring devices. This applies to VWHM and HWHM of the emitters. In an advantageous variant, the measuring device in the aforementioned sense has at least one group of identical emitters for at least one property of the emitters (see Fig. 14d). In a preferred variant, the device has a group number of at least 2, up to 4, up to 8, up to 16 or more such groups.

In an advantageous variant, the measuring device in the aforementioned sense has at least one property of the emitters within a group of identical emitters with an emitter number of at least 2, preferably at least 3 (see Fig. 14c), preferably at least 4 (see Fig. 14c), preferably at least 5, preferably at least 6 (see Fig. 14), preferably at least 7, preferably at least 8, preferably at least 9, and preferably more than 10 emitters.

In a preferred variant, the measuring device in the aforementioned sense includes, for at least one property of the emitters, some groups of identical emitters that have a larger number of emitters, while other groups have a smaller number of emitters (see Fig. 14).

Advantageously, the measuring device has, for at least one property of the emitters, at least a first group number of identical emitters from the above set of advantageous group numbers, which contain at least one emitter number of the above-mentioned advantageous emitter

numbers (see Fig. 14). Advantageously, the measuring device has at least one further group number from the above set of advantageous group numbers for at least one property of the emitters, which contain at least one emitter number from the above-specified advantageous emitter numbers (see Fig. 14).

The measuring device is particularly advantageous if at least one property of the emitters has, for example, at least 3 groups of identical emitters with at least 4 emitters each. In an advantageous variant, at least one property of the emitters additionally has at least one group of identical emitters with at least 5 emitters. In a further advantageous variant, if at least one emitter property is present, there are at least four groups of identical emitters with two emitters each (see Fig. 14e). In a preferred variant, the emitters of an interval do not cover the entire width of the interval. This means that for emitters assigned to an interval, the values of the property do not scatter so widely, or the values do not differ so greatly, and that the full bandwidth of the interval is required for these emitters to be assigned to the interval (see Fig. 14e). In a more preferred variant, the emitters of an interval cover the entire width of the interval. This means that for emitters assigned to an interval, the values of the property scatter or differ so much that the full bandwidth of the interval is required for these emitters to be assigned to the interval (see Fig. 14a, interval blue (10cb)).

In a preferred variant, the wavelength range covered by all intervals with the same emitters is smaller than the wavelength range covered by the gaps between the intervals. In further preferred variants, the wavelength range covered by all intervals with the same emitters is, for example, up to 20 nm smaller, for example up to 40 nm smaller, for example up to 80 nm smaller, for example up to 100 nm smaller, for example up to 200 nm smaller, for example up to 400 nm smaller, or for example up to 800 nm smaller, than the wavelength range covered by the gaps between the intervals in total. In a preferred variant, the wavelength range covered by all intervals with the same emitters in total is greater than the wavelength range covered by the gaps between the intervals in total. In further preferred variants, the wavelength range covered by all intervals with the same emitters in total is, for example, up to 20 nm greater, for example up to 40 nm larger, for example up to 80 nm larger, for example up to 100 nm larger, for example up to 200 nm larger, for example up to 400 nm larger, or for example up to 800 nm larger, than the wavelength range covered by the gaps between the intervals in total. In a preferred variant, the wavelength range covered by all intervals with equal emitters in total is identical or nearly identical to the wavelength range covered by the gaps between the intervals in total. In another preferred variant, there are no gaps between the intervals of identical emitters. In an

advantageous variant, the method is used in the production of a device according to the invention, whereby at least one optical property of at least one part of the emitters is measured.
In an alternative advantageous variant, the measurement during production can be omitted by inferring at least one optical property of the emitters from the measured values of several measurements carried out by the user. This can be done, for example, by mathematical or statistical methods or AI algorithms. In an advantageous variant, numerous product pieces of the device according to the invention are produced and placed on the market. The product units placed on the market are used to perform numerous measurements. It is particularly advantageous to collect a large amount of measurement data and, in an advantageous variant, to store it. In an advantageous variant, the measured values collected in this way are used. This can generate insights into possible improvements to the product. In an alternative advantageous variant, the accuracy of the devices in the field can be improved either on the basis of their individual measured values or on the basis of statistical values of all devices or by a combination of both. In an advantageous design, the device is designed so that the raw optical data can be recorded and stored individually. This allows the device to be optimized retrospectively using the above-mentioned methods, even if these are not yet in use at the time of market launch, for example. In this context, raw optical data refers to information from which the properties of individual emitters can be inferred. In a particularly advantageous variant is stored information which is recorded by one or more detectors when only one of the emitters is activated. In an advantageous manner, information is not only recorded when several emitters of an interval with the same optical properties are activated simultaneously and are therefore located in close proximity to each other, so that conclusions cannot be drawn about the optical properties of the individual emitters.

Detector

For the assignment of detectors to a group of identical detectors, for example, the peak wavelength and/or center wavelength of the wavelength range in which detectors receive photons from emitters is selected. Advantageously, intervals with identical detectors have, for example, the following interval lengths: 10 nm, 20 nm, 50 nm, 100 nm, 200 nm, 300 nm, 400 nm, 500 nm, 800 nm, 1000 nm, 1100 nm, 1200 nm.
In an advantageous variant, there are at least 2 detectors in each interval of equal detectors. In further advantageous variants, there are at least 3, at least 4, at least 5, at least 6, at least 7, at least 8, at least 9, or at least 10 detectors in an interval. In a preferred variant, there are at least two detectors in an interval of identical detectors which the peak wavelengths of differ by up to 5

nm. In further preferred embodiments, the difference is up to 10 nm, up to 20 nm, up to 40 nm, up to 80 nm, or up to 100 nm.

In an alternative advantageous variant, the difference in peak wavelength and/or center wavelength of the detectors described above occurs only in some of the measuring devices produced, preferably in at least 1%, particularly preferably in up to 10% and particularly preferably in up to 90% of the measuring devices. As the interval length for assigning detectors to a group of identical detectors, one of the following intervals is selected, for example, for the full half-width (FWHM) of the detectors in an advantageous variant: up to 50 nm, up to 100 nm, up to 150 nm, up to 200 nm, up to 250 nm, up to 300 nm, up to 400 nm, up to 500 nm, up to 600 nm, up to 700 nm, up to 800 nm. Similarly, one of the following intervals is selected for the half peak width (HWHM) of the detectors, for example: up to 25 nm, up to 50 nm, up to 75 nm, up to 100 nm, up to 125 nm, up to 150 nm, up to 200 nm, up to 250 nm, up to 300 nm, up to 350 nm, up to 400 nm. In a preferred variant, there are at least two detectors in an interval of identical detectors which the full half-widths of differ by up to 1 nm. In further preferred embodiments, the difference is up to 5 nm, up to 10 nm, up to 20 nm, up to 40 nm, up to 50 nm, up to 100 nm, or up to 150 nm. This applies analogously to the half-width of the detectors, where two detectors differ by up to 0.5 nm. In further preferred embodiments, the difference in HWHM is up to 2.5 nm, up to 5 nm, up to 10 nm, up to 20 nm, up to 25 nm, up to 50 nm, or up to 75 nm.

In an alternative advantageous variant, the difference in the half-width of the detectors described above only occurs in some of the measuring devices produced, preferably in at least 1%, particularly preferably in at least 10% and especially preferably in at least 90% of the measuring devices. This applies to both FWHM and HWHM. As an interval length for assigning detectors to a group of identical detectors, one of the following interval lengths is advantageously selected for the amplification factor with which the recorded photons are converted into electrical signals: up to 2 times, up to 5 times, up to 10 times, up to 50 times, up to 100 times, up to 200 times, up to 500 times, up to 1000 (see Fig. 15). In a preferred variant, there are at least two detectors in an interval of identical detectors which the amplification factors of differ by up to a maximum of 10%. In further preferred embodiments, the difference is max. up to 20%, max. up to 50%, max. up to 100%, max. up to 200%, max. up to 500%, or max. up to 1000% (see Fig. 15).

In an alternative advantageous variant, the difference in the amplification factor of the detectors described above only occurs in some of the measuring devices produced, preferably in at least 1%, particularly preferably in at least 10% and particularly preferably in at least 90% of the measuring devices. In an advantageous variant, the measuring device in the aforementioned sense has at least one group of identical detectors for at least one property of the detectors. In a

preferred variant, the measuring device has at least 2, at least 4, at least 8, at least 16 or more such groups. In an advantageous variant, the measuring device in the aforementioned sense has at least one property of the detectors within a group of identical detectors with a detector number of at least 2, preferably at least 3, preferably at least 4, preferably at least 5, preferably at least 6, preferably at least 8, preferably at least 9, or preferably at least more than 10 detectors. In a preferred embodiment, the measuring device in the aforementioned sense includes, for at least one property of the detectors, some groups of identical detectors that have a larger number of detectors, while other groups have a smaller number of detectors. Advantageously, the measuring device has, for at least one property of the detectors, at least a first group number of identical detectors from the above set of advantageous group numbers, which contain at least one detector number of the above-mentioned advantageous detector numbers.

Advantageously, the measuring device has at least one further group number from the above set of advantageous group numbers for at least one property of the detectors, which contains at least one detector number from the above-mentioned advantageous detector numbers.

It is particularly advantageous if the measuring device has at least one property of the detectors, for example at least 3 groups of identical detectors with at least 4 detectors each. In an advantageous variant, at least one group of identical detectors with at least 5 detectors is additionally present for at least one property of the detectors. In a further advantageous variant, at least one property of the detectors additionally has at least 4 groups of identical detectors, each with 2 detectors. In a preferred variant, the detectors of an interval do not cover the entire width of the interval. This means that for detectors assigned to an interval, the values of the property do not scatter so widely, or the values do not differ so greatly, that the full bandwidth of the interval is required for these detectors to be assigned to the interval (see Fig. 15). In a more preferred variant, the detectors of an interval cover the entire width of the interval. This means that for detectors assigned to an interval, the values of the property scatter or differ so much that the full bandwidth of the interval is required for all detectors to be assigned to the interval. In a preferred variant, the measuring device has a total of at least 2 detectors. In further preferred variants, the measuring device has, for example, up to 4, up to 8, up to 16, up to 20, or more than 20 detectors.

Combination of same emitters and same detectors

In a preferred variant, for a specific width of the wavelength range or the entire wavelength range from UV to infrared in the above sense, the intervals of same emitters and the intervals of same detectors are combined with each other.

In a further preferred variant, the measuring device in the aforementioned sense has, for a property such as full half-width (FWHM), a combination of narrow-band emitters with, for example, an interval width for same emitters of e.g. 5 nm, 10 nm, 15 nm or 20 nm, in which the assigned emitters cover at least 50% of the interval width, with broadband detectors which, for example, have an interval width for equal detectors of, for example, 500 nm, 600 nm, 700 nm or 800 nm, and where the assigned detectors cover at least 50% of the interval width. The same applies analogously to half the half-width (HWHM) with an interval width for identical emitters of, for example, 2 nm, 5 nm, 7 nm, 10 nm and broadband detectors with an interval width for identical detectors of, for example, 250 nm, 300 nm, 350 nm, 400 nm. In a further preferred variant, the measuring device in the aforementioned sense has, for at least one property, for example the full half-width (FWHM), a combination of broadband emitters with an interval width for equal emitters of, for example, 300 nm, 400 nm, 500 nm or 600 nm, in which the assigned emitters cover at least 50% of the interval width, with narrow-band detectors having an interval length for identical detectors of, for example, 10 nm, 20 nm, 30 nm, 40 nm, 50 nm, or 100 nm, and in which the assigned detectors cover at least 50% of the interval width.
The same applies analogously to half the half-width (HWHM) with an interval width for identical emitters of, for example, up to 150 nm, up to 200 nm, up to 250 nm, or up to 300 nm and narrow-band detectors with an interval length for identical detectors of, for example, up to 5 nm, up to 10 nm, up to 15 nm, up to 20 nm, up to 25 nm, or up to 50 nm.

Sensor components with identical properties and non-identical properties

The measuring device claimed here for measuring substances or parameters for determining physiological states of humans can, in a preferred embodiment, contain, in addition to the sensor components previously described as identical, sensor components that differ from these identical sensor components in at least one technical property.
Sensor components are considered to be <u>different</u> sensor components if the value of a technical property does not lie within the interval length of an interval of identical sensor components, but rather, for example, in an interval gap. An example of a different emitter in a gap of intervals of identical emitters is shown in Fig. 14c.
The measuring device claimed here, for example, in a preferred embodiment, has at least one property with both identical sensor components and sensor components that differ in the aforementioned sense from the identical sensor components in at least one property. Examples of this are shown in Figures 14c and 14d based on the peak wavelength and half-widths of emitters.
In a further preferred variant, the measuring device in the aforementioned sense has, for

example, only identical emitters and identical detectors in at least one property. In a further preferred variant, the measuring device in the aforementioned sense has, for example, identical emitters and non-identical detectors or identical detectors and non-identical emitters in at least one property.

In a further preferred variant, the measuring device in the aforementioned sense has, for example, the same emitters and the same detectors for at least one property and, for another property, the same emitters and different detectors or, for the further property, different emitters and the same detectors.

It is clear to the skilled person that, in the aforementioned sense, the combination of identical and non-identical sensor components results in a large number of variants, for example with regard to the number of respective properties, the interval length for identical sensor components, the combination of intervals to cover a range or the complete wavelength range of UV and infrared, which have identical and/or non-identical-identical sensor components and which improve the measurement accuracy and/or repeatability and/or comparability of the results when measuring parameters and/or substances and/or physiological states of humans for the respective application.

In a preferred variant, for a specific width of the wavelength range or the entire wavelength range from UV to infrared in the above sense, the intervals of identical emitters and the intervals of identical detectors are combined with each other.

In a preferred embodiment, the measuring device has a total of up to 6 emitters and detectors, and, in a further preferred embodiment, a total of up to 9 emitters and detectors, which, in the aforementioned sense, are either considered to be identical sensor components and/or differ from the sensor components considered to be identical in at least one technical characteristic. In other preferred embodiments, the measuring device has a total of 10 to 16 emitters and detectors, while, in further preferred embodiments, the sum of emitters and detectors is between 17 and 30, and, in other particularly preferred embodiments, the sum of emitters and detectors is between 31 and 50, in further particularly preferred embodiments, the sum of emitters and detectors is between 51 and 70, in further particularly preferred embodiments, the sum of emitters and detectors is between 71 and 100, and, in additionally particularly preferred embodiments, the sum of emitters and detectors is greater than 100. In all embodiments, RGB emitters are counted as 3 emitters. In an advantageous embodiment, the system described here uses the patent numbers EP 3013217; EP 3175783; US 10,416,079; US 11,08,5876 and applications US 17/396,556, EP 4005469A1 to estimate the physiological state of the individual by measuring various parameters and/or substances with the aid of sensor components. In an advantageous

embodiment, the substance concentrations are determined transcutaneously at different depths of the human skin down to the blood. Inhomogeneously distributed substances and homogeneously distributed substances are detected.

Measurement procedure

In a preferred embodiment, the emitters of the measuring device are switched on individually and in a specific sequence to measure parameters or substances or physiological states of an individual. The sequence may vary.

In another preferred embodiment, two emitters of the measuring device are always switched on simultaneously to measure parameters or substances or physiological states of an individual. The order in which the two emitters are switched on first and then subsequently can vary. Analogous to the above, in equally preferred embodiments, three emitters, four emitters, or five emitters are switched on simultaneously. The order in which three, four, or five emitters are switched on first and which three, four, or five emitters are switched on next may vary.

In a preferred embodiment, the two, three, four, or five emitters that are switched on together are identical emitters that vary, for example, in their peak wavelength or center wavelength but that belong to an interval. In a further preferred variant, the two, three, four, or five emitters each belong to more than one interval. In another preferred variant, only two, three, four, or five emitters are switched on simultaneously.

In a further preferred embodiment, the variants described above involve emitters that are not identical. The distribution of the emitters over the wavelength range from ultraviolet to infrared is designed such that, in a preferred embodiment, the differences in peak wavelength or center wavelength are, for example, greater than 50 nm. In further preferred variants, the differences are, for example, more than 75 nm, more than 100 nm, more than 150 nm, or more than 200 nm. With regard to specific applications, in the even more preferred embodiment, all emitters are switched on simultaneously.

Description of measuring device - distribution of sensor components

In a preferred embodiment, the measuring device has a sensor surface that is in direct contact with the outer layer of the skin when measuring various parameters and/or substances and/or physiological conditions of humans. In a preferred embodiment, this skin contact does not exist continuously throughout the entire measurement period. In a more preferred embodiment, this skin contact exists throughout the entire measurement period. In a further preferred embodiment, contact and non-contact alternate during a measurement. In a further preferred variant, only part

of the sensor surface is in continuous contact with the outer layer of the skin during the entire measurement period. In a further preferred variant, part of the sensor surface is not in continuous contact with the outer layer of the skin during the entire measurement period.

The sensor surface is understood to be a three-dimensional volume (3) with a specific thickness. In a preferred embodiment, the three-dimensional volume has a curvature toward the side of the skin contact. In a more preferred embodiment, the curvature is concave, and in a further preferred embodiment, the curvature is convex (see Figures 2 to 3a). In a further preferred embodiment, the three-dimensional volume has concave and convex curvatures, but these are not opposite each other.

In relation to the two-dimensional extension of the volume of the sensor surface (3a), this size is determined by the arrangement and/or placement of the emitters and detectors. In a preferred embodiment, the size and shape of the two-dimensional extension of the volume (3a) corresponds to the area that the emitters and detectors together occupy as components when they are mounted on a common printed circuit board (PCB) of the measuring device or are located on a common plane (3b) (see Figures 1, 1a). In a preferred variant, the printed circuit board or the common plane is impassable or virtually impassable for photons. In another preferred variant, the printed circuit board or the common plane can be completely or partially heated or cooled, e.g., electrically.

In further preferred variants, the two-dimensional extension of the sensor surface (3a) is up to 0.5% larger, up to 1% larger, up to 2% larger, up to 4% larger, up to 8% larger, up to 15% larger or up to 30% larger than the area (3b) occupied by the emitters and detectors as components when they are mounted, for example, on a common printed circuit board (PCB) (6).

In a preferred variant, the three-dimensional volume of the sensor surface is designed such that the emitters and detectors are not in direct contact with the skin during measurement. In a preferred embodiment, this is achieved by the three-dimensional volume of the sensor surface having continuous openings in the area of the emitters and detectors. The shape of these openings may vary. In a preferred variant, the openings are rectangular, and, in further preferred variants they are square or round or have square or rectangular openings with bevelled corners, or consist of a mix of the aforementioned openings (see Figs. 4 and 4a).

In a more preferred variant, the three-dimensional volume of the sensor surface is designed so that photons can be emitted and detected through the three-dimensional volume (see graphic (figure 1). The volume can be transparent so that photons can pass through the volume almost unimpeded and without noticeable scattering. In a preferred embodiment, this volume is less transparent and photons are scattered by the material of the volume in such a way that, when

they leave the volume, they penetrate the skin in almost all possible spatial directions, i.e., without a preferred direction. This can be achieved, for example, by scattering bodies that are part of the volume or are deliberately introduced into it. In another preferred embodiment, the material for the volume is selected so that only photons of certain wavelengths can pass through it. In another preferred embodiment, the photons are bundled as they pass through the volume by the design and choice of material, so that when they leave the volume, they tend to enter the outer layer of the skin in a point-like manner in one or more preferred directions. The material can, for example, be designed to be lens-shaped.

In a more preferred embodiment, the three-dimensional volume of the sensor surface (3) contains three-dimensional components (5) which the material of is selected so that it is impassable or at least nearly impassable for photons. Individual components can be connected to form a continuous component (5b) (see Fig. 9b). Metals, aluminum, or plastics are possible materials for the components. In a similarly preferred embodiment, these components may be present in all of the previously described embodiments of the three-dimensional volume.

In a preferred embodiment, the thickness and placement of the impassable or nearly impassable parts are chosen such that they spatially separate the emitters and detectors located below the sensor surface in such a way that emitted photons cannot reach the detectors within the measuring device (see, for example, Figs. 6, 7, 8, 9, 10).

In a preferred embodiment, the spatial separation of the emitter and detector can be designed such that, in conjunction with the three-dimensional volume of the sensor surface, enclosed spaces are created, which, in their basic geometric form, correspond to round, rectangular, or square volumes, which, as described above, may have bevelled corners or edges (see Fig. 5a). In a preferred embodiment, the thickness of the impassable parts is greater than the thickness of the three-dimensional volume of the sensor surface. In a preferred embodiment, the step between the two bodies resulting from the difference can be located on the side of the sensor surface that faces the skin during measurement (see Fig. 6b). In a further embodiment, the step may be located on the underside (see Fig. 5). This refers to the side of the three-dimensional volume that is not facing the skin. In this variant, for example, the three-dimensional volume and the components that are impassable for photons can form a form-fitting or nearly form-fitting surface on the side facing the skin (see Fig. 5).

In a further preferred embodiment, the thickness of the impenetrable parts is such that there is a step (3.3) on both the side facing the skin and the side facing away from the skin relative to the three-dimensional volume of the sensor surface (see Fig. 6). In a preferred variant, the resulting enclosed spaces can each contain an emitter or a detector. In a further preferred variant, there is

more than one emitter and/or more than one detector in each of the spaces (see Fig. 7). An RGB LED counts as three emitters. These spaces can have single or multiple openings (3.2) in the sensor surface, which are, for example, facing the skin (see Fig. 7). In a preferred solution, the entire volume of the enclosed spaces consists of the material selected for the three-dimensional volume of the sensor surface. In this embodiment, for example, the thickness of the impassable three-dimensional components corresponds to the thickness or approximately the thickness of the three-dimensional volume of the sensor surface, so that there is no or virtually no step between the sensor surface and the impassable component (see Fig. 8). In another preferred variant, the enclosed spaces each contain a cavity filled with gas, for example air. (see Figs. 5, 6, 7).

In a particularly preferred embodiment, the three-dimensional volume of the sensor surface (3) and the components (5) that are at least nearly impassable for photons form a unit (9) that can be subsequently applied to the printed circuit board with the emitters and detectors. In a preferred embodiment, the unit is connected to the printed circuit board in such a way that the contact point between the printed circuit board (6) and the unit (9) is also almost impenetrable to photons. The connection can be made, for example, by liquid bonding or by double-sided adhesive tape or by melting and pressing the material that is virtually impenetrable to photons to the printed circuit board or by screwing it to the printed circuit board. The unit can be manufactured, for example, by injection molding (see Figs. 9 and 9a).

In another preferred variant, the components (5) that are impenetrable to photons are a monolithic unit (5b) that is applied to the circuit board in the aforementioned sense (see Fig. 9b). This unit can be part of the housing of the measuring device. In this case, the circuit board (6) is inserted into the housing. Either as a monolithic unit or as part of the housing, the openings (3.2) located in this component, which are located above the emitters and detectors after placement, are then filled or molded with the material of the three-dimensional volume of the sensor surface (see Fig. 9c). The material then closes off toward the skin with the upper edge of the components (5) that are impervious to photons. As a result of capillary forces, the surfaces of the molded openings may be concave, for example (see Figs. 9b, 9c). Other curvatures or waviness of the surfaces are also possible. The photons emitted by the emitters pass through the sensor surface either through openings in the sensor surface or by passing through the three-dimensional volume of the sensor surface (3), penetrate the skin, migrate within it and leave it, e.g. at another point on the skin, overcome or pass through the three-dimensional volume of the sensor surface (3) again in the aforementioned sense (either through openings in the sensor surface or by passing through the three-dimensional sensor surface) in order to be then detected by a detector of the measuring device (see Figs. 7 and 7a).

In a similarly preferred variant, three-dimensional components (5a) that are virtually impenetrable to photons may, in addition to being integrated into the three-dimensional volume of the sensor surface, also be arranged above the three-dimensional sensor surface (3) (see Fig. 11). The components can be rectangular, square, or polygonal, for example, and have bevelled corners or edges; they can be round or oval, or the components can form any pattern on the sensor surface. They can be in contact with the three-dimensional sensor surface (3) or be located at a defined distance above the surface. The additionally arranged components (5a) can together form a monolithic unit (5b).

In a preferred embodiment, three-dimensional components (5) are located on the printed circuit board, these forming spaces surrounding the emitters and detectors without being in direct contact with the three-dimensional volume of the sensor surface. The emitters (1) and detectors (2) are then located in enclosing spaces that are not closed toward the skin. Additional components (5a) may be located on these components (5), which partially close the opening of the spaces toward the skin. The additional components (5a) can be arranged so that, during emission, the photons can only leave the spaces at limited angles, or, after passing through the skin, can re-enter them (see Fig. 10). In a further preferred variant, the three-dimensional volume of the sensor surface (3) is located below the additional components (5a) (see Fig. 3). The photons must pass through the three-dimensional volume of the sensor surface (3) during their emission and detection (see Fig. 10a).

In a preferred variant, additional components (5a) are arranged so that they are located at a defined distance parallel to each other on the components (5) (Figs. 12, 12a). The resulting distances between the additional components can vary, resulting in slits through which the photons can leave the spaces exclusively or almost exclusively in three main directions in order to enter the skin. If, for example, the slots run in an east-west direction, then one main direction is east, the second main direction is west, and the third main direction runs perpendicular to the printed circuit board (6) in the direction of the skin (Fig. 12). It is clear to the skilled person that, depending on the width of the slots, photons can also leave the spaces in directions that deviate slightly from the three main directions. In other preferred embodiments, the slots do not run in an east-west direction, but in a north-south direction or in all other directions in between, resulting in different first and second main directions.

In a preferred embodiment, a transparent component (7) may be located above the additional components (5a) and be in contact with the skin during measurement (Figs. 12b to 12e). The material thickness of the component (7) can be designed such that a cavity (8) is formed, within

which the components (5, 5a) that are impervious to photons and the emitters (1) and detectors (2) are located (see, for example, Fig. 12b and Fig. 12b2 or, for example, Fig. 12c, 12c2).
In a further preferred embodiment, the additional components (5a) are integrated into the volume of the component (7) (see, for example, Fig. 12b1 or, for example, Fig. 12c1).
In a further preferred variant, the three-dimensional volume of the sensor surface (3) is located above the emitters (1) and detectors (2) so that the additional components (5a) and the component (7) are located above the sensor surface (3) (see, for example, Fig. 12b3, 12b4, 12b5 or, for example, Fig. 12c3, 12c4, 12c5). In a preferred embodiment, the component (5a) can break through the transparent component (7) in such a way that it is impossible or virtually impossible for photons to migrate within the material thickness of the component (7) in any spatial direction (see, for example, Fig. 12d, 12d1, 12d2).
The component (7) may, for example, be made of plastic or glass, it may have optical properties that, for example, allow photons to pass only in certain preferred directions and/or certain wavelengths, it can be a lens that directs the photons in a specific manner, the material can be opaque or scattering, the component can have thermal properties and, for example, be electrically heatable or have a cooling effect, for example to establish comparable temperatures between the skin and the measuring device during measurement. The component (7) can also be located above all other variants of the measuring device described.
Due to the component being impenetrable or almost impenetrable to photons, detectors can only detect photons from an emitter that have passed through the skin or the human body at a certain depth and in a certain direction. Depending on the wavelength of the emitted photons, on the geometric or spatial placement of the emitters and detectors, on their number, and on the respective direction of entry of the photons into the measuring point/contact point on the skin, the light paths of the photons are different.
In the variants described above, the components (5, 5a) that are at least almost impenetrable to photons can be arranged and designed in such a way that the angle of the photons when they enter the contact surface of the skin, and thus, the direction of travel of the photons in the skin can be specifically influenced. In this way, it is possible to influence the quantity of photons that enter the skin at a steep or flat angle, and, on average, travel through the skin at shallow or greater depths before exiting it, and, if present, pass through the three-dimensional volume of the sensor surface again and are then detected by the sensors. Due to this influence, the detector (2) can only detect photons that exit the skin at certain spatial angles. The respective angles for emission and detection may be different. An example is shown in Figs. 10 and 10a.

Influence on the angle of entry of the photons into the skin beyond the influence on the angle of emission described above may result from component (7). This may be related, for example, to the lens function or any scattering bodies in this component. During detection, any influence on the angle caused by component (7) only affects the number of photons reaching the detector at a certain angle, with components (5) and (5a) limiting the possible angles.

Provided that component (7) has no directional or angle-influencing function, this document results in a solid angle during emission, formed by a straight line in the direction of the skin, which starts at any point on the emitter and penetrates unhindered into the outer surface of the skin as a tangent of a component (5, 5a) that is virtually impenetrable to photons. The angle size is determined from the intersection of this straight line with a line that runs parallel to the circuit board (6). For each emitter, there is a smallest angle among all possible solid angles at which photons can enter the skin. In a preferred variant, the smallest of all possible spatial angles of an emitter at which photons can enter the skin, is not greater than 1°. In further preferred variants, the angle is up to 5°, up to 10°, up to 20°, up to 40°, up to 45°, up to 60°, and up to 90°. The same applies analogously to a detector when detecting photons. Here, the straight line begins on the outside of the skin and runs as a tangent of a component that is impassable for photons through the upper side of the three-dimensional volume of the sensor surface (3) facing the skin, if present, down to any point on the detector. The angle size is determined from the intersection of this straight line with a line that runs parallel to the circuit board (6) (see, for example, Fig. 10, 10a).

In a preferred embodiment, there are large differences between the emitters and between the detectors in terms of the smallest angle when emitting or detecting photons. In a further preferred embodiment, the differences between emitters and between detectors are negligible. In another preferred alternative, there are both large differences and/or smaller differences and/or negligible differences when comparing emitters to emitters or detectors to detectors or emitters to detectors. The materials of the components (5, 5a) that cause, for example, the smallest angles for a specific emitter or detector may differ in colour, material composition, and resulting properties (e.g., absorbent, reflective) from emitter to emitter or detector to detector or between emitters and detectors.

Distribution of emitters and detectors

In a preferred technical design, the emitters (1) and detectors (2) are distributed approximately evenly in the area of the sensor surface, so that both different emitter-detector distances and redundant emitter-detector distances result (see Fig. 13a).

Emitter-detector distances are measured on the plane of the sensor surface as a direct line from the center of one of these components to the center of the other component (see Fig. 13a). In the case of a curved sensor surface, the curvature is not taken into account when determining the distance. The distance is the straight line at right angles to the perpendicular to the respective centers of the components (see Fig. 13). Elsewhere in this document, the emitter-detector distance is also referred to as the light path.

In a further preferred embodiment, emitters and detectors, which are preferably used to detect a specific substance, are distributed in such a way that the distance lengths between the emitter and detector are predominantly those that contribute most to the detection of this substance. In a preferred technical embodiment, the advantageous distance lengths are up to 10% higher, in another preferred embodiment up to 20% higher, in a further embodiment up to 30% higher, in a particularly preferred embodiment up to 40% higher, and in a particularly preferred embodiment up to 50% higher than the less significant distance lengths. In a preferred embodiment, the number and distribution of the emitters and detectors result in a total of up to 50 light paths, and in a further preferred embodiment up to 100 light paths. In more preferred embodiments, there are up to 200, up to 400, up to 800, up to 1600, and more than 1600 light paths, whereby more than one emitter may be located in a previously described enclosed space (see, for example, Fig. 7). In a preferred embodiment, the measuring device has a total of up to 6 emitters and detectors, and in a further preferred embodiment, a total of up to 9 emitters and detectors, which in the aforementioned sense are either considered to be identical sensor components and/or differ from the sensor components considered to be identical in at least one technical characteristic. In the aforementioned sense, in other preferred embodiments, the measuring device has a total of 10 to 16, in further preferred embodiments, the sum of emitters and detectors is between 17 and 30, in other particularly preferred embodiments, the sum of emitters and detectors is between 31 and 50, in further preferred embodiments, the sum of emitters and detectors is between 51 and 70, in further preferred embodiments, the sum of emitters and detectors is between 71 and 100, and in additionally preferred embodiments, the sum of emitters and detectors is greater than 100. In all embodiments, RGB emitters are counted as 3 emitters.

Through targeted design and combination of the above-mentioned influencing factors, the sensor can be specifically aligned with the substances to be measured.

This also includes switching on the emitters for measurement according to a specific sequence so that only one emitter emits photons at a time.

Surprisingly, it was found that within a measurement sequence, the following factors influence the accuracy of the detection of a substance concentration: sequence, duration, light intensity,

and frequency of switching on the respective emitters. A measurement sequence is defined as a defined part of a measurement. This means that measurements can consist of one or more measurement sequences between which the contact between the sensor and the skin is not interrupted. To accurately determine substances, it may be necessary to perform several measurements with their respective measurement sequences one after the other.

The measurement sequences can be designed so that a sequence is dedicated to the detection of one single substance, and, for example, only certain emitters are switched on for a specific duration with a selected light intensity and according to a specific sequence. The measurement sequence can therefore be designed differently for each substance.

When performing multiple measurement sequences or even complete measurements, bleaching effects may occur, which affect the accuracy of the concentration determination of substances. This effect can vary between substances. If the concentration of a substance at a certain depth of the skin area detected by the sensor is low, the bleaching effect has a stronger impact on the signal-to-noise ratio and, in contrast to a higher concentration, also reduces the accuracy of the measurement more significantly or makes it impossible to detect the substance correctly.

Another cause may be that substances are predominantly distributed in certain layers of the skin or in the blood. If deeper skin layers or even blood vessels need to be analyzed, it may be necessary to improve the signal-to-noise ratio for the long light paths so that even low concentrations can be detected well.

Surprisingly, it was found that by specifically adjusting and/or combining the switch-on time and/or light intensity and/or frequency of switching-on certain emitters within a measurement sequence, as well as the order in which the emitters are switched on within a measurement sequence, the bleaching effect has no or only a limited effect on the detection of substances. If the targeted adjustment of a measurement sequence influences the accuracy of the concentration determination of another substance to be detected in a subsequent measurement sequence, the adjusted measurement sequence is performed as the last sequence of a measurement. Due to the inhomogeneous distribution of substances, which not only applies to the skin areas of a person but also varies from person to person, the influencing factors of emitter switch-on time, emitter light intensity, and the sequence and frequency of emitter switching-on, can be determined individually for each user. The influencing factors are determined individually by first establishing how much a skin area or a person deviates from an empirically determined standard setting. Therefore, the first measurement sequence within a measurement must always correspond to this standard setting. By analyzing the individual light paths, the ratio of absorption (or concentration of the substance?) between light paths of different lengths is

determined and the deviation from the empirical standard is calculated, using all emitters of the sensor in this measurement sequence. In accordance with the previous definition, the light path is understood here as the distance between emitter and detector, and absorption is understood as the electrical signal that, for example, emitted photons generate in the detectors of the measuring device as a consequence of the sole activation of one emitter.

In a second measurement sequence, the influencing factors are individually adjusted to the measurement area or the person depending on the deviation. This can be the same for all substances to be detected. However, it is also possible that the adjustment is different for the individual substances and that each substance must be detected using a separate measurement sequence in which only certain emitters are switched on. The order of the substance-related measurement sequences is then determined, for example, in view of minimizing the bleaching effect.

The user perceives this as two separate measurements because he/she is asked to break contact between the skin and the sensor after the standard measurement sequence has been completed. Once the application has received the customized settings, it asks the user to reestablish skin contact with the sensor. The follow-up measurement with the customized measurement sequences starts automatically as soon as the application registers that skin contact has been reestablished. The customized settings can be determined by the application itself, for example.

By customizing the measurement in terms of the measurement sequences it contains, each user can obtain a measurement that is optimized for the correct concentration determination.

It is possible that the computing power required for individualization cannot be provided by the measuring device itself, but must be provided by an external server. In this case, the measuring device sends the spectral data of the standard measurement sequence to a server, e.g. using a special application, and receives the settings for the individually tailored measurement sequences from the server. The data can be sent to the external server via the Internet, for example from the measuring device itself, using an application to send the data via a mobile network, or by the application dialing into an existing WiFi network to send the data to the external server via the Internet.

In a particularly preferred variant, the measuring device sends the data via WiFi or Bluetooth, e.g., to a mobile device (e.g., smartphone or tablet), which then sends it via mobile communications (e.g., 4G, 5G) over the Internet to the external server or uses an existing WiFi network to send the data. In a preferred embodiment, the data is encrypted before being sent. In another preferred embodiment, the server sends the settings for the individually tailored

measurement frequencies back to an application on the mobile device in encrypted form using the same method. The server always sends the settings only to the device that sent it the data.

The individualization of the measurement also allows the influence of certain skin characteristics on the measurement result, such as skin type, skin spots, wrinkles, scars, or skin roughness, to be compensated for. Within a measurement, the number of repetitions of the individual measurement procedure is another option for correctly determining the concentration of the substance. First, a standard setting is selected, which includes, for example, 1, 2, 3, 4, 5, or more repetitions of the measurement procedure. The concentration of the substance is then calculated for each individual measurement procedure and the deviation of the individual results from each other is determined. If the deviation is too large, the user is prompted to perform another measurement with a certain number of measurement procedures. As experts know, more measurements reduce the measurement error of a device, i.e., more measurements lead to a lower standard deviation of the measurement result from the mean value or the actual value. For this reason, the number of measurement procedures, or even the number of measurements, could, of course, be increased from the outset in order to ensure a correct result. However, the advantage of the aforementioned procedure is that no more measurement sequences or complete measurements need to be performed than is necessary for the individual case. The number of measurement sequences required within a measurement may vary between individuals. Since almost all substances in skin and tissue are distributed inhomogeneously, the concentration may vary from measurement point to measurement point. The size of the sensor and the placement of the emitters and detectors are therefore selected, within the scope of this invention, so that the sensor size covers a representative section of the inhomogeneous distribution and so that the same measurement results are obtained when the sensor is brought into contact with the skin again, provided that the concentration of the substance has not changed for physiological reasons. For everyday use, an appropriately selected sensor size/sensor area is a great advantage, because, in a repeated measurement, the measured concentration is virtually unaffected by the inhomogeneous distribution, so that a changed measurement result can be traced back to physiological changes within the measurement error tolerance. Surprisingly, it was found that with a certain sensor area size and by specifically designing the above-mentioned measurement sequence adjustment in conjunction with the choice of the time for the first repeated measurement, the dynamics of a substance concentration change can already be determined. This means that future substance concentration values can be predicted.

The sensor surface that comes into contact with the skin during a measurement should therefore be between 0.5 cm^2 and 9 cm^2 if possible. In a preferred embodiment, the sensor surface has a

size of up to 1 cm², in another preferred embodiment a size of up to 1.5 cm², in a further preferred embodiment up to 2 cm², in a more preferred embodiment up to 2.25 cm² and in a more preferred embodiment up to 4 cm².

Therefore, the total size of the sensor area of the measuring device (see Fig. 1a) is, in a preferred embodiment, for example, up to 10 mm x 10 mm, in a further preferred embodiment up to 12 mm x 12 mm, in a highly preferred technical embodiment up to 15 mm x 15 mm, and in a particularly highly preferred technical embodiment up to 20 mm x 20 mm. Depending on the detection task, it may also be larger than 20 mm x 20 mm.

For special applications, the preferred sensor size can also be up to 8 mm x 8 mm, and in a particularly preferred embodiment, it can be up to 6 mm x 6 mm.

It is clear to experts that the sensor surface does not have to be square. It can be rectangular, round, or approximately round, for example, but it can also have any other shape.

Measurement of substances

Surprisingly, it was found that the measuring device described above enables the differentiated analysis of different substances. This includes, for example, the measurement of carotenoid concentrations in human tissue and blood, allowing a distinction to be made between the concentrations of lutein, zeaxanthin, ß-cryptoxanthin, α-carotene, ß-carotene, and lycopene. When measuring humans, it is important to measure carotenoids individually because, for example, the absorption of ß-carotene and lutein interfere with each other. Surprisingly, spectroscopic measurement revealed that the measuring device described here can be used to determine the individual metabolism of food.

In order to determine the physiologically determined individual metabolism from the concentration measurement of substances that are also contained in a food, additional information is required from the user. This is information that may influence the measured concentration level independently of metabolism or at least partially independently of metabolism. Examples include lifestyle or living habits such as smoking, alcohol consumption, sleep duration, current exposure to the sun, use of solariums, and the intensity, frequency, and duration of physical activity, e.g., through sports. The strength of their influence on the concentration determination can be determined, for example, by comparing the measurement results of users under the aforementioned aspects with each other in order to determine an average influence on the concentration determination with the help of artificial intelligence. In order to determine individual metabolism, this average influence is taken into account when measuring the concentration of a substance.

The measurements are repeated at specific intervals. In a preferred variant, the measurements take place at intervals of up to 24 hours. In further preferred variants, the intervals are up to 36 hours, up to 2 days, up to 4 days, up to 1 week, up to 2 weeks, and up to more than 2 weeks. In a preferred variant, up to 10 measurements are taken at the aforementioned intervals. In other preferred variants, up to 20 measurements, up to 30 measurements, and up to more than 30 measurements are taken at the intervals specified between measurements. During the measurement period, the user can, for example, enter the types and quantities of fruits and vegetables he/she consumes each day into an application, which stores this information in a database, e.g., on an external server.

In a preferred solution, the user can provide additional information. For example, whether he/she ate the food cooked or raw, or whether he/she consumed it with or without oil. This data is used to calculate how much of a particular substance, e.g., a particular carotenoid, the user has consumed. The amount of a substance consumed is compared with the measured concentrations, taking into account the average influence of the above-mentioned lifestyle factors. This comparison is carried out at all measurement times.

In a preferred solution, the comparison also takes into account whether substances that inhibit the absorption of another substance were consumed at the same time. By comparing measurement results from different measurement times, it is possible to determine whether there is an individual saturation curve for the absorption of certain substances and what gradient exists between the absorption of a substance and the measured concentration in tissue and blood. The result is the individual metabolism of substances in food.

In a preferred solution, in conjunction with individual metabolism, a comparison is made between the concentration levels of two or more substances if their ratio is relevant to health. An example of this is the desired ratio of omega-3 fatty acids to omega-6 fatty acids, the effect of foods in terms of their glycemic load, or, in general, the reduction of health risks when certain food components are present in sufficient quantities in the body.

The results of the concentration determination of the various substances, e.g., carotenoids, whether as a result of joint measurement or individual measurements of the various substances, are stored, in a preferred variant, on the measuring device and/or transmitted via the Internet to an external server, stored, and calculated with each other in such a way that, for example, the user can also see an individual degree of mutual interference in their absorption or metabolism of carotenoids. Two substances, e.g., two carotenoids, but also more than two substances, may be involved in the mutual inhibition of metabolism. In their mutual influence, they can significantly affect the absorption or metabolism of certain other substances. This functional relationship

applies not only to carotenoids, but also to other substances in the diet. The individual degree of interference is determined, for example, by first comparing the measured concentrations with health recommendations for the concentration in the human body. If deficiencies or excessive concentrations are detected, the concentrations of the substances that interfere with each other's absorption and metabolism are first compared with each other to determine the individual degree of mutual interference. These could be carotenoids, for example.

In a preferred embodiment, this calculation formula is supplemented, for example, by the target health values for the substances under consideration. The result is, for example, a key figure for the balance of the individual carotenoid diet.

It is clear to the skilled person that this also applies analogously to other substances in the diet that interfere with each other's metabolism. With the help of this key figure, individuals can be compared with each other despite taking into account their individual metabolism. In a preferred embodiment, this comparison is displayed to the user on his/her mobile device, which receives the measurement results from the server, for example in the form of a graph. This information helps him/her to assess where he/she stands in comparison with a reference group. It is generally known that such comparisons motivate people to make behavioral changes that minimize their risks of disease.

A change in the composition of the fruits and vegetables consumed may be sufficient, due to individual metabolism, to improve the ratio of mutually inhibiting substances, e.g., two carotenoids, without having to change the total amount of fruits and vegetables consumed.

In a preferred variant, the user of the measuring device can, for example, be informed of the types of fruits and vegetables he/she should consume as alternatives in order to achieve a better ratio of concentrations, for example of carotenoids, while consuming the same amount. The different information that can be provided to the user of the measuring device via the measurement result message and how this can be done is discussed in more detail below.

In another preferred variant, the user can be suggested, for example, a time separation for the intake of substances that interfere with each other. For example, recipes containing vegetables or fruits with high concentrations of a particular carotenoid (e.g., carrots/beta carotene or tomatoes/lycopene) may be suggested for lunch, while recipes containing only low concentrations of this carotenoid but high concentrations of the other carotenoid may be suggested for dinner. In another preferred variant, the time interval can be extended to more than 12 hours. In further variants, it can be extended to up to 24 hours, up to 36 hours, or up to 48 hours.

With regard to the different health effects of certain substances, e.g., carotenoids, individuals have different preferences when it comes to compensating for deficiencies by consuming appropriate foods. For example, test subjects may want to increase the concentration of a certain substance because it influences the development of a certain disease, regardless of whether this leads to a reduced intake of other substances. This applies, for example, to macular degeneration, where sufficient lutein and zeaxanthin must be consumed in order to adequately counteract the symptoms.

In a preferred embodiment, based on the indicator for the balance of the individual carotenoid diet, the user is recommended certain types of fruits and vegetables and certain consumption quantities in order to increase the intake of these carotenoids against the background of individual metabolism and the individual degree of disorder. Possible influences on the reduced intake or metabolism of other substances are then not taken into account.

In a preferred variant, the multidimensional algorithms required to select the types of fruits and vegetables and the quantities to be consumed use certain forms of artificial intelligence (AI) to provide the user with appropriate suggestions.

In a preferred variant, the determination of the individual degree of disorder is repeated after at least 2 days. In further preferred variants, the repetition takes place after at least 4 days, after at least 1 week, after at least 2 weeks, after at least 4 weeks, or after more than 4 weeks. In a preferred embodiment, the user is prompted to repeat the measurement several times at the intervals mentioned above. The dynamics of the change are determined and displayed on the measuring device or on a device that can be connected to the measuring device. In a preferred variant, a prognosis of the development of the degree of disability is made on the basis of this data.

Surprisingly, it has been found that measuring the water content in the skin or tissue can be used to determine when a person needs to drink in order to, for example, enable optimal cognitive performance, prevent negative effects on other bodily functions (e.g., bowel movements) and/or organs (e.g., kidneys), and check the effectiveness of moisturizers for skin tightening. Surprisingly, it was found that the body fat percentage can be measured using the measuring device described above. The measurement can be taken at different parts of the body. However, in a preferred embodiment, the measurement is taken on the inside of the hand in the area of the palm. This measurement makes it possible, for example, to detect the effects of diets at a very early stage. This is a great advantage for the user, as it allows him/her to check the quality of a diet before any weight loss is visible on the scales. If the diet is successful, this increases the motivation to continue, while if it is not, the diet does not need to be continued. Based on the

measurement results, users can also be supported in preparing their meals, for example. This is discussed in more detail elsewhere in this document.

This allows the following statement to be made during measurement, for example: The measured fat percentage corresponds to an average person with a BMI of X.

The body mass index (BMI) is a measure used to classify a person's body weight in relation to his/her height. It allows you to classify your own body weight into the following categories: underweighted, of normal weight, overweighted, extremely overweighted (obese), and severely obese. One disadvantage of BMI is that it does not distinguish between fat and muscle mass.

Surprisingly, it was found that the measuring device described here can be used to take measurements on the palm of the hand, which can be used to calculate BMI values that do not take muscle mass into account. This makes it possible for the first time to determine BMI in a way that is relevant for weight management, as people who are on a diet, for example, want to lose fat and not muscle mass. In a preferred embodiment, this new BMI determination is called "BMI 2.0."

Surprisingly, it has been found that glucose measurement can be used to detect and even predict the development of inflammation in the body. In a preferred solution, for example, the rise and fall of glucose levels are determined over a certain period of time by measurements before and after meals in order to record the maximum and minimum glucose levels.

In a preferred embodiment, the measurement period during which the rise and fall of the values before and after meals is tracked is, for example, one day. In a further preferred embodiment, this period is, for example, two days. In a more preferred embodiment, the period is, for example, three days. In an even more preferred embodiment, the period is, for example, one week, and in the most preferred embodiment, the period is, for example, two weeks, in order to determine the average rise and fall of the glucose values of the person being measured. This individual average value is compared, for example, with a statistical average value of the population. Age, gender, and number of meals can be taken into account. The deviation of the individual value from the standard value is assigned to individual risk classes for the occurrence of inflammation, for example. For each risk class, measures are determined to reduce the maximum fluctuations in glucose levels. These include, for example, suggestions for the components of food intake, e.g. based on the glycemic index or the number and timing of meals per day. The number and timing of previous meals can be determined from the timestamp of the glucose measurement. The implementation of the suggestions by the person taking the measurements is checked, for example, using subsequent glucose measurements. The differences

in glucose values found in this way can lead, for example, to a reassignment to a lower risk class. In this way, the risk is gradually reduced.

Surprisingly, it was found that, for example, when glucose and C-reactive protein are measured simultaneously, the assignment to risk classes can be more accurate.

Surprisingly, it was found that, for example, when glucose and C-reactive protein and cortisol are measured simultaneously, the assignment to risk classes can be even more accurate.

Surprisingly, it was found that, for example, when glucose and C-reactive protein and cortisol are measured simultaneously, it is also possible to predict the development of future inflammation. To do this, the values measured in the past are analyzed together with the time span of their change using artificial intelligence methods. The result is a predicted value for the development and severity of inflammation for a specific period in the future.

Surprisingly, it was found that the accuracy of the prognosis improves when, for example, alpha-linolenic acid is measured at the same time.

For successful nutrition and weight management, it is advisable to monitor blood sugar levels, among other things. Body fat is not broken down, or only partially broken down, if there is sufficient energy in the form of glucose in the blood. Since glucose and insulin rise to similar levels after a meal and insulin blocks lipolysis, fat is not burned or metabolized. As a result, the fat consumed with the meal is at least partially stored in the fat cells. This leads to weight gain and the expansion of existing fat cells.

If there is little glucose in the blood, either because insulin has previously transported the glucose to the body's cells for energy or because calorie intake has been stopped, the body first breaks down its glycogen reserves. Glycogen is a form of carbohydrate that is stored in the muscles and liver (approx. 300 - 400 g). When energy is obtained from glycogen, water is released and flushed out of the body. Although this leads to a measurable weight loss on the scales, it has nothing to do with successful weight management and the reduction of excess pounds. Despite exercise, emptying the glycogen stores reduces the breakdown of fat reserves in the body. Weight loss through fat burning is reduced accordingly.

Surprisingly, it has now been found that, for example, when blood sugar, water, and fat levels are measured simultaneously, an individual corridor can be determined, within which a decrease in body weight (net weight loss) occurs without the weight reduction later visible on the scale being distorted by water loss. This is of great importance to users, as they have not previously been able to distinguish between water loss and actual weight loss.

At the same time, it was surprisingly found that the corridor also determines the point in time at which it is most effective to start burning fat through exercise. This means that the user is

informed when to start a sporting activity in order to achieve the greatest reduction in body fat through exercise.

The individual corridor is determined, for example, by specific mathematical calculations of blood sugar, water, and fat values. (Note: name calculation methods) Within the corridor, further mathematical methods, e.g. based on AI, can be used to identify areas where, for example, net weight loss varies. The individual areas can be identified using special key figures that describe the relationship between the individual measured values.

Surprisingly, it has been found that measuring the three parameters and calculating them mathematically makes also possible, for example, to predict the achievement of the weight loss that will actually occur later. The prediction becomes particularly accurate when, in addition to the three parameters, the length of time spent in the corridor is determined, because the longer the body remains in this individual corridor, the greater the net weight loss. The determination of future net weight loss becomes even more accurate if, for example, the length of time spent in the different weight loss ranges is determined and included in the calculation.

Since fat levels change more slowly than blood sugar and water levels, it was surprisingly found that the ratio of fat to blood sugar and water levels can be used to retrospectively calculate the period of time during which the body has been in the individual corridor for weight loss. Preferably, the retrospective calculation of the period is carried out, for example, by including a measurement that was previously taken within the corridor.

The possibility of retrospective calculation is new compared to the state of the art and represents a significant customer benefit, as it is obviously not necessary to continuously determine the three measurement parameters and the time spent in the corridor in order to predict future net weight loss. In a preferred variant, repeated measurements are performed at intervals of up to 3 hours. In further preferred variants, they are performed at intervals of up to 2 hours, at intervals of up to 1 hour, at intervals of up to 30 minutes, at intervals of up to 20 minutes, at intervals of up to 10 minutes, or at intervals of 1 minute. If this measurement interval is repeated on several days or over a longer period of time, the net weight loss can be extrapolated for different periods of time.

In a preferred variant, the net weight loss can be extrapolated, for example, for a period of up to 1, 2, 3, or 4 weeks, and, in further preferred variants, for a period of up to 2, 3, 4, 5, 6 months, in further preferred variants for a period of 7, 8, 9, 10, 11 months, and in equally preferred variants for a period of up to 1, 2, 3, and more years. Compared to the state of the art, this offers a considerable benefit to the customer, as the physiological conditions make weight loss quantifiable before it becomes visible on the scales. This is an objective weight loss that does not

depend, for example, on the measuring accuracy of the scales or the resolution of the measurement result on the scales.

This is a considerable advantage, as the customer no longer needs an expensive bathroom scale that can display weight differences in the gram range with a very low measurement error in order to notice motivating weight loss at an early stage.

It is also possible to measure blood sugar, water, and fat at different times to determine the corridor. However, it has been found that this method results in a less accurate corridor. It is well known that blood sugar levels rise and fall in the first two hours after a meal. Scientific studies show (Postprandial glycaemic dips predict appetite and energy intake in healthy individuals. in: Nat Metab. 2021 April 01; 3(4): 523–529. doi:10.1038/s42255-021-00383-x), that some individuals experience a sharp drop in blood sugar levels 2-4 hours after a peak in sugar levels before the level rises again. People affected by this experience stronger feelings of hunger and consume an average of 300 calories more per day than people whose blood sugar levels do not drop as sharply. This behavior can lead to weight gain of 10 kg within a year.

For sustainable weight management, it is therefore helpful to inform individuals whether they belong to the group with sharply falling sugar levels, and, therefore, consume more calories than others. A special measurement procedure and a visualization of blood sugar levels are required to identify this group of individuals.

A preferred method for identifying individuals with rapidly falling sugar levels is as follows: before performing a glucose measurement, users can specify the time that has elapsed since their last meal on the user interface of the measurement application. In a preferred embodiment, this can be done, for example, via a selection menu or by manually entering the time period. In addition, in another preferred variant, it is possible to document the components of the previous meal, for example by entering them, selecting them, or taking a digital photograph.

In a preferred version, the measurement application controls the measurement using the measuring device described above. It can be located on a mobile device (e.g., smartphone, tablet), which uses the application to retrieve the data from the measuring device and forward it to a central server for calculation and/or data storage. The data transfer can take place via the Internet, to which the mobile device can connect automatically (e.g., by dialing into an existing Wi-Fi network or sending data via G4, G5, etc.). The measurement data of all users stored on the server is analyzed for sugar values that drop over time. AI is used to define risk levels for users with rapidly falling blood sugar levels. Each user is assigned one of these levels. Since the assignment to a level also depends on the number of blood sugar measurements stored for the user, the assignment may change over time. At the same time, the probability of a correct

assignment increases with more measurements. The user is therefore shown the probability of a correct assignment, for example in graphical form or as a numerical value. If the user has stored information about the components of his/her meal or digital photos of his/her meals in the application, the components of a meal or the photographed meals that contributed most to the assignment to a risk level are also displayed when assigning a risk level. In a preferred embodiment, the measuring device described here can be used to measure alpha-linolenic acid (omega 3), arachidonic acid (omega 6), and linoleic acid (omega 6). In a further preferred embodiment, the acids are detected simultaneously within a measurement, which may consist of several measurement sequences.

In an additional preferred embodiment, the respective acid concentration is measured at different depths of the skin down to the blood. In a preferred embodiment, the different depth concentrations for the individual acids are determined simultaneously during a measurement, which may have several measurement sequences.

For further analysis, the measurement results for the different depths can be analyzed separately or, for example, calculated in relation to each other. For example, the concentration in the blood can be used to predict the future concentration in fatty tissue. In another preferred embodiment, the ratio of omega-3 to omega-6 fatty acids is determined. Surprisingly, it was found that, for example, the future concentration of the acid can be calculated when alpha-linolenic acid (omega-3) and carotenoids are measured simultaneously.

Surprisingly, it was also found that when alpha-linolenic acid (omega-3), carotenoids, and linoleic acid (omega-6 fatty acid) and/or, as an alternative to linoleic acid, arachidonic acid (omega-6 fatty acid) are measured simultaneously, the future concentration of the various acids can be calculated. Acids and carotenoids are also referred to below as calculation components. Previous measurement results can be used to calculate the prognosis. For the prognosis, the results of the aforementioned calculation components and the time at which they were measured can be compared and analyzed using mathematical methods. These mathematical methods also include artificial intelligence methods.

In a preferred embodiment, the interval between the times of the previous measurements at which the concentration of the calculation components was measured simultaneously within a measurement is, for example, up to 12 hours. In a further preferred embodiment, the interval is up to 24 hours, in a slightly more preferred embodiment, the interval is up to 2 days, in an even more preferred embodiment, the interval is up to 4 days, in a somewhat preferred embodiment, the interval is up to 8 days, in a somewhat more preferred embodiment, the interval is up to 8 days, in a significantly more preferred embodiment, the interval is up to 2 weeks, in a somewhat

more significantly preferred embodiment, the interval is up to 4 weeks, and in the most preferred embodiment, the interval is up to 2 months.

In a preferred embodiment, the time intervals between the simultaneous measurements of the calculation components used for the forecast are equal. In a more preferred embodiment, the time intervals between the simultaneous measurements of the calculation components differ.

In a preferred embodiment, the differences in the time intervals between the simultaneous measurements of the calculation components are up to 2 hours. In a more preferred embodiment, the differences in the time intervals are up to 12 hours, in an equally more preferred embodiment, the differences in the time intervals are up to 1 day, in an even more preferred embodiment, the differences in the time intervals are up to 4 days, in an equally even more preferred embodiment, the differences in the time intervals are up to 4 days, in a much more preferred embodiment, the differences in the time intervals are up to 1 week, in an equally much more preferred embodiment, the differences in the time intervals are up to 2 weeks, and in a most preferred embodiment, the differences in the time intervals are up to 4 weeks.

In a preferred embodiment, three measurements of the calculation components are taken simultaneously to calculate the future concentration of the acids. In another preferred embodiment, up to 6 of these measurements of the calculation components are used, in a more preferred embodiment, up to 8 of these measurements of the calculation components are used, in an even more preferred embodiment, up to 10 of these measurements of the calculation components are used, and in a most preferred embodiment, up to 20 of these measurements of the calculation components are used. Surprisingly, it was found that the calculation of the future concentration of alpha-linolenic acid, arachidonic acid, and linoleic acid is also possible if, in contrast to the embodiments above, for example, the concentration of the four calculation components (carotenoids, alpha-linolenic acid, arachidonic acid, and linoleic acid) is <u>not</u> determined simultaneously in a measurement that may have different measurement sequences.

In a preferred embodiment, carotenoids, alpha-linolenic acid, arachidonic acid, and linoleic acid can also be measured separately one after the other in order to calculate the future concentration of one of the acids from the four concentration values. The time intervals between the measurements carried out separately one after the other can be up to 10 days, for example.

In a preferred embodiment, the interval between the individual measurements of the calculation components is up to 5 days, in a somewhat more preferred embodiment, the interval between the individual measurements of the calculation components is up to one day, in a more preferred embodiment, the interval between the individual measurements of the calculation components is up to 12 hours, in an even more preferred embodiment, the interval between the individual

measurements of the calculation components is up to 1 hour, in an even more preferred embodiment, the interval between the individual measurements of the calculation components is up to 10 minutes, and in a most preferred embodiment, the interval between the individual measurements of the calculation components is up to 1 minute. In a preferred embodiment, the time intervals between successive, separately performed measurements of carotenoids, alpha-linolenic acid, arachidonic acid, and linoleic acid are approximately equal.

In a somewhat more preferred embodiment, the time difference between successive, separately performed measurements of the calculation components is up to 5 days. In a somewhat more preferred embodiment, the time difference between successive measurements of the calculation components is up to 1 day. In a somewhat more preferred embodiment, the time difference between successive measurements of the calculation components is up to 12 hours. In an even more preferred embodiment, the time difference between successive measurements of the calculation components is up to 6 hours. In a most preferred embodiment, the time difference between successive measurements of the calculation components is up to 1 hour. In the most preferred embodiment, the time difference between successive measurements of the calculation components is up to 10 minutes.

In a preferred embodiment, when the calculation components are measured separately to calculate the future concentration of alpha-linolenic acid, arachidonic acid, and linoleic acid, three separate measurements of the calculation components are used. In another preferred embodiment, up to six separate measurements of the calculation components are used. in a more preferred embodiment, up to 8 separate measurements of the calculation components are used, in an even more preferred embodiment, up to 10 separate measurements of the calculation components are used, and in the most preferred embodiment, up to 20 separate measurements of the calculation components are used.

Surprisingly, it was found that when using the calculation components, the prediction of future concentration values of carotenoids, alpha-linolenic acid, arachidonic acid, and linoleic acid is more accurate than when, for example, only the concentration value of the respective acid alone is included in the calculation.

Measurement of C-reactive protein and cortisol

Using a version of the sensor described here, it is possible to measure C-reactive protein in the human body. Using another version of the sensor, it is possible to measure cortisol in the human body.

Measurement of carotenoids

With the help of the sensor described here, it is possible to measure the concentration of carotenoids in the human body. This has already been claimed in patent ..... for the MSRRS method. If the MSRRS method is used in conjunction with the properties of the measuring device described here, the concentration of the various carotenoids can be determined more accurately than with the MSRRS method alone. Surprisingly, it has now been found that the measurement error between the determined and actual concentration of carotenoids is reduced when, for example, the carotenoid concentration is calculated taking into account the optical measurements of C-reactive protein and/or cortisol.

Surprisingly, it was also found that the repeatability of the carotenoid measurement improves when, for example, the concentration calculation of the carotenoid measurement is performed taking into account the optical data of C-reactive protein and/or cortisol. Surprisingly, it was also found that when dietary and behavioral changes are made to improve carotenoid levels, the increase in carotenoid concentration is detectable earlier if, for example, C-reactive protein and/or cortisol are measured at the same time and taken into account in the carotenoid concentration calculation.

Surprisingly, it was also found that the deviation between the predicted carotenoid concentration and the carotenoid concentrations actually measured later is smaller if, for example, the measurement results of the C-reactive protein and/or cortisol measured at the same time are taken into account when determining the trend.

With regard to the number of measurements required for trend calculation, the time intervals between the individual measurement times, the time differences between the measurements, and the conditions described for calculating the future concentration of fatty acids apply analogously.

Surprisingly, it was found that spectroscopic measurement of the aforementioned substances is also possible using the transmitted light method. In contrast to reflection spectroscopy, in this method, the emitters and detectors are not located on a common plane, so that measurement is only possible at certain points on the body (e.g., fingertips, earlobes). However, the measurement results show that the measurement accuracy is much lower.

Initialization – Creating a user profile in the application

As described above in various places, the measuring device disclosed here and the methods for performing the measurement enable the determination of physiological states of an individual or the accurate measurement of the concentration of substances in the human body. In order to fully fulfill the measuring device's task of serving the user's health and well-being, additional

important information is provided to the user based on the measurement results, or communication with relevant persons or institutions is enabled. Surprisingly, it has been found that this can improve well-being in the long term. In a preferred variant, the user can specify which additional information he/she wishes to receive and in what context. The additional information and communication provided on the basis of the measurement, e.g., via a special application with which the measuring device communicates, concerns, for example, the following:

- History of measurement results for individual or multiple measurement parameters, e.g., in the form of a list of the corresponding individual measurement values with time stamps or as a graphical representation of the trends over time.
- Display of health limits for the concentration of individual measurement parameters or combinations of measurement parameters, evaluation of preferences that the user can set for certain measurement parameters.
- Determination and display of the compliance value resulting from the preferences when the user selects or consumes individual foods or complete meals.
- Presentation of trend statements for the development of individual measured values or the combination of several measured values.
- Comparison of the measurement results obtained with, for example, mean values or medians of reference groups (subdivided, for example, by age and/or gender and/or school education and/or occupation) at regional level (e.g., user's hometown or state), national level (user's country), international level (e.g., continent, worldwide). Summary of all results in weekly, monthly, or annual reports.
- Option to forward results, e.g., automatically or after confirmation by the user, to user groups in social networks, to followers in social networks, to individuals, e.g., family doctor, friends, family members, to national or international institutions, e.g., hospital, statistics offices, Ministry of Health, WHO.
- Option for the user to send explanatory voice messages together with the measurement results to selected persons or institutions via the measuring device application.
- Access to certain databases, e.g. with the help of search algorithms provided, which contain health-related information, e.g. prescriptions, scientific publications, experience reports from affected persons, by digitally entering search queries or verbally expressing queries.

- Option for the user to receive reminders at freely definable intervals, e.g., a reminder email or WhatsApp message, if, for example, a new measurement is advisable based on existing measurement results.
- Information about the availability of experts in the user's vicinity, for example on health and nutrition-related issues or on legal issues that may arise, for example, from nutrition or the purchase of food or visits to restaurants.
- Information about institutions in the field of nutrition, e.g., health authorities, ministries, consumer advice centers, including possible contact persons.
- Automatic appointment scheduling, e.g., with doctors, nutritionists, health experts, if measurement results exceed certain limits.
- Automated provision of up-to-date information about opening hours and unavailability due to vacation or illness of, for example, doctors, health and nutrition experts, or experts on legal issues that may arise from nutrition, food procurement, or restaurant visits
- Automated reminders to perform and adhere to sports activities, relaxation exercises, or rest periods based on the evaluation of measurement results.
- Option for the user to inform the system consisting of the measuring device and application, of any allergies, intolerances, preferences, e.g. with regard to certain foods, dietary styles, e.g. vegan, vegetarian, or flexitarian.
- Provision of personalized advice on how to improve measurement results, taking into account, for example, the user's preferences, likes, dietary habits, measurement history, and regional and seasonal availability of food.
- Provision of information on food shopping options, e.g., grocery stores, weekly markets, farm shops in the user's vicinity, taking into account, for example, quality (e.g., organic products), cost, distance, accessibility, and opening hours.
- Provision of information about restaurants, fast food restaurants, snack bars, food delivery chains.
- Automated ordering of food, e.g., for recipes that the user selects for his/her meals and which are delivered to his/her home.
- Automated monitoring of the user's food supplies based on the food consumed.
- Provision of information about special offers on food from stores in the user's vicinity.

Additional information about the user is required to calculate certain values, generate individual advice on how to improve measurement results, or provide additional information. This includes,

for example, age, gender, height, weight, occupation, location of the user, but also data regarding certain diseases that influence the measurement results or their interpretation, such as diabetes.

In a preferred variant, additional information also includes information previously required in connection with determining individual metabolism. This includes, for example, lifestyle or living habits such as smoking, alcohol consumption, sleep duration, current exposure to the sun, use of solariums, intensity, frequency, and duration of physical activity, e.g., through sports. The applicable data protection regulations are taken into account when using this information. In a preferred solution, the user can enter this information, if he/she wishes to do so, for example once when configuring the application that the measuring device uses to perform its tasks. This process can take place immediately after downloading the application for using the measuring device from the app store. In another preferred solution, this can also be done later. The user can change, add, or delete the necessary entries at any time. If a measuring device is used by several people, e.g., other family members, it must be possible to assign the measurement to a specific person. This can be done, for example, by creating user profiles that must be selected before each measurement. In addition to the name chosen by the user (alias), the personal information of the additional users described above is also stored in the user profile.

In general, the more frequently a person takes measurements, the more accurately his/her physiological conditions and changes can be recorded and the more targeted advices can be given, e.g., via the application. Therefore, the user can select in his/her user profile a function that prompts him/her to take a measurement.

This is particularly advantageous when analyzing whether a user belongs to the group of people with rapidly falling blood sugar levels, because the user is then prompted to take measurements at specific times and at a specific interval, which makes it more likely that rapidly falling values will be detected.

To select the time, the application can, for example, rely on the analysis of previous measurements as well as on times when the user typically eats meals. The user can also store typical meal times in his/her user profile, for example. If there are enough measurement results in an assigned database that allow the user to be assigned to the group with rapidly falling blood sugar levels or that rule out that he/she belongs to this group, he/she will no longer be prompted to take measurements for this application feature.

The request to take a measurement can be made directly via the application when it is open. If the application is not open on the smartphone, the message can be sent via the server, for example as a push message via SMS, email, or social networks. For a preferred option, measurement results and/or additional information provided must be appropriately visualized,

processed, and enriched with supporting information so that they can be used by the person taking the measurement without special knowledge, and implemented in everyday activities. This can be achieved, for example, by providing the aforementioned results and/or additional information in varying degrees of detail and allowing the user to select the level of detail as required.

In a particularly preferred variant, the user of the measuring device is also informed of the measured value of a specific substance, for example, certain carotenoids, or of how much fruits and vegetables would need to be consumed daily if the user were to change certain behaviors. This includes, for example, the average influences determined in connection with individual metabolism, such as smoking, alcohol consumption, sleep duration, exposure to the sun, etc.

Support for the user with regard to health-conscious nutrition

In a preferred variant, based on the measurements taken with the measuring device described here, the user is suggested, for example, foods for consumption that help to stabilize and/or increase or improve the concentrations of certain substances present in the blood and/or tissue and/or the measured physiological conditions of the user.

In a particularly preferred variant, the user is suggested the quantities of certain foods that still need to be consumed. Fig. 17 shows, for example, information on the amount of fruits and vegetables that the user should consume daily over the next 4 weeks. In a more preferred variant, the user is given detailed information regarding the quantities of individual types of fruits and vegetables that enable the target value, based on a preference selected by the user, to be achieved.

In another preferred variant, the user is suggested foods for consumption which the ingredients of can also be measured in human tissue or blood using the measuring device and of which the deficiency compared to target values is indicated by the application. These include, for example, omega-3 and omega-6 fatty acids or certain vitamins.

In another preferred variant, the suggested foods and quantities are based, for example, on the user's preferences regarding the time frame within which the concentrations and/or physiological states measured in the user should change. Here, the user can, for example, specify categories of rates of change in the measuring device's application. Main categories could be, for example, "rapid change" or "moderate change." In the case of a rapid change, the suggested amount of the detected substance to be consumed is higher than in the case of a moderate change. In another preferred variant, the suggestions for foods and the amount to be consumed are based on generally accepted and/or scientifically proven target levels in human blood or tissue and/or

amounts recommended by recognized institutions or, for example, the average concentrations measured with the measuring device in a comparison group relevant to the user or target values defined by the user himself/herself. In a preferred variant, there may also be several target amounts. These can be used, for example, if their levels are different and the user has not reached a sufficiently high target value.

In a preferred variant, the user determines which target values are used for comparison.

In another particularly preferred variant, the user is not only suggested individual foods, but also complete recipes for a day's food intake. In a preferred solution, the user can also be suggested several foods or several complete recipes, from which he/she can select the one he/she wants. In another preferred solution, for example, new recipes are always suggested to him/her until he/she decides on one.

In another particularly preferred variant, the quantities of the detected substances suggested for consumption in a day are distributed, for example, over three main meals: breakfast, lunch, and dinner. In a further preferred variant, the quantity is distributed over additional snacks that can be consumed, for example, after a meal or between meals (see Fig. 18). In another preferred variant, dishes offered in a restaurant located at a distance chosen by the user from his/her location can also be suggested.

In another preferred variant, the measured glucose concentration is used to determine which foods and quantities of a food are recommended for consumption. In another preferred variant, this may also relate to the time of day at which the food is to be consumed. In this way, for example, there can be resolved the conflict in which, on the one hand, deficiencies of certain substances in the individual's body must be compensated for, but on the other hand, the user wants to maintain his/her body weight at the existing level or reduce or increase his/her body weight by a defined amount within a certain period of time. The method of determining measured values described elsewhere in this patent application and any associated process steps can be used, for example, to reach a compromise.

All substances mentioned in this patent application which the concentrations of have been measured in the user's blood and tissue and which are stored accordingly in the user-specific database are taken into account when generating suggestions for individual foods, recipe suggestions for meals, or dishes offered in restaurants, provided that they are not produced exclusively by the human body itself. This means that all recipes will indicate the quantities of these substances they contain. In a preferred variant, the respective quantity of a substance can be determined, for example, by referring to information from the Internet or, for example, by targeted research in special databases, whereby AI (artificial intelligence) is used for the

necessary search algorithms or for formulating the search criteria. In a preferred variant, it is not the information itself that is made available, but rather the search algorithms or research strategies, so that the user can repeatedly determine the content of interest to him/her in order to keep the associated information up to date.

In another preferred variant, the respective quantity of a substance can be determined using a self-created database to which the measuring device's application has access and in which the results of previous Internet searches have been stored.

If it is not possible to compensate for measured deficits, e.g. due to physiological dependencies, by changing behavior or diet, the measures suggested to the user follow, in a preferred variant, a hierarchy of deficit compensation specified in the application. This hierarchy is based, for example, on the general medical knowledge that applies to most people. In another preferred variant, the hierarchy is based on the preferences specified by the user.

In a particularly preferred variant, the suggestions also include information on the costs of purchasing the food, the ingredients for the recipes, or the costs indicated for a dish on a restaurant menu. This also includes the costs incurred if the user has the necessary ingredients or restaurant meals delivered by a delivery service. In other equally preferred variants, the suggestions quantify the total effort required by the user to implement the suggestions. This includes, for example, the time required to purchase and prepare food or cook the recipes. First, the effort required for shopping at the stores or grocery stores suggested by the application or for visiting the restaurants suggested by the application is calculated. If the user chooses other stores or restaurants, this effort can also be calculated if the user enters the corresponding address. In addition, in another preferred variant is also quantified the ecological footprint, which results, for example, from the production of the food, its transport and storage at the point of sale, traveling to the point of sale or delivery by a delivery service, as well as the energy required to prepare the food and the possible disposal of food leftovers.

For all foods or all suggested recipes or dishes selected from restaurant menus, the quantities of various ingredients are determined using the method/procedure described above. This also includes those detected in the user's blood or tissue using the measuring device (e.g., carotenoids or fatty acids). Based on the amount of ingredients available from recipes or restaurant offerings, as well as, for example, the individual metabolism of a substance (as determined above), the contribution or degree of fulfilment of the recipes, dishes, or foods toward achieving the target values selected by the user is calculated. The achievement can be expressed as a percentage, for example. This parameter is communicated to the user so that he/she can make his/her selection accordingly or at least be informed of the relevant consequences when making his/her decision.

In a preferred variant, the user is provided with additional parameters that enable him/her to determine the contribution that a food, recipe, or dish offered by a restaurant makes to achieving the target values or to his/her well-being.

Nutritional quality indicator

A key figure is derived, for example, from the ratio of the amount of fruits and vegetables in a recipe or dish, e.g. in grams, to the amount of fruits and vegetables still required, which has been determined by measurement and must be consumed in order to achieve a specific target value. In Germany, for example, this target value may be the 650 g per day, specified by the German Nutrition Society (Deutsche Gesellschaft für Ernährung). Instead of a recipe or dish, the key figure can also refer to all selected recipes or meals of the day or another period of time, including selected or consumed snacks. In a preferred solution, the user can specify a preference for the speed at which the target value should be achieved. In a preferred variant, the user should consume the amount of fruits and vegetables still missing, as determined by the measuring device, in order to reach the target value of, for example, 650 g. This preference can be defined, for example, as a "moderate" improvement to achieve the target value of 650 g/day.

In another preferred variant, the user should consume twice as much fruits and vegetables per day as recommended by the measuring device. In a further preferred variant, however, this amount should not exceed 650 g/day. This preference can be defined as a "rapid improvement" to reach the target value of 650 g/day. In a preferred variant, the achievement of the measured requirement still to be consumed is displayed as a percentage (see Fig. 18). In another preferred variant, if the daily requirement still to be consumed is exceeded, the percentage value is set to 100%, for example, and the excess is displayed by means of additional stars or similar information. The number of stars then reflects the extent to which the selected recipe or all recipes for a day exceed the measured value. The more stars, the greater the excess of the measured value (see Fig. 18). In a further preferred variant, a percentage value of the excess can be displayed in the application instead of stars.

In another preferred variant, this key figure is called "nutritional quality."

In another preferred variant, the user can also be shown a history of the degree of fulfillment of the nutritional quality. In another preferred variant, the observation period is 30 days, whereby the amount of fruits and vegetables consumed or selected in recipes and the amount of fruits and vegetables that has been measured and still needs to be consumed in order to achieve the target value are displayed graphically, for example in a joint X-Y diagram. In a preferred variant, the

selected or consumed amount of fruits and vegetables is displayed, for example, as a bar chart and the measured value for the amount still to be consumed as a curve on the bar.
In another preferred variant, the higher-level target value, e.g., 650 g/day, is also specified in the nutrition quality history, against which the daily amount of fruits and vegetables still to be consumed was determined by measurement. In a preferred variant, the target value is also plotted as an area in the X-Y diagram.
In another preferred variant, the nutritional quality history also shows the start of the observation period, the current date, and the user's priority for how quickly the target should be achieved, e.g., moderate speed.
In another preferred variant, the nutrition quality history also contains a statistical statement on the central tendency of all individual daily results. For example, the diagram can show the average value for the achievement of the goals set by the user. In another preferred variant, this can also be expressed using colours, with green tones symbolizing that the user's goal has been achieved, yellow tones indicating that the goal has been narrowly missed, and red tones indicating that the goal has been significantly missed.

Weight management indicator

In a preferred variant, the application contains an additional key figure that informs the user whether the selected recipes or the food consumed correspond to his/her preferences for weight loss, weight gain, or maintaining his/her current body weight (within freely definable limits) (see Fig. 18).
In a preferred version, this key figure is referred to as "weight management."
In another preferred version, the user can also specify in the application how drastically or extensively he/she wants to change his/her current eating habits in order to achieve his/her preference for weight loss or weight gain. For example, he/she can select the category "moderate" in the application, which means that he/she should consume 250 kcal/day less than his/her average calorie requirement if he/she wants to lose weight, or 250 kcal/day more if he/she wants to gain weight. However, he/she can also select the "fast" category, for example, in which he/she should consume 500 kcal/day less or more than his/her calorie requirement. In another preferred option, users can specify the number of kcal with which they want to limit their daily calorie intake directly in the application.
To calculate the key figure, the application determines the energy value in kcal for all suggested recipes or restaurant offers that a user selects for a day and compares the total with the average calorie requirement of that user per day.

In a preferred variant, the average calorie requirement is determined using a recognized calculation method. The following calculation methods can be used, for example: Harris-Benedict method, Mifflin and St. Jeor method, method according to WHO and the Food Agricultural Organization of the United Nations

Since the calculation methods do not determine the exact same calorie requirement, the user can specify which calculation method should be used in a preferred variant. In another preferred variant, the application makes a suggestion that the user can accept or reject.

In another preferred option, all calculation methods are used, for example by using a measure of central tendency (e.g., mean, median) to determine the user's daily calorie requirement from all calculation results.

In another preferred variant, the consumption of kcal during the consumption and metabolism of food is also taken into account when determining calorie requirements. In another preferred variant, the key figure also expresses the degree of fulfilment of the preferences selected by the user in weight management, analogous to nutritional quality, by, for example, expressing as a percentage the comparison between the average calorie requirement and the actual calorie intake resulting from the suggested recipes or restaurant dishes. In another preferred variant, if the weight management goals are exceeded, analogous to nutritional quality, the degree of fulfilment is set to 100%, for example, and the excess fulfilment is displayed in the form of additional stars or comparable symbols. The number of stars then reflects the extent to which the selected recipe or all recipes or dishes of a day exceed the required weight loss or weight gain. The more stars, the greater the overachievement of the target set by the user (see Fig. 18). In a further preferred variant, a percentage value of the overachievement can be displayed in the application instead of stars.

In another preferred variant, the user is also shown a history of the degree of achievement of the weight management (see Fig. 19). In a preferred variant, this is done, for example, in the form of a bar chart in which the time, e.g., in days, is plotted on the X-axis and the kcal for the increase and decrease are plotted on the Y-axis.

In another preferred variant, the observation period is 30 days, with the bars for weight loss and weight gain being colour-coded, for example. In a preferred solution, the base of the bar chart is a zero line, with the bars for weight gain having a positive value and the bars for weight loss having a negative value. In an additional preferred solution, the area in the negative range is distinguished from the area in the positive range, e.g., by colour. In another preferred variant, the diagram also distinguishes between whether the targets for weight loss or weight gain have been achieved for each day, or whether weight loss or weight gain has occurred but the level of gain

or loss specified by the user has not been achieved. These differences can also be expressed in colour, for example.

In another preferred embodiment, the limits for the target values set by the user are indicated in the diagram. In a preferred embodiment, they are represented by a horizontal line that intersects the Y-axis at the respective target value.

In another preferred variant, the weight management history also shows, for example, the start of the observation period, the current date, and the user's priority for how quickly the target should be achieved, e.g., moderate speed. In a further preferred variant, a numerical value is entered as the target for weight gain or loss. In another preferred variant, the diagram also contains a statistical statement about the central trend of all individual daily results. For example, the diagram can show the average weight gain or loss over a period of time and how well the user has achieved the goals he/she did set himself/herself.

In another preferred variant, this can also be expressed using colours, with green tones symbolizing that the user's goal has been achieved, yellow tones indicating that the goal has been narrowly missed, and red tones indicating that the goal has been significantly missed.

Healthy Food Ratio

The energy (calories) consumed in food in the form of carbohydrates, fats, and proteins is used by the body to maintain bodily functions (breathing, heartbeat, brain activity, etc.). Energy is mainly produced by the supply of oxygen through the combustion of fatty acids and carbohydrates (aerobic metabolism). This produces free radicals. If these are present in excess, oxidative stress occurs, which is considered a contributing factor to a variety of diseases. Because the antioxidants contained in fruits and vegetables (vitamins, carotenoids, etc.) can neutralize free radicals, it is important to provide the body with adequate amounts of fruits and vegetables. Therefore, the ratio of fruits and vegetables to total calories reveals the long-term health effects of a diet. It is therefore an important criterion for evaluating selected dishes.

The key figure that reflects this ratio is defined in a preferred variant as the "Healthy Food Relation" (see Fig. 18). Based on all meals in a day for which recipes or restaurant dishes are suggested, it indicates how many calories (kcal) are contained in one gram of fruit + vegetables (grams/kcal).

In a preferred variant, the Healthy Food Relation achieves a percentage value of 100% if 1 kcal is attributable to 1 gram of fruits and vegetables.

The same applies to the Healthy Food Relation indicator as to nutritional quality and weight management in relation to exceeding targets: in a preferred variant, the indicator shows a value

of 100%, with additional stars indicating that the target has been exceeded. The more stars, the higher the degree of overachievement.

In a preferred variant, the user is also shown the history for the Healthy Food Relation in the application.

In another preferred version, the history is displayed as a bar chart, for example, with the time on the X-axis and the ratio of grams of fruits and vegetables to kcal of the recipes or restaurant meals selected for the day on the Y-axis.

In a preferred variant, the bars showing a gram/kcal ratio of <1 are colored differently from the bars showing a gram/kcal ratio of <= 1.

In another preferred variant, the bars indicating a ratio of <1 are, for example, blue, while the bars indicating a ratio of ≥ 1 are, for example, green.

In another preferred variant, the observation period of the history is 30 days.

In another preferred variant, during this observation period, the area of the diagram showing a gram/kcal ratio of < 1 is, for example, colour-coded to distinguish it from the area of the diagram showing a gram/kcal ratio of >= 1.

In another preferred variant, the area with a ratio of < 1 is colored red, for example, while the area with a ratio of >= 1 is colored blue.

In a further preferred embodiment, an average fulfilment of the Healthy Food Relation is calculated for the observation period and displayed in the application. The average fulfilment can, for example, be described in words and/or output as a numerical value.

In a particularly preferred variant, any other measure of central tendency can be used instead of the mean value to show the fulfilment of the Healthy Food Relation within a period of observation.

ORAC value

Another key figure that can be used to evaluate suggested foods, recipes, or dishes offered in restaurants is the ORAC value. ORAC stands for "Oxygen Radical Absorbance Capacity," which is the ability to scavenge oxygen radicals. The value indicates how many free radicals can be neutralized per gram of juice or fruit, thus describing a chemical property of the food measured.

In a preferred variant, the ORAC value is determined for the foods, recipes, or meals offered in restaurants that the application recommends for consumption on a given day.

In a preferred variant, this value is not displayed together with all other key figures in a common overview in the application, but is only made available to interested users as additional

information, as the significance of ORAC values for human nutrition is controversial. In a further preferred variant, this also applies to the history of ORAC values.

In another preferred variant, the ORAC value is displayed together with all other key figures in a joint overview in the application. In another preferred variant, this also applies to the history of the ORAC values. In another preferred variant, the recommended intake for users is assumed to be 7,000 µmol TE per day. In a further preferred variant, the recommended intake for users is assumed to be 5,000 µmol TE per day. In a preferred variant, the observation period for the displayed history is 30 days. In another preferred variant, the history is displayed as a bar chart, for example.

In a preferred variant, the time is plotted on the X-axis and the ORAC value on the Y-axis, with the bars indicating a value of ≤ 7000 µol TE per day being colored differently from the bars indicating a value of < 7000 µol TE per day.

In a preferred variant, the bars indicating a value of ≤ 7000 µol TE per day have, for example, a bluish tone, while the bars indicating a value of > 7000 µol TE per day have, for example, a reddish tone. In another preferred variant, the target value of 7000 µol TE per day is indicated in the bar chart as a horizontal line.

In a preferred variant, the area in the observation period with a value of < 7,000 µol TE per day is distinguished in colour from the area with a value of ≥ 7,000 µol TE per day.

In a preferred variant, the area with a value < 7,000 µol TE per day is colored blue, for example, while the area with a value ≥ 7,000 µol TE per day is colored white, for example.

In a further preferred embodiment, an average fulfilment of the ORAC value per day is calculated for the observation period and displayed in the application. The average fulfilment can, for example, be described in words and/or output as a numerical value.

In a particularly preferred variant, any other measure of central tendency can be used instead of the mean value to show the fulfilment of the ORAC value per day within an observation period.

User interface for selecting and evaluating application suggestions

Figure 18 shows a user interface of an application that communicates with the measuring device and presents the user with recipe suggestions for main meals, breakfast, and a snack for one day on a technical system with a screen. The technical system can be, for example, a smartphone, a tablet, or a computer screen.

In an advantageous variant, new suggestions are presented automatically at intervals determined by the user. This individualization of the presentation rhythm allows the user to consider the

suggestions at his/her own pace. In an advantageous embodiment, new suggestions can be presented, for example, by briefly clicking on the screen interface.

In an advantageous embodiment, the recipes or dishes of a restaurant are described in writing and additionally explained by one or more images, for example.

In an advantageous embodiment, the complete recipe can be displayed on the screen and/or printed out via a connected printer. In an advantageous variant, the application allows, for example, the display/printout of the individual ingredients of the recipe and the quantity of each ingredient for a freely selectable number of persons, the type and duration of preparation of the dish, how long uneaten portions of the dish can be stored refrigerated, a shopping list, the possibility of adding to the ingredient list, the option of ordering the ingredients from a store or delivery service and having them delivered, of individually rating the respective dishes after consumption, of adding the dishes to a favorites list, of prioritizing the dishes on the favorites list according to specific criteria, and of repeating the automatic presentation after a freely selectable period of time.

In a beneficial version, without having to view the ingredients in detail, the user is informed for each suggested recipe/dish, for example, whether it is a vegetarian or vegan option, of the quantities (e.g., in grams) of vegetables, fruit, fish, meat, of how much time is needed for preparation, of the calorie content (e.g., in kcal) and of the ORAC value of the recipe/dish, and whether consuming all of the dishes suggested for that day will affect his/her body weight (see Fig. 18).

In a useful feature, the user can decide whether he/she wants to receive suggestions for breakfast, main meals, and snacks. He/she can do this by selecting individual categories or all categories on the screen, for example by ticking a box. In Fig. 18, for example, there is no tick next to the snack category, so no recipes or meals have been suggested for this category. In a useful variation, the user can tell the application for which categories he/she does not want to see any further suggestions, e.g. by entering the recipe number of a suggested recipe on the screen. Fig. 18 shows an example where recipe numbers are listed in the "Selection" column so that no new suggestions are made for the breakfast and main course categories. The "Daily balance" line shows how many grams of vegetables, fruit, fish, or meat the dishes for that day contain. This line also shows the ORAC value of all dishes in µol TE and that the user is consuming 759 kcal less than his/her daily requirement with this selection. This means that he/she will lose weight with this selection.

In a preferred variant, there may be a second area below the recipe suggestions that displays the rating of these suggestions.

In another preferred variant, the suggestions are rated as previously described in detail in this patent specification, e.g., taking into account the measurement results of the user, the preferences selected by the user, and the determined individual metabolism of ingredients contained in the ingredients of the recipes/dishes.

In Fig. 18, the individual key figures for weight management, nutritional quality, and healthy food ratio reflect this evaluation. With regard to the combined, synergistic effect of all key figures, the "Overall fulfilment level" in this example shows the overall result for the user as 87.7%. In a preferred variant, the field in which the result is displayed numerically can be colored so that the colour indicates the meaning of the numerical value. In a preferred variant, for example, the traffic light colours red, green, and yellow are used for characterization, with green colours indicating a positive assessment result, red colours indicating a negative assessment result, and yellow colours indicating a critical but not yet negative assessment result.

In another preferred variant, lighter or darker shades of green, red, and yellow indicate gradations within the evaluation results. For example, a dark shade of green can stand for a particularly positive evaluation result, a light shade of green for a moderately positive result, and a very light shade of green for a result that is just positive. In a further preferred variant, the user can save the current selection of recipes.

In an equally preferred variant, this can be done in the user interface by pressing a button. In Fig. 18, this is the "Save daily balance" button.

The user can then request recipe/meal suggestions for another day. In a preferred variant, the user must press another button to do this. In Fig. 18, this is the "Restart monitoring" button. In a preferred variant, the application alerts the user that when selecting dishes for a future day, the currently available measurement results will be used to evaluate the recipes/dishes. This means that the evaluation result may be different if the measurement results change before the day on which the user cooks the recipes and eats the dishes. In a preferred variant, the user can set his/her daily meals for a period of up to one week. In other preferred variants, this can be for a period of up to two weeks, up to three weeks, or up to four weeks.

In another preferred variant, the evaluation results for several days or weeks are displayed in an overview graphic or table, for example.

In another preferred variant, the results of each new measurement are automatically applied to all daily selections of recipes/dishes that are after the measurement time. This ensures that the evaluation results contained in the overview graphic always correspond to the user's current status.

In a particularly preferred variant, any changes in the evaluation results are marked accordingly so that, for example, the user can reselect the recipes/dishes for specific days contained in the overview graphic.

In a further preferred variant, the user can decide whether the evaluation results should be updated on the basis of new measured values.

This invention is considered as an optimization of the invention already known in patents EP 3013217; EP 3175783; US 10,416,079; US 11,08,5876 and applications US 17/396,556, EP 4005469A1. All aspects presented in this invention can therefore be combined with the embodiments mentioned in this invention. The disclosure of this invention is to be regarded as part of this disclosure.

In an advantageous embodiment of the invention, the sensor is integrated into an object that is regularly used by the user in everyday life. In an advantageous embodiment, this object has at least one further function.

Integration into electronic devices is particularly advantageous. It is particularly advantageous in devices with a display or communication capability with devices with a display.

Particularly suitable devices are smartphones, smartwatches, computers, computer peripherals, or accessories for the aforementioned devices. Integration into devices that already contain optical emitters or optical detectors is particularly advantageous. In an advantageous variant, the emitters used in the device for other applications can also be used for the sensor functionality according to the invention. In an advantageous variant, the detectors used in the device for other applications can also be used for the sensor functionality according to the invention.

Integration into devices with an integrated camera is particularly advantageous.

Integration into devices that have multiple cameras is particularly advantageous.

Fig. 25 shows a smartphone without a sensor arrangement

Fig. 26 shows a smartphone with a sensor arrangement

Fig. 27 shows a smartphone with a sensor arrangement and a scale for describing the arrangement

Fig. 25 shows the rear of a smartphone (1001) with a camera arrangement (1002). The example of smartphone is equipped with four cameras (1003, 1004, 1005 and 1006). Arrangements with other numbers of cameras or a different arrangement of the cameras are also possible. Smartphones with such or similar camera arrangements on the rear pertain to the present state of the art. Fig. 26 shows a smartphone with a sensor arrangement according to the invention. The smartphone has also the elements shown in Fig. 25, which are not shown in Fig. 26 and Fig. 27 for the sake of clarity. The sensor arrangement (1007) shown as an example consists of the

cameras (1003, 1004, 1005 and 1006), which are used as light detectors. The arrangement also contains one or more additional light detectors. An additional light detector is shown as a white circle in the arrangement example. The arrangement example contains a large number of light emitters. These are shown as white rectangles.

The emitters and light detectors are designed, for example, as shown in one of the other figures. Fig. 27 shows the arrangement from Fig. 26. The elements designated in (1001) to (1007) are also present in Fig. 27 and are not shown here for clarity. The scales (1008 and 1009) are not attached to the smartphone, but are only used to designate individual emitter positions. The division line at which the number (1008) is marked is the first division line along the X-axis. To the right of this is division line 2. To the right of this is division line 3, and so on.

The division line on which the number (1009) is marked is the first division line along the Y-axis, i.e. Y-position 1. The division line above it is division line 2, and so on.

Emitters are referred to in the following description by their coordinates, which are specified as (X,Y) coordinates. For example, emitter (1010) is emitter (2,1).

According to this naming convention, emitter (1011) is emitter (10,13).

However, the emitters do not have to be placed exactly on grid positions. An arrangement in which other positions are also possible is shown in the arrangement example. In an advantageous embodiment, several emitters are present in the arrangement. In the example, 87 emitters and five detectors are shown. Four of the detectors are the cameras of the smartphone. However, other numbers of emitters and detectors are also possible. In an advantageous design, there are different distances between the light emission location and the light detection location. In a typical arrangement, these locations are not points but areas. In an advantageous design, these areas are limited by an opaque material of the contact surface that limits a transparent area of the contact surface. The contact surface is defined as the part of the outer shell of the smartphone that is located in the area of the cameras and light emitters. Typically, this surface does not come into contact with objects when the smartphone is in use, but only when it is stored, e.g., in a pocket. The use of the cameras while the transparent surface in the camera area is in contact with an object is not an instance of use intended in the current application.

Light detectors, cameras, or light emitters can thus act on the transparent areas. In the case of light emitters, it is understood that the light emitters emit light through the transparent surface, which is bounded by non-transparent material. This can be done for a transparent surface area by one or more light emitters. In an advantageous variant, these can also emit different wavelengths relative to each other.

In the case of a camera, it can be seen that a camera is not a single light detector, but usually an arrangement of many individual pixels, each of which represents a light detector. In an advantageous design, it is a colour camera that has pixel groups with different wavelength characteristics. RGB cameras are a common arrangement. These, typically, have a pixel group that is sensitive to light in the red range. In addition, there are, typically, pixel groups that are sensitive to light in the green range and pixel groups that are sensitive to light in the blue range. However, some cameras also have additional colour groups, which is often advantageous for the use according to the invention. In an advantageous variant, cameras have additional sensors for light intensity, in particular those used for the autofocus function. These often include light detectors sensitive to the infrared range and light detectors used for the autofocus process in the so-called phase comparison method. In an advantageous embodiment, several or even all of these pixels and sensors of the camera can be used for the sensor technology according to the invention. In summary, when referring to light detectors of the camera in the following, not only the pixels are meant, but also other light detectors integrated in the camera or used in conjunction with it. This includes, in particular, those of the autofocus. In an advantageous embodiment, cameras are equipped with additional devices. These include devices for changing the focus of the camera, devices for changing the aperture of the camera, and devices for compensating for camera movements. The latter are also referred to as image stabilizers and reduce the occurrence of blurred images or videos.

Although these devices and the light detectors described are primarily designed for creating images and videos, it is surprising that the devices mentioned can also be used advantageously for determining substances in, for example, human tissue. The following describes an advantageous approach for doing this. The devices described are referred to as camera functions.

To accurately determine the optical properties of a sample, it is made use of light that passes through the sample.

To determine the desired properties of the sample, it is advantageous to use light of different wavelengths. The effective wavelength range is determined, on the one hand, by the light wavelength range emitted and, on the other hand, by the light wavelength range detected. In an advantageous approach, the effective wavelength range is derived from the combination of these light wavelength ranges. It should be noted that the ranges often do not have hard boundaries, but rather show a wavelength-dependent intensity that decreases toward the edges of the ranges. The effective wavelength range can therefore be adjusted particularly finely by combining light emitters of different wavelength ranges with light detectors of different wavelength ranges. Another advantageous application is the use of fluorescence in the sample. The sample is

irradiated with short-wave light to which at least some of the camera's light detectors are not sensitive, so that they essentially only receive light originating from fluorescent substances in the sample. In an advantageous configuration, the substances in the sample are identified from the analysis of which wavelengths are absorbed as they pass through the sample. In an advantageous variant, fluorescence effects are also evaluated.

In practice, it has been shown that in the case of complex samples such as the skin or tissue of living beings or the analysis of foodstuffs such as fruit or packaged food, a further capability is highly advantageous. Such samples are often inhomogeneous. For example, they may consist of different layers. In a living organism, these would be the layers of skin and the underlying tissue. It may be of interest to identify a substance that is only found in the blood but not in the upper layers of the skin. In the case of an orange, for example, it may be that you are not interested in the properties of the peel, but want to analyze substances in the flesh of the fruit. In the case of packaged foods, you may not want to determine the properties of the packaging, but rather those of the packaged product. For this reason, it is advantageous to influence how deeply the light penetrates the object to be analyzed. In an advantageous variant, measures are taken to ensure that the light penetrates deeply into the tissue to be analyzed. In an advantageous design, light is emitted in such a way that a large proportion of the emitted photons move in a direction that forms a minimum angle to the contact surface of the sample, which is close to 90 degrees.

Quantifying this statement, it is advantageous that some light emitters emit at least 25%, but preferably at least 50%, of the photons emitted by the light emitter and reaching a selected light detector at an angle to the contact surface of the sample that is greater than 20 degrees, preferably greater than 30 degrees, preferably greater than 45 degrees, preferably greater than 60 degrees. Since the above statement refers to a pair of emitter and light detector and only considers those photons that reach the light detector from the emitter, the nature of the sample to be analyzed also plays a role. In order to remove this from the consideration, an artificial sample that simulates the nature of a typical sample is assumed for the consideration.

Another aspect that can influence whether the photons also pass through deep layers of the sample is the distance between the center of gravity of the contact surface of the light emission location and the center of gravity of the contact surface of the light detection location. Alternatively, this center of gravity can also be calculated taking into account the light intensity that passes through the respective surface element. The further apart the light emission location and the light detection location are, the deeper the photons that reach the light detector typically penetrate into the sample. However, even if photons are allowed to pass through the sample at a sufficient depth, this is often not enough to determine, for example, the concentration of a

substance at the desired depth. This is because the photons, typically, have to pass through flat layers of the sample in order to reach the deeper layers. In doing so, the photons interact with the flatter layers of the sample, which influences the measurement signal. Therefore, in an advantageous design, photons are also emitted in such a way that they essentially only pass through flat layers of the sample. In this way, the optical properties of the shallow layers of the sample can be determined. In an advantageous design, the influence of the flat layers of the sample upon the photons that have passed deeper through the tissue, as explained above, can be determined. In an advantageous design, measured values of the flat layers can be algorithmically linked to measured values of light that has passed through flat and deep layers, so that the optical properties of the deep layers are obtained as a result. In order to carry out such compensation and to determine the optical properties of a sample as accurately as possible, it is advantageous to use a large number and variety of pairs of light emitters and light detectors. The totality of the volume elements that are traversed with a specified probability by one of the photons that travel from the light emitter to the light detector is referred to as the light path volume.

In an advantageous design, the light path volumes of different pairs of emitters and detectors are differently shaped, and also reach different depths of a typical sample. In an advantageous variant, a large number of differently shaped light path volumes are possible, thus enabling a more accurate determination of the properties of the sample. This is particularly the case if the sample does not consist of defined layers, but, for example, has a gradual transition of properties depending on the depth, i.e., the distance of a volume element to be analyzed from the surface of the sample.

In an advantageous embodiment, the device also has light path volumes at different locations. In an advantageous embodiment, these can have the same light path volume shapes. In an alternative embodiment, however, the shapes of the light path volumes can also be different. This design is particularly well suited for measuring samples with spatial inhomogeneity. This includes, in particular, samples in which the concentration of a substance varies not only as a function of the depth of a volume element in the sample, but also as a function of the location on the surface of the sample at which the measurement is taken.

The radiation characteristics of the light emitters play an important role in the shape and light path volumes, and in particular in the depth through which the light path volumes pass. This is especially true for the radiation characteristics relative to the detector of a pair consisting of a light emitter and a light detector. If, for example, it is considered an emitter that emits light on average in a direction that is not perpendicular to the sample surface, the following advantageous case can occur. The emitter emits light in the direction of a detector A, so that a flat light path

volume shape develops in the pair consisting of the light emitter and detector A. In contrast, in the pair with a detector B that is not located in the direction of the light emission of the emitter, a light path volume shape develops that penetrates significantly deeper into the sample.

In an advantageous design of a measuring system, arrangements are therefore used which have the above-described property that emitters have a different radiation characteristic in the direction of one detector than in the direction of another detector.

It should be noted at this point that properties such as directional characteristics, emission direction, and the distribution of the emission over different solid angles in the above text have mostly been explained using the emitter as an example. However, these properties also exist in equivalent form on the detector side. However, the detector side is somewhat more difficult to formulate linguistically. For example, the equivalent of the sentence "an emitter emits photons perpendicular to the contact surface" is "the detector is designed so that it can detect photons that arrive at the detector along a line perpendicular to the contact surface." However, it is explicitly pointed out here that the optical properties described using the example of emitters apply in the same way to detectors. Where an advantageous arrangement, design, or property of the emitters is described, it is hereby clarified that this text also describes and discloses the equivalent advantageous design for detectors.

As far as the optical properties of the pair of light emitter and light detector are concerned and the targeted influence on these properties has only been explained with regard to the light emitter, it must be taken into account that the light detector typically has a comparable influence to that of the light emitter. The properties of the pair are determined by the light emitter and light detector. To shorten the text, a pair consisting of a light emitter and a light detector is referred to below as an ED pair, its light path volume as ED-LW, and the shape of the ED-LW as ED-LWF. This applies in particular to the light path volume shape and the light penetration depth into the sample. In an advantageous embodiment are provided materials with which the emission direction of light emitters or the direction from which detectors can receive photons can be influenced. In an advantageous embodiment, these are used to influence the light path volume shape and the light penetration depth into the sample. The above explanation clarifies the advantages of having a large number of light path volume shapes available for determining the optical properties of a sample. Having explained the basic ways in which this diversity can be achieved, the advantages of the arrangement according to the invention for determining the optical properties of a sample will now be explained.

The arrangement shown in Figures 25 to 27 has many of the above-mentioned advantages, which will be explained below. Advantageously, the arrangement has several light detectors, some in

the form of cameras, and several light emitters. This results in a large number of ED pairs and thus also a large number of ED-LWF.

Advantageously, the arrangement has emitters that have different emission direction characteristics. This results in a greater variety of ED-LWF.

Advantageously, each individual light detector of the camera can be used to form a separate ED pair with each detector. Since, for example, the pixels of the camera are arranged next to each other, this results in different distances between the light emitter and the light detector, which leads to a greater variety of ED-LWF.

Advantageously, the light detectors of the camera have different reception direction characteristics. These result, for example, from the position of a pixel relative to the lens or to opaque components such as the aperture, lens holder, or edge of the camera opening. This again results in a greater variety of ED-LWF.

Advantageously, the arrangement produces ED-LWF due to the small distance between the camera pixels, which allows for a gradual gradation of the penetration depth. As a result, evaluation algorithms not only have data about a few discrete penetration depths at their disposal, but also a gradation that has a similar number of steps between the greatest and least penetration depths as there are pixels in a row or column of the camera.

Advantageously, the camera functions can be used to further increase the variety of ED-LWF. This is advantageously achieved by moving components of the camera functions into different mechanical positions. This advantageously influences the direction from which the light detectors of the camera can receive light. In one advantageous manner, a lens is moved. In another advantageous manner, the detector chip is moved. In an alternative advantageous manner, the aperture is adjusted or a filter is placed upstream. In an advantageous manner, a measurement is performed in which at least one of the movable components of a camera function is in one position, and then a second measurement, is performed, in which this movable component is in a second position. This results in multiple ED-LWFs for at least some of the ED pairs. In a further preferred variant, one or more additional measurements are performed in which at least one component of a camera function is in a different state than in the previous measurements. In this context, measurement refers to the detection of brightness information by the light detectors, which may also be multiple pieces of light information resulting, for example, from an activation sequence of multiple light emitters or the use of multiple light detectors. It is advantageous for the cameras to have a large number of light detectors. This results in a large number of measured values, so that the accuracy can be increased by mathematical methods. For

example, noise components can be averaged out. Effects caused by inhomogeneities in the sample and leading to errors in the interpretation of the data can also be detected and reduced.
However, the arrangement described has also advantages for the camera function and other functions of the smartphone. In an advantageous variant, at least some of the emitters are used to illuminate the object to be photographed. In an advantageous design, it is made use of emitters that are mounted on different sides of the camera, so that the advantages of a ring light are obtained and no disturbing shadows are produced.
In an advantageous embodiment, emitters of different colours are used to illuminate the photos. This increases the spectral resolution of the camera. This enables a more accurate determination of the colours in the image than is possible with the human eye. This allows many tasks to be performed, that would otherwise require a multispectral camera. Examples include: verifying the authenticity of objects and detecting counterfeit products or money, contactless detection of the composition of substances or food, and accurate determination of colours and their appearance under different lighting conditions, e.g., in cosmetics. In an advantageous design, the emitters are used for signalling, e.g. for signalling the arrival of different messages on a smartphone lying on a table by means of different colours or patterns. In an advantageous design, the light emitters can be used to better detect the distance to photo subjects at close range, thereby enabling better autofocus.
In an advantageous embodiment, objects can also be measured three-dimensionally by illumination from different light emitters. In an advantageous embodiment, the colored light can be used for decorative or party purposes. In an advantageous embodiment, the brightness of the illumination of photos can be increased, because the light sources are distributed over a larger area and thus cause less damage when looking into them. Waste heat from the LEDs can also be dissipated more effectively over a larger area.
In an advantageous embodiment, the infrared light emitters can also be used to control devices with infrared receivers. Other data can also be exchanged optically, which can also be done bidirectionally thanks to the cameras and light emitters.
In an advantageous design, the light emitters can be used to determine the location and position of the smartphone in the room, for example, by means of a camera fixed in the room. This function can be used to implement game controller functions, for example.
In an advantageous design, UV light can be used for illumination in order to photograph fluorescent markings, e.g. on banknotes.
In an advantageous embodiment, smartphones can also use this arrangement as a distance sensor, reflex light barrier, or for improved gesture recognition.

In an advantageous embodiment, smartphones can use the arrangement both as a sensor designed to be brought into contact with a sample and as a multispectral sensor that analyzes a sample without contact. Since both types of applications have advantages, a system that can implement both measurement methods is advantageous. In an advantageous variant, transmitted light analyses can also be performed by using an external camera or light source or a second smartphone. In an alternative advantageous variant, a transmitted light analysis can be performed by means of an additional element, such as a sample vessel with a mirror on the side facing away from the sensor.

A particularly advantageous variant results from combining this arrangement with the use of light emitters with the same optical property, such as the peak wavelength, which are designed so that the optical property does not have to be the same for all light emitters, but can vary within a range. The advantage is that the arrangement can detect the variation in the peak wavelength of the light emitters using the cameras. In an advantageous design, this can be done using the camera's colour sensor technology when measuring the sample. In an alternative advantageous variant, a test specimen is used. This can be, for example, a printed card or cardboard box held in front of the camera. In the case of the cardboard box, this can be the packaging of the smartphone, which helps to create a defined distance to the optically active part of the test specimen. The part of the test specimen captured by the camera can, for example, be white or have colored areas. By using the test object, the camera can determine which of the light emitters has which peak wavelength. In an advantageous variant, this information can be used to improve the quality of the evaluation of the measurement results. In a particularly advantageous variant, the arrangement variants described above can be used to collect information about a person's food. Multispectral photos allow more accurate conclusions to be drawn about the composition of food. A more accurate distance detection and three-dimensional measurement of the volume of food allow a better estimation of food quantities. Improved recommendations can be made to the user based on data about the quantity and type of food. In an advantageous variant, the information can be used to facilitate or evaluate the selection of food. Alternatively, the information can be used to identify the actual amounts and types of food consumed. In a beneficial variant, the user takes a photo of his/her plate of food. In an alternative beneficial variant, the smartphone is positioned so that it can recognize and measure the food on, for example, a fork or spoon.

Fig. 28 shows a section of the arrangement of Figures 25 to 27 in cross-section.

The camera module (1012) with transparent cover (1013) and lens (1014) mounted in a lens holder (1021) is shown. The camera chip (1022) has numerous pixels. For simplicity, only 5

pixels are shown here. The pixel furthest to the left is designated by (1015). The pixel furthest to the right is designated by (1016). Several light emitters are shown, which are numbered from (1018) to (1020) or are not numbered. The number (1017) denotes a surface made of at least partially transparent material, which, in a preferred embodiment, protects the light emitters from contact and contamination. It can fill the entire cavity in which the light emitter is located, or, in an alternative preferred embodiment, it can be only a disc so that the light emitter is surrounded by air, for example.

The number (1023) refers to the material of the sample to be examined, which is brought into contact with the arrangement. Figure 29 shows the same elements as in Fig. 28. Some of the designations have been omitted for clarity. The figure shows the area within sample (1023) where the ED-LW is located. The volume area of the light path ED-LW of the ED pair light emitter (1018) and light detector (1016) can be seen in Fig. 29.

The area through which photons from light emitter (1018) reach light detector (1016) with significant intensity is bounded by the dashed lines (1024 and 1025). The sharply drawn boundary here should not obscure the fact that the area has naturally a smooth transition in the number of photons. However, a smooth boundary would have been difficult to represent in a black and white graphic. For this reason, a fixed boundary is used for the illustration. The position of the light detector on the far right means that only photons arriving almost vertically or from the left side of the image can be received. This means that the photons that travel from the light emitter to the light detector have a high average penetration depth into the sample (1023).

Figure 30 shows a comparable situation for the light detector (1015). Due to its position on the left edge, photons arriving flat from the right side of the image can be detected. The emitter (1018) also enables the flat emission of photons due to its position on the right side of the emitter cavity. For these reasons, this arrangement results in a significantly flatter ED-LW.

By moving the focus lens (1021), it would be possible to change both the ED-LW from Fig. 29 and the ED-LW from Fig. 30 in order to increase the variety of ED-LWFs.

All variants and embodiments described in this disclosure can be combined with each other in any combination and combined to form advantageous systems or embodiments of devices. The application of all embodiments shown in the form of a process or method can be combined with the described methods to form any advantageous overall methods. The following description describes further embodiments and methods. These can be combined with the other devices and methods described in this text.

In particular, they represent an exemplary and advantageous embodiment for processing signals originating from component groups with identical sensor components.
It is made use of continuous kernels for processing unevenly and incompletely recorded data sets with position-dependent characteristics.

Brief summary – Continuous kernels are a new development in the field of convolutional neural networks. Such kernels are used to process data recorded in different resolutions, as well as unevenly recorded data. Convolutional neural networks have translation-invariant properties (i.e., features are recognized independently of their position in the measurement range), which is disadvantageous for certain data sets in which the positions of the features are relevant. On the other hand, the ability of continuous kernels to process irregularly recorded data is desirable. This article describes a novel method that uses continuous kernels to detect global features at absolute positions in the measurement domain. Using an application case in the field of multiple location-resolved reflection spectroscopy, in which data is recorded unevenly and incompletely, it is shown that the presented method can process the data natively and without further preprocessing. Furthermore, it is shown that the presented method has a higher prediction accuracy than comparable models on a dataset with position-dependent features. In addition, increased robustness against missing data is observed compared to comparable models, which allows the network to adapt itself to sensors with failed individual components without retraining.
Index terms – Machine learning; Neural networks; Continuous kernels; Unevenly recorded data; Reflection spectroscopy

1. Introduction

Conventional machine learning methods assume that data is recorded consistently. This implies that each block of recorded data has the same form and that each data point it contains always has the same meaning. In real-world applications, however, there is often inconsistency in data recording, for example due to production fluctuations in the sensor that records the data. In some cases, individual data points may even be missing entirely. To process such data, imputation methods can be used to restore missing data [1]. Some methods also use neural networks to supplement or correct missing data [2]. For certain network architectures [3], continuous kernels are used to circumvent these assumptions and process such uneven and incomplete data natively, rather than relying on special preprocessing methods [4] [5] [6]. Convolutional neural networks have translation-invariant properties, which are unsuitable for processing data that has features at consistent absolute positions in the measurement range. Common examples of this type of data

are spectral data, both visual and auditory, as they contain relevant features such as intensity maxima at specific, constant wavelengths instead of wavelength-independent features in the form of intensity curves.

In order to be able to process such data with position-dependent features natively, even if the data has been recorded unevenly and incompletely, a novel method is presented in this article. It has already been shown that neural networks, such as sinusoidal representation networks (SIRENs) [7], can be used as functions definable by learnable parameters, which enables their use as continuous kernels. Such kernels are capable of modeling global long-term dependencies [4]. By using such continuous kernels outside the context of convolutional neural networks, the presented method is able to natively process unevenly and incompletely recorded data with position-dependent features.

The rest of this article is structured as follows: Section 2 explains the current state of the art. Section 3 deals with the definition of a continuous kernel. Section 4 introduces the novel method using continuous kernels. Section 5 demonstrates the effectiveness of the method in relation to the processing of spectroscopic data. Section 6 discusses possible future research on the use of continuous kernels in the field of explainable artificial intelligence. The summary concludes the article.

2. State of the art

Previous research on continuous kernels has largely focused on applications in convolutional neural networks to process unevenly sampled data. In [4], continuous kernels are used to process various types of sequential data, including unevenly sampled sequences. The article also deals in detail with different types of parameterization of continuous kernels. [5] uses continuous kernels in convolutional neural networks to process non-rasterized data such as representations of atoms in chemistry. In [6], continuous kernels are used in three-dimensional convolutional neural networks for processing point clouds. All of these articles discuss the use of continuous kernels for the convolution step in convolutional neural network architectures, all of which have translation-invariant properties, making these methods unsuitable for use on data with position-dependent properties. The use of neural networks as a function defined by learnable parameters, called implicit neural representation, was analyzed by [8] [9] for the representation of signed distance functions, which are useful for representing three-dimensional geometry. In [7], an architecture for implicit neural representation, called SIREN, is presented, which is suitable for various types of data, including audio, images, and signed distance functions.

3. Definition of continuous kernels

Basically, continuous kernels are functions that assign a weight to a data point at any position in the measurement range [5]. Unlike in applications in a convolutional neural network, the positions weighted by the kernel are the absolute positions, not the positions relative to a convolution point.

In order to represent a continuous variant of a weighting kernel, kernel functions must be defined in such a way that they can ideally approximate any function using learnable parameters. It has been shown that multilayer perceptrons with sine-based nonlinearities, such as SIREN networks [7], are suitable for this purpose.

Formal:

Lowercase letters denote scalars, bold lowercase letters denote vectors. Uppercase letters denote a corresponding set. Subscripts under values denote an index of the value within a set containing that value, superscripts denote an index of an element of a vector.

Definition:

Let $p_i \in P \subset \mathbb{R}^n$ be the position of the value $d_i \in D \subset \mathbb{R}$ of the i^{th} data point in the set of all data points D in a n-dimensional measurement range. A continuous kernel in the presented architecture is now defined as a function

$$\psi: \mathbb{R}^n \rightarrow \mathbb{R} \quad (1)$$

which assigns a weight to each position p_i in the measurement range. As shown in [4], such a function can be defined using implicit neural representations such as multilayer perceptrons with sinusoidal nonlinearities, for example SIREN networks. In the method presented, such a multilayer perceptron is used as a function ψ. The multilayer perceptron has n input neurons, which serve as input for the respective position $p_i \in \mathbb{R}$ of a data point, and one output neuron, which serves as the weighting for the respective data point. The other parameters of the kernel are the number and size of the hidden layers in the multilayer perceptron, which can be adjusted depending on the problem to be learned. The multilayer perceptron operating as the function ψ is not pre-trained separately, but is trained as part of the overall network consisting of several kernels, among other things.

4. Use of continuous kernels

Fig. 31 shows the basic structure of the proposed model architecture. Roman I shows the set of input data points for the model, each representing a value at a specific position in the measurement range. In the method presented, the first level, called the continuous feature level, contains several independent continuous kernels (see Roman II in Fig. 31). Each of the independent continuous kernels weights all input data. The input data may have been recorded unevenly. To compensate for any uneven distribution of measurement points, the local point

density of the measurement points is also calculated (not explicitly shown in Fig. 31). While the kernel density estimation method is used to calculate the local point density in the presented method, whereby the size of the kernel is a learnable parameter of the network, alternative methods can also be used. Each input data point is weighted by the inverse local point density at the position of the data point, as suggested in [6]. The data points weighted by both kernel and inverse point density are shown in Fig. 31 in Roman III and are formally described by equation 2. For each kernel, the weighted data points are reduced to a value as defined in equations 3 and 4 and as shown in Fig. 31 in Roman IV. In the presented method, a sum is used as a reduction operation, but other reduction operations such as a mean value can also be used. Combining the reduced values results in a feature vector of constant size, which depends on the number of continuous kernels in the continuous feature space. Since the continuous feature layer thus reduces inputs of any size to a feature vector of a constant and known size, the continuous feature layer can now be followed by classic elements of neural network architectures, such as a multilayer perceptron (see Fig. 31, Roman V). The output of this multilayer perceptron then serves as the output of the entire network, as shown in Fig. 31, Roman VI. The network architecture described here is referred to as a continuous feature network in the following. The continuous feature layer thus has three main parameters: the number of continuous kernels, and the number and size of the layers of the continuous kernels themselves.

Formal definition:

Let the set Ψ be the set of independent continuous kernels ψ_k of the continuous feature layer. In this set, each ψ_k describes a feature that may be present in the data. Let $d_i \in D$ be the i^{th} data point of the input data with the position $p_i \in P$ within the measurement range. Let $\rho(p_i)$ be defined as the local point density of the recorded data at position p_i within the measurement range. This results in the following definition for the weighted data points:

$$w_{i,k} := d_i \cdot \psi_k(p_i) \cdot \frac{1}{\rho(p_i)} \quad (2)$$

The components of the fixed-size feature vector v are defined as follows:

$$v^k(D,P) := \sum(w_{i,k}) \quad (3)$$

$$= \sum\left(d_i \cdot \psi_k(p_i) \cdot \frac{1}{\rho(p_i)}\right) \quad (4)$$

Since the fixed-size characteristic vector v is a function of the data points and their positions, the characteristic vector can be described as a function of the following type:

$$v: \mathbb{R}^i, \mathbb{R}^{i \times n} \rightarrow \mathbb{R}^k \quad (5)$$

v describes the feature vector with a constant size k as a reduction of the input of any size i for the data, and $i \times n$ for the position of the data. Since the size of the feature vector is constant and does not depend on i , the feature vector can be used as input for traditional neural networks, such as multilayer feedforward neural networks, for any i without having to retrain the network.

5. Experiments

The presented method is tested using a dataset consisting of data from multiple spatial reflection spectroscopy (MSRRS, [10]). The data was recorded in parallel with a reference measurement of the concentration of carotenoids in human skin in vivo on a scale from 0 to 12. The measurement system, as described in [10], consists of several light emitters and light detectors. The training and validation datasets are disjoint and were recorded on different groups of people with the use of different MSRRS sensors. As described in Section 4, the recorded spectroscopy data are well suited for the use of continuous kernels and continuous feature networks. The reason for this is the nature of MSRRS-based spectral data in the form of relative brightnesses for a few discrete wavelengths and emitter-detector distances. These discrete wavelengths and emitter-detector distances are neither recorded at regular intervals nor always at the same wavelengths. Due to production variations, there are slight deviations in the wavelengths of the emitters. However, it is possible to measure these for each sensor and use the actual peak wavelengths as position data for the continuous feature layer. Furthermore, it can be assumed that in such spectral data, the interesting information is not in the form of the features, but in the position of the features (which in this case are the absorption wavelengths of the carotenoids), which is suitable for the method presented here.

To analyze the presented method, a continuous feature network with a continuous feature layer containing 64 continuous kernels is used. Each kernel consists of a SIREN network with three hidden layers, each with 48 neurons with sinus-based nonlinearities. Behind the continuous feature layer is a feedforward layer with 64 neurons, which is followed by an output layer with one output neuron for predicting the carotenoid concentration. This network has approximately 320,000 parameters. For comparison, a multi-layer forward network with a comparable number of parameters is used. This multi-layer forward network, with a total of approximately 375,000 parameters, is fed to each emitter-detector pair as an input neuron, followed by two hidden layers with 256 and 128 neurons, respectively, followed by an output layer with one neuron for the predicted carotenoid concentration.

In addition, a convolutional neural network-based model was analyzed, but it was unable to make adequate predictions about the carotenoid concentration in human skin and is therefore not

discussed further. Both networks analyzed in more detail are implemented using the ADAM optimization algorithm [11] and the LibTorch framework.

Fig. 32 shows the accuracy of the presented method compared to the accuracy of the comparison model. To assess the ability of the continuous network to process unevenly recorded data, the prediction accuracy was measured while withholding data from different numbers of light detectors. For each data measurement point, the detectors of which the data is withheld are randomly selected according to the number of detectors to be withheld. For the continuous feature level, the withheld data is not used as input. For the multi-layer forward network, the withheld data is interpolated from data of similar wavelength and emitter-detector distance. This is necessary because multi-layer forward networks are not able to process the shorter input data vector without retraining. If data with comparable distance and wavelength are not available, the value for input into the multi-layer forward network is set to 0. The results show that the continuous feature network makes more accurate predictions than the multi-layer forward network of comparable size for all investigated quantities of retained detectors. When data from all detectors is available, the continuous feature network is able to achieve a mean square error of up to 19% less than the multi-layer forward network. The increased prediction accuracy is therefore due to the fact that the continuous feature network is well suited for MSRRS data and can thus better abstract the data correlations, and that the continuous feature network can take into account the actual measured wavelengths of the individual emitters of each sensor for the position of the data points. In addition, it can be observed that, unlike the multi-layer forward-looking network, the continuous feature network can provide a stable prediction for a longer time even when multiple detectors are withheld. This can be seen in Fig. 33 and Fig. 34. Fig. 33 shows a histogram of the prediction error. In the various graphs, data from a different number of randomly selected light detectors was withheld from input into the continuous feature network. As the graph shows, although the number of highly accurate predictions decreases, the number of highly inaccurate predictions (> 2.4) does not increase significantly. This shows that the continuous feature network is able to adapt itself to the low availability of data without having to be retrained. Fig. 34 shows a histogram of the prediction error of the multi-layer forward network. Similarly, the various graphs show the prediction error for different numbers of detectors of which the data was withheld. In addition to a reduction in highly accurate predictions, the multi-layer forward network also shows that the number of highly inaccurate predictions (> 2.4) increases rapidly as soon as the amount of data withheld exceeds 25%. The slight increase in highly inaccurate predictions of the continuous feature network when no data is

withheld is probably due to an inaccurate calculation of the point density of the input and will be part of future research.

6. Potential for explainable artificial intelligence

A side effect of the continuous feature level is the resulting potential for explainable artificial intelligence. Since continuous kernels represent weights for each position in the measurement range, the importance of certain regions of the measurement range can be calculated from the learned weights. The mean value of the absolute values of the weights across all kernels could serve as a yardstick for the importance of data in the respective regions. This could allow the use of continuous kernels as an interpretable model [12]. However, since the magnitude of the input data can vary at different positions in the measurement range, the respective importance at the positions can also be influenced accordingly and must be compensated for when considering the results. In addition, the multi-layer perceptron that processes the feature vector must also be considered when comparing the importance of different kernels. Nevertheless, the use of continuous feature levels as a tool for explainable artificial intelligence is an interesting topic for future research.

7. Summary and future research

This article introduces the continuous feature network, a novel method for processing unevenly and incompletely recorded data with position-dependent features, such as optical or acoustic spectra. In addition, it is shown that the continuous feature network achieves a 19% lower mean square error in predicting carotenoid concentration in human skin from MSRRS data compared to a similarly sized multi-layer forward network. This shows that the continuous feature network is better able to abstract the relationships between MSRRS data and the reference carotenoid concentration in human skin. Furthermore, it is shown that the continuous feature network can continue to make stable predictions of carotenoid concentration in human skin even with up to 50% of the input data missing, while comparable multi-layer forward networks already show high prediction errors when 25% of the data is missing. Further possible applications exist in cases in which data is recorded unevenly and features depend on their position in the measurement range, such as in other types of spectra, e.g., audio spectra. Continuous feature networks also show potential for explainable artificial intelligence, and further investigation in this direction is interesting.

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Patent claims

1. Device for optically measuring substance concentrations or biomarkers in a sample,
with a contact surface that can be brought into contact with the sample during a measurement process, and
optoelectronic components in the form of a plurality of optical emitters for emitting photons, and
a plurality of detectors for receiving at least some of the photons emitted by the emitters and passing through at least a partial volume of the sample, and
wherein the emitters and the detectors are located in a common plane,
and at least nine emitters are provided,
and at least three detectors are provided,
and the emitters and detectors are mounted at a distance of less than 15 mm from the contact surface,
wherein there are at least three wavelength intervals which do not overlap and which have an interval length between 2 nm and 20 nm, and in each of the wavelength intervals at least the peak wavelength of three of the emitters lies, and
in each wavelength interval, at least two of the emitters, both of which are within the wavelength interval, have a difference in peak wavelength of at least 0.5 nm.

2. Device according to claim 1, characterized in that the device is intended for non-invasive measurement on living beings.

3. Device according to one of claims 1 to 2, characterized in that there are pairs of emitters and detectors and, for each wavelength interval, there are at least two pairs of emitters and detectors in which the distance from the emitter to the detector differs by at least 50% from the distance between the emitter and detector of the other pair.

4. Device according to one of claims 1 to 3, characterized in that the contact surface consists of at least one transparent material and at least one non-transparent material.

5. Device according to one of claims 1 to 4, characterized in that the device is integrated into a smartphone and uses at least one of the cameras of the smartphone as at least one of the detectors.

6. Device according to one of claims 1 to 5, characterized in that it has at least four cavities which are surrounded on all sides except one by non-transparent material and in which there is either at least one emitter or one detector.

7. Device according to any of claims 1 to 6, characterized in that the control of the emitters is designed such that the emitters can be activated one after the other and individually in a sequence and the brightness detected by each detector for the step of the sequence can be fed to a data processing device.

8. Method for the optical measurement of substance concentrations or biomarkers in a sample consisting of human skin, wherein a measuring device has a sensor surface which is a contact surface of the measuring device to the skin,

and the contact surface to the skin has partial surfaces that are not transparent, and the contact surface to the skin has partial surfaces that are sufficiently transparent so that photons can be emitted and detected through the contact surface,

and at least nine emitters and at least three detectors are located on a common plane

and the emitters and detectors are mounted at a distance of less than 15 mm from the contact surface,

and the emitters are switched on in a measurement sequence,

and switched-on emitters emit photons that penetrate the skin through the sensor surface,

and some of the emitted photons pass through the skin, interact with it, exit it, pass through the sensor surface again, and are then detected by one of the detectors of the measuring device,

wherein at least three wavelength intervals of optoelectronic components and/or three distance intervals of the emitter-detector distance of emitter-detector pairs exist,

and in each of these intervals there are at least two optoelectronic components that differ in their wavelength or two emitter-detector pairs that differ in their emitter-detector distance,

and the performance of the measurement enables the determination of physiological states of an individual and/or the measurement of the concentration of substances in the human body.

9. Method according to claim 8, characterized in that

there are at least three wavelength intervals that do not overlap and have an interval length between 2 nm and 20 nm, and in each of the wavelength intervals at least the peak wavelength of three of the emitters lies,

and in each wavelength interval, at least two of the emitters, both of which are within the wavelength interval, have a difference in peak wavelength of at least 0.5 nm.

10. Method according to claim 8 or 9, characterized in that

for a first emitter-detector pair, a first measured value for the quantity of detected photons is recorded, and
for a second emitter-detector pair, a second measured value for the quantity of detected photons is recorded, and
the emitter of the first emitter-detector pair is in the same wavelength interval as the emitter of the second emitter-detector pair, and
the emitter of the first emitter-detector pair differs from the emitter of the second emitter-detector pair by the difference in the peak wavelength of the emitter, and
the difference in the peak wavelength of the emitter causes a difference between the first measured value and the second measured value, and
the measured values are recorded separately so that the difference between the measured values can be evaluated to enable an increase in the accuracy of the substance concentration determination.

11. Method according to any one of claims 8 to 10, characterized in that the differences in the peak wavelengths of the emitters are included in the calculation of the concentration of the analyte and improve the accuracy of the result.

12. Method according to one of claims 8 to 11, characterized in that data recorded or measured during the production process of the measuring device is used.

13. Method according to one of claims 8 to 12, characterized in that measurement data from measuring devices placed on the market can be stored for evaluation,
or in that the measuring devices are equipped with at least one data storage device.

14. Method according to one of claims 8 to 13, characterized in that raw optical data from which the properties of individual emitters can be inferred can be recorded and stored, thereby enabling subsequent optimization of the device.

15. Method according to one of claims 8 to 14, characterized in that nutritional recommendations are calculated and issued on the basis of the measured substance concentrations.