

SYSTEM FOR ANALYTE SPECTRAL COLLECTION AND SYSTEM FOR TESTING ANALYTE

TECHNICAL FIELD

5 The present invention relates to the field of optical analysis, and in particular
to a system for analyte spectral collection and a system for testing an analyte.

BACKGROUND

Diabetes is a common metabolic endocrine disease, which is caused by the
10 lack of insulin in the human body or receptor abnormalities, and is characterized by
high blood glucose, which is a worldwide epidemic. In recent years, the incidence
of the disease has increased significantly, and approximately 10% of adults
worldwide suffer from the disease, and the age of onset tends to be younger. In
China, there are approximately 40 million diabetic patients. Testing of blood
15 glucose is extremely important for clinical diagnosis and blood glucose control in
diabetic patients.

At present, an authoritative testing method for diabetes is still an
extracorporeal venous blood test or fingerstick blood test, which will cause pains to
patients, resulting in the inability to monitor blood glucose changes at any time,
20 and increasing the chance of infection. As the number of diabetic patients increases
year by year, to control blood glucose and improve the quality of life, patients and
people at high risk of diabetes are no longer satisfied with traditional testing
methods. Therefore, a fast, simple, sensitive, accurate, non-destructive, and
relatively inexpensive testing method and instrument are urgently needed to
25 complete daily testing, to approach blood glucose changes at any time and achieve
the purpose of effective blood glucose control.

In an existing patent document with a publication No. CN108542402B, a

portable infrared spectrometer is used to collect spectral spectrum on the surface of human skin, collect a large number of infrared spectra of blood glucose on the surface of human skin, and establish a basic database. Subsequently collected infrared spectra need to be processed, any invalid spectrum needs to be eliminated
5 to form a database, only infrared spectrum data is collected, and there is a large amount of workload in subsequent data processing.

In an existing patent document with a publication No. CN106645013B, a testing apparatus includes a terahertz spectral module and a testing room, the testing room is provided with a terahertz spectral transmitting terminal and a
10 terahertz spectral receiving terminal. The terahertz spectral transmitting terminal and the terahertz spectral receiving terminal are connected to the terahertz spectral module separately, the testing system includes a testing apparatus and a control calculation module. A testing method is as follows: based on a spectral characteristic absorption principle, comparing transmitting information and
15 reflection information, and calculating a blood glucose concentration. The terahertz spectral module is complicated and has high requirements for a working environment.

An existing patent document with a publication No. CN112790762A includes: a shell, a controller, a Raman spectroscopy transceiving assembly, a Raman
20 spectroscopy processor, a communication apparatus, and a battery, to implement collection of Raman spectral data. A blood glucose concentration of an object to be tested is obtained by characteristic analysis of the collected Raman spectral data by a handheld part. The use of Raman spectroscopy for testing a blood glucose concentration in vivo currently relies on a laboratory-grade Raman spectroscopy
25 system, which is bulky and expensive.

SUMMARY

To overcome defects in the prior art, the present invention is intended to provide a system for analyte spectral collection and a system for testing an analyte.

A system for analyte spectral collection provided according to the present invention includes a shell and an imaging spectrum detection apparatus, wherein
5 the shell is capable of fitting a tested part of a tested object and forming an imaging area at a fitting position;

the imaging spectrum detection apparatus obtains a light signal from the imaging area, the imaging spectrum detection apparatus includes a sensor and a periodic pixel-level light filtering structure, and the periodic pixel-level light
10 filtering structure is disposed on a surface of the sensor; and

the periodic pixel-level light filtering structure performs spectral modulation on an incoming light signal, and the sensor generates an image containing spectral information to be tested.

Further, the periodic pixel-level light filtering structure includes a plurality of
15 light filtering image element channels with pixel-level light filtering structures of different shapes. The light filtering image element channels with pixel-level light filtering structures of different shapes correspond to different spectral filter coefficients, and the pixel-level light filtering structures with different spectral filter coefficients are combined in a fixed order and then arranged periodically.

20 Further, specifications and sizes of all light filtering image element channels are the same and evenly arranged.

Further, a length or width of any light filtering image element channel is an integer multiple of a pixel size within the sensor.

Further, the system for analyte spectral collection further includes a lens, the
25 light signal from the imaging area enters the imaging spectrum detection apparatus after passing through the lens.

Further, the system for analyte spectral collection further includes a second bandpass filter, which is located between the lens and the imaging spectrum detection apparatus; and the second bandpass filter allows light within a preset

wavelength range to pass through and light outside the preset wavelength range to be cut off.

Further, light signals in the imaging area include a reflection signal generated by the analyte when irradiated by light and an excitation signal generated by the analyte when irradiated by light.

Further, an image generated by the sensor and containing spectral information to be tested includes spectral data that indicate uneven distribution of a reflection signal in the imaging area and/or spectral data that indicate uneven distribution of an excitation signal in the imaging area.

The system for testing an analyte according to the present invention includes a system for analyte spectral collection.

Further, the system for testing an analyte includes a portable apparatus, wherein the system for analyte spectral collection is integrated in the portable apparatus.

Compared with the conventional technologies, the present invention has the following beneficial effects.

1. In this application, the periodic pixel-level light filtering structure disposed on the surface of the sensor performs spectral modulation on the incoming light signal, so that the sensor generates an image containing spectral information to be tested, helping analyte spectral collection be performed more simply. During testing, electrochemical reaction with the analyte is not required, and a testing manner is more easily implemented, especially when an analyte in a living body is tested, so that non-invasive testing can be achieved.

2. In this application, spectral data of different areas can be obtained by utilizing uneven distribution of the analyte in the imaging area. Because other components in the imaging area except the analyte are distributed relatively uniformly, a difference in spectral data in different areas can directly demonstrate the information about the analyte (such as a concentration of the analyte) correlated to the spectral data after the influence of a non-analyte is excluded.

3. In this application, fluorescence spectroscopy is used for testing, preventing a traditional Raman method for measuring the analyte, thereby achieving low costs and miniaturization of the testing system and achieving real-time testing.

5

BRIEF DESCRIPTION OF DRAWINGS

Other features, objects, and advantages of the present invention will become more apparent by reading detailed description of non-limiting embodiments with reference to the following drawings:

10 FIG. 1 is a schematic structural diagram of a device for testing an analyte provided in a first embodiment;

FIG. 2 is a schematic diagram of a watch structure provided in the first embodiment;

15 FIG. 3 is a schematic exploded diagram of a watch internal structure provided in the first embodiment;

FIG. 4 is a schematic diagram of a watch wearing structure provided in the first embodiment;

FIG. 5 is a schematic diagram of a watch back structure provided in the first embodiment;

20 FIG. 6 is a flow chart in a second embodiment;

FIG. 7 is a schematic diagram of a first image collected in a third embodiment;

FIG. 8 is a schematic diagram of a second image collected in the third embodiment;

25 FIG. 9 is a schematic diagram of a testing model in the third embodiment;

FIG. 10 is a schematic diagram of testing point-reference point spectral data obtained in the third embodiment;

FIG. 11 is an experimental result of analysis result accuracy of an analysis

model; and

FIG. 12 is a schematic structural diagram of an electronic device provided in a sixth embodiment;

In the accompanying drawings,

- 5 100: imaging area; 200: testing device;
 201: light source; 202: imaging spectrum detection apparatus;
 203: controller; 204: first bandpass filter;
 205: lens; 206: second bandpass filter;
 207: circuit board; 501: processor;
10 502: memory.

DETAILED DESCRIPTION OF EMBODIMENTS

The present invention is described below in detail with reference to specific embodiments. The following embodiments help those skilled in the art further
15 understand the present invention, but do not limit the present invention in any form. It should be noted that those skilled in the art may make some improvements and transformation without departing from the idea of the present invention. The improvements and transformation shall fall within the protection scope of the present invention.

20 First embodiment

FIG. 1 is a structural diagram of this embodiment. A system for analyte spectral collection provided in this embodiment includes a shell and an imaging spectrum detection apparatus. The shell is capable of fitting a tested part of a tested object and forming an imaging area 100 at a fitting position. The imaging spectrum
25 detection apparatus obtains a light signal from the imaging area 100. The imaging spectrum detection apparatus includes a sensor and a periodic pixel-level light filtering structure, and the periodic pixel-level light filtering structure is disposed on a surface of the sensor. The periodic pixel-level light filtering structure performs

spectral modulation on an incoming light signal, and the sensor generates an image containing spectral information to be tested.

The periodic pixel-level light filtering structure includes a plurality of light filtering image element channels with pixel-level light filtering structures of different shapes. The light filtering image element channels with pixel-level light filtering structures of different shapes are corresponding to different spectral filter coefficients, and the pixel-level light filtering structures with different spectral filter coefficients are combined in a fixed order and then arranged periodically. Specifications and sizes of all light filtering image element channels are the same and evenly arranged. A length or width of any light filtering image element channel is an integer multiple of a pixel size within the sensor. The system for analyte spectral collection further includes a lens 205. The light signal from the imaging area 100 enters the imaging spectrum detection apparatus after passing through the lens 205. The system for analyte spectral collection further includes a second bandpass filter 206, which is located between the lens 205 and the imaging spectrum detection apparatus 202. The second bandpass filter 206 allows light within a preset wavelength range to pass through and light outside the preset wavelength range to be cut off.

Light signals in the imaging area 100 include a reflection signal generated by the analyte when irradiated by light and an excitation signal generated by the analyte when irradiated by light. An image generated by the sensor and containing spectral information to be tested includes spectral data that indicate uneven distribution of a reflection signal in the imaging area 100 and/or spectral data that indicate uneven distribution of an excitation signal in the imaging area 100.

Specifically, the imaging spectrum detection apparatus is a part of a testing device 200, and the testing device 200 further includes a light source 201, a controller 203, the first bandpass filter 204, the second bandpass filter 206, and the lens 205. The controller 203 establishes an electric connection or communication connection with the light source 201 and the imaging spectrum detection apparatus

separately.

The light source 201 can provide light within a preset wavelength range. Because obtaining the distribution data and spectral data of the analyte requires irradiation by light of different wavelength ranges, there are two implementation
5 manners: a light source 201 that can provide light with a larger wavelength range or two light sources 201 that can respectively provide light with smaller wavelength ranges. When there is one light source 201, the wavelength range of the light provided by the light source 201 needs to cover both the wavelength range within
10 which analyte distribution data can be obtained and the wavelength range within which analyte spectral data can be obtained, such as a halogen lamp. When there are two light sources 201, the two light sources 201 provide different pieces of light. A wavelength range of the analyte distribution data can be obtained through a wavelength coverage of one piece of light, and a wavelength range of the analyte spectral data can be obtained through a wavelength coverage of the other piece of
15 light, such as an infrared lamp combined with an ultraviolet lamp, a visible light lamp combined with an ultraviolet lamp.

To enable the imaging area 100 to be irradiated evenly, a ring-shaped light source 201 may be used. The light source 201 has a plurality of light-emitting modules evenly distributed on a same circumference. When there are two light
20 sources 201, the light-emitting modules of the two light sources 201 are arranged alternately.

The imaging spectrum detection apparatus can image the imaging area 100 based on an instruction to obtain a corresponding image, and can obtain corresponding spectral data based on the instruction. The imaging spectrum
25 detection apparatus includes a sensor and a periodic pixel-level light filtering structure arranged on a surface of the sensor. The periodic pixel-level light filtering structure is configured to perform spectral modulation on an incoming light signal, so that the sensor generates an image containing spectral information to be tested.

The periodic pixel-level light filtering structure includes a plurality of light

filtering image element channels with pixel-level structures of different shapes. The plurality of light filtering image element channels have same specifications and sizes and are evenly arranged, and lengths and widths thereof are integer multiples of a pixel size in an image sensor. Light filtering image element channels of pixel-level light filtering structures of different shapes are corresponding to different spectral filter coefficients, and the pixel-level light filtering structures with different spectral filter coefficients are combined in a fixed order and then arranged periodically. The sensor modulates a received first testing light through the periodic pixel-level light filtering structure arranged on the surface of the sensor, to form a mosaic image containing spectral information, and then reconstructs a grayscale image including the spectral information to be tested using an algorithm.

The controller 203 is configured to control the light source 201 to provide light within a preset wavelength range to irradiate the first area, control the imaging spectrum detection apparatus to image the first area to obtain an image of an imaging area 100, and control the imaging spectrum detection apparatus to obtain, from the image, spectral data that indicate uneven distribution in the imaging area 100 of the reflection signal or excitation signal generated by the analyte when irradiated by light; and obtain information about the analyte in the imaging area 100 based on the obtained spectral data, where the information about the analyte includes information about the analyte correlated to the spectral data. When there is one light source 201, one image is formed. When there are two light sources 201, two images are formed. When the first light source 201 is turned on, the second light source 201 is turned off. Similarly, when the second light source 201 is turned on, the first light source 201 is turned off. The two light sources do not interfere with each other.

The first bandpass filter 204 is located between the light source 201 and the imaging area 100. A function of the first bandpass filter 204 is to allow light within a preset wavelength range to pass through, while cutting off light outside the preset

wavelength range, thereby reducing the impact of other external light on a test result. In this implementation, the ring-shaped first bandpass filter 204 is preferred, and the ring shape of the first bandpass filter 204 is matched with the ring-shaped light source 201, so that light emitted by the light source 201 enters the imaging area 100 through the first bandpass filter 204.

The second bandpass filter 206 is located between the imaging spectrum detection apparatus 202 and the lens 205. A function of the second bandpass filter 206 is to allow light within a wavelength range in which the reflection signal or excitation signal generated by the analyte when irradiated by light is located to pass through, while cutting off light within another wavelength range, thereby reducing the influence of the reflection signal or excitation signal of a non-analyte on the test result.

The lens 205 can be configured to fix focus, to obtain a high-definition image. In another embodiment, the second bandpass filter 206 may alternatively be located on a side of the lens 205 away from the imaging spectrum detection apparatus 202, which is not limited in the present invention.

The system for analyte spectral collection in this embodiment can be integrated into the testing system and the testing device 200. The testing device 200 is a portable non-invasive testing device 200 for a human body, which may be a single testing device 200 or be integrated into a watch or mobile phone, to implement easy and rapid testing of the analyte in the surface of the human body.

As shown in FIG. 2, FIG. 3, FIG. 4 and FIG. 5, for example, the testing device 200 in this embodiment is a watch, the system for testing is integrated in the watch, and the lens 205, the second bandpass filter 206, the light source 201, and the first bandpass filter 204 are arranged sequentially from the inside to the outside. The controller 203 is integrated on a circuit board 207 of the watch, and an opening area that fits the skin of a user's wrist is formed on a back housing of the watch. During testing, the imaging area 100 is a place where the opening area on the back of the watch fits the skin of the user's wrist. The reflection signal or excitation

signal of the human body enters the light-transmitting window, passes through the light source 201 and a hollow part in the middle of the first bandpass filter 204, enters a second bandpass filter 206 through a lens 205, and enters an imaging spectrum detection apparatus 202 after being filtered by the second bandpass filter 206.

Second embodiment

This embodiment provides a method for testing an analyte based on the first embodiment. FIG. 6 is a flow chart of this embodiment, and includes:

Imaging: providing light within a preset wavelength range through a light source to irradiate a first area, and imaging the first area through an imaging spectrum detection apparatus, to obtain an image of an imaging area. The image can demonstrate, during light irradiation within a preset wavelength range, distribution data and spectral data in the imaging area of a reflection signal or an excitation signal generated by the analyte when irradiated by light. The first area may be an area on a surface of a human skin. To prevent the influence of external light such as ambient light on testing, a lens of the imaging spectrum detection apparatus needs to be tightly attached to the surface of the human skin in the first area, and the imaging area means an area within a lens range of the imaging spectrum detection apparatus. In general, the imaging area may be a part of the first area, or may be the same area as the first area.

Because obtaining the distribution data and spectral data of the analyte requires irradiation by light of different wavelength ranges, there are two implementation manners: the light is light with a larger wavelength range provided by one light source or light with smaller wavelength ranges provided by two light sources respectively. When there is one light source, the wavelength range of the light provided by the light source needs to cover both a wavelength range within which analyte distribution data can be obtained and a wavelength range within which analyte spectral data can be obtained. When there are two light sources, the two light sources provide different pieces of light. A wavelength range of the

analyte distribution data can be obtained through a wavelength coverage of one piece of light, and a wavelength range of the analyte spectral data can be obtained through a wavelength coverage of the other piece of light. In addition, when there is one light source, one image is formed; when there are two light sources, two
5 images are formed. For ease of processing, imaging areas of the two images are required to be the same, that is, the lens of the imaging spectrum detection apparatus does not move on the surface of the human skin.

In this application, the analyte may be glucose, ketones, alcohol, lactate, oxygen, hemoglobin A1C, acetylcholine, amylase, bilirubin, cholesterol, chorionic
10 gonadotropin, creatine kinase (such as CK-MB), creatine, creatinine, DNA, fructosamine, glutamine, growth hormone, hormone, peroxide, prostate-specific antigen, prothrombin, RNA, thyroid-stimulating hormone, or troponin in the blood vessel, or may be a drug such as antibiotics (such as gentamicin, vancomycin, or the like), digitoxin, digoxin, drugs of abuse, theophylline, or warfarin. In an
15 implementation in which two or more analytes are tested, the analytes may be tested at the same or different time. In another embodiment, the analyte may alternatively be another substance on the surface of the human body, and non-invasive testing can be implemented according to the present invention.

Spectrum obtaining: obtaining, from the image by the imaging spectrum
20 detection apparatus, spectral data that indicate uneven distribution in the imaging area of the reflection signal or the excitation signal generated by the analyte when irradiated by light. Specifically, the imaging area can be partitioned based on different pieces of distribution data, so that a position of the spectral data can be selected from different partitions.

25 analyzing step: obtaining information about the analyte in the imaging area based on the obtained spectral data, where the information about the analyte includes information about the analyte correlated to the spectral data. Due to a difference in distribution of the analyte in different areas, there is a difference in the reflection signal or excitation signal produced by the analytes when irradiated

by light. For example, the human skin is divided into three parts: an epidermis tissue, a dermis tissue, and a subcutaneous tissue, and blood vessels such as veins are located in the subcutaneous tissue. Corresponding spectral data can be obtained by irradiating a skin area with blood vessels and a skin area without blood vessels
5 irradiated by ultraviolet light, or the corresponding spectral data can be obtained from a skin area with thicker blood vessels and a skin area with thinner blood vessels. Therefore, a difference between the two pieces of spectral data can demonstrate the information about the analyte correlated to the spectral data in the blood vessels, such as intermediate information such as a degree of influence of the
10 analyte on the spectral data for further analysis, or a concentration of the analyte and other information can be obtained directly through the analysis model.

Third embodiment

This embodiment is based on the second embodiment. For example, glucose testing in human blood vessels is used as an example, and a non-invasive glucose
15 testing method is provided, including the following steps.

Imaging: irradiating, by infrared light, skin on the wrist and the back of the hand at which the veins are located, in a first wavelength range of 800–1,000 nm, and collecting the first image of the imaging area, where the first wavelength range is preferably a near-infrared band; and irradiating, by ultraviolet light, a same
20 position in a second wavelength range of 300–390 nm, to obtain the second image of the imaging area.

As shown in FIG. 7, an abscissa is a transverse coordinate of the first image, an ordinate is a longitudinal coordinate of the first image, white boxes represent selected testing point pixel blocks on venous blood vessels, and black boxes
25 represent reference point pixel blocks on surrounding skin. In the first image, some of the infrared light penetrates the human skin and some is absorbed by the human skin, and is also absorbed by the venous blood vessels in large quantities in an area at which the venous blood vessels are located, presenting a characteristic that a pixel grayscale value of the area at which the venous blood vessels are located is

small, and a pixel grayscale value of the area at which non-venous blood vessels are located is large, thereby easily dividing the imaging area into the area at which the venous blood vessels are located and the area at which the non-venous blood vessels are located.

5 As shown in FIG. 8, an abscissa is a transverse coordinate of the second image, an ordinate is a longitudinal coordinate of the second image, white boxes represent selected testing point pixel blocks on the venous blood vessels, and black boxes represent reference point pixel blocks on surrounding skin. In the second image, because it is difficult to distinguish between the area at which the venous
10 blood vessels are located and the area at which the non-venous blood vessels are located, the first image is required for distinguishing. Excitation light in the second wavelength range of 300–390 nm is used to obtain a high-quality effective fluorescence spectral signal. A main response band of the imaging spectrum detection apparatus is 400–800 nm. When the wavelength of the excitation light is
15 less than 300 nm, a main peak of a fluorescence spectrum of the excited fluorescence radiation signal is in a band <400 nm, and it is difficult for the imaging spectrum detection apparatus to obtain the high-quality effective fluorescence spectral signal. When the wavelength of the excitation light used
20 is >390 nm, the excitation light itself is visible light, the spectral signal of the excitation light and the fluorescence spectral signal are superimposed together, and it is difficult to eliminate the interference of the spectral signal of the excitation light and extract the effective fluorescence spectral signal. After absorbing ultraviolet light in the wavelength range of 300–390 nm, glucose in the venous blood vessels can emit a fluorescence radiation signal in a visible light band of
25 400–800 nm, and the band is in an effective response range of the imaging spectrum detection apparatus. A characteristic spectral intensity of the fluorescence radiation signal is positively correlated with the concentration of glucose, which has high fluorescence excitation efficiency.

Spectral obtaining: based on grayscale distribution of pixels in the first image,

dividing the imaging area into the area at which the venous blood vessels are located and the area at which the non-venous blood vessels are located, selecting a testing point from a position corresponding to the second image in the area at which the venous blood vessels are located, selecting a reference point from a position corresponding to the second image in the area at which the non-venous blood vessels are located, and respectively obtaining spectral data of the testing point and spectral data of the reference point in the second image. Specifically, based on a grayscale value of the pixel in the second image, a pixel whose grayscale value meets preset requirements is selected from the area at which the venous blood vessels are located as the testing point, or a combination of the pixel and an adjacent pixel is selected as the testing point, and a pixel whose grayscale value has a deviation from the selected testing point within a preset deviation range is selected from the area at which the non-venous blood vessels are located as the reference point, or a combination of the pixel and a plurality of adjacent pixels is selected as the reference point, and the fluorescence spectral data of the testing point and the fluorescence spectral data of the reference point are calculated in the second image. The spectral data is taken from the testing point, a pixel of the reference point, or a combined average of a plurality of pixels, which can be properly selected based on the width of the blood vessel. The combined average of the plurality of pixels can improve a signal-to-noise ratio, but is limited by the width of the blood vessel, preventing the spectral data from being taken from an extravascular area. Selection of a single pixel leads to high spatial resolution, which is proper for a thin blood vessel, but has a low signal-to-noise ratio. A preset requirement for the grayscale value may be using a point with the smallest grayscale value as the testing point, which is not limited in this application. A calculation result is shown in FIG. 10, an abscissa is the wavelength (in nm), an ordinate is a relative radiance (in W/nm), a solid line is the spectral data of the testing point, and a dashed line is the spectral data of the reference point. The grayscale value of the reference point and the grayscale value of the selected

testing point are within the preset deviation range because the skin in the imaging area may be influenced by skin colors, pigmentation spots, cosmetics, and the like, which has a direct impact on the spectral data of the reference point, and the first image cannot distinguish the area including these influencing factors. These
5 influencing factors can be effectively excluded by setting the preset deviation range of the grayscale value. In addition, the grayscale value and the grayscale value of the selected testing point are within the preset deviation range, which can ensure that the reference point is selected to be close to the testing point, such as an edge of the venous blood vessel. In this way, in addition to the blood vessels, the color,
10 thickness, and other parameters of the epidermis tissue, the dermis tissue, and the subcutaneous tissues are approximately the same, so that a deviation between the spectral data of the testing point and the spectral data of the reference point can be excluded from the influence of a non-analyte as much as possible.

In addition to a spectrum reconstruction algorithm, the spectral data may
15 alternatively be obtained by forming a radiometric calibration coefficient through previous radiometric calibration, and spectral lines are obtained by calculating the grayscale value * radiometric calibration coefficient.

When a combination of a plurality of pixels is selected at the testing point, the fluorescence spectral data at the testing point may be an average of
20 fluorescence spectral data of these pixels. In addition, there may be one or more testing points and reference points. When there is a plurality of testing points and reference points, the average of the fluorescence spectral data of all testing points and the average of the fluorescence spectral data of all reference points can be calculated respectively.

25 analyzing step: preprocessing the obtained spectral data of the testing points and reference points, inputting the preprocessed data into a trained testing model, and outputting a concentration of glucose or an intermediate result of glucose correlated with the spectral data. When the testing model is trained, it is necessary to obtain spectral data and an accurate test result of a tested object, such as a blood

collection test result, the spectral data is used as the input of the testing model, a blood collection test result is used as the output of the testing model, to train the testing model.

5 The testing model may be a convolutional neural network model, including an input layer, at least two convolutional layers, at least two activation function layers, a Flatten layer, a fully connected layer, and an output layer in sequence, and the convolutional layer and the activation function layer are spaced apart. An activation function used for the activation function layer is a Relu function.

10 In the convolutional neural network model, a size of each layer of convolutional kernels is 1, the number of convolutional kernels of a first convolutional layer is 32, and the number of convolutional kernels of a second layer is 64, which are both used to extract blood glucose features, and the output of the convolutional layer is transformed nonlinearly by the activation function. The Flatten layer flattens the output of the convolutional layer into a one-dimensional
15 vector, to connect the subsequent fully connected layers, resulting in a final output dimension of 1. The Adam optimizer is used for model training during model training, a mean square error is used as a loss function, and a mean absolute error is calculated as a performance indicator of model evaluation.

20 When an output result of the testing model is glucose concentration, if an error between the output result and a measured standard glucose concentration value meets a preset condition, training is stopped, to obtain the testing model. When the output result of the testing model is the intermediate result of glucose correlated to the spectral data, such as an intermediate neuron result, if the error between the output result and the intermediate neuron result meets the preset
25 condition, training is stopped to obtain the testing model. The intermediate neuron result is further model-corrected to obtain the concentration of glucose.

As shown in FIG. 9, the input layer is a spectral data input layer, which is obtained after the original spectral data is preprocessed. A hidden layer is a middle hidden layer, and a finally predicted blood glucose concentration value is output in

an output layer after feature combination through convolution operation deep learning. Alternatively, through convolution operation deep learning, a neuron Output1 is output as an intermediate result value after feature combination, and model training is performed again on the intermediate result values Output1 and two infrared IR feature brightness values, to further correct a blood glucose prediction error, and the finally predicted blood glucose concentration value Output2 is output. Different parameters need to be set for a training degree of the testing model according to the needs, and a plurality of extracted glucose eigenvalues are continuously learned based on setting of different parameters, until an error between an output result and a standard glucose value of the above label value meets the requirements, and then training is stopped, to obtain the testing model.

Through a plurality of iterations of training, neurons can learn corresponding changes between different glucose concentrations and glucose spectral characteristics of different sampled objects, thereby improving the universality of the testing model and implementing prediction of glucose concentrations for different users.

In the whole glucose testing process, there is no need to pierce the skin for collecting blood or pierce the skin for implantation, and spectral information of a person to be tested is obtained based on the fluorescence spectrum, and a glucose test result of the person to be tested is obtained based on the spectral information, preventing pain and discomfort, and improving testing comfort and convenience. In the method, a spectral signal for blood vessels and a spectral signal for the skin can be finely distinguished, which provides a possibility for subsequent accurate extraction of a glucose signal, and also enables the spectral signal to be strongly correlated with the glucose concentration, implementing accurate measurement of the glucose concentration, so that a test result is more accurate, and processing is more easily performed.

FIG. 11 shows a schematic diagram of an experimental effect of the trained

testing model, where an abscissa is a reference blood glucose concentration (in mmol/L) collected by a blood glucose meter, and an ordinate is a blood glucose concentration (in mmol/L) predicted in the method in the patent. There are totally 2,037 samples of tested objects, including 1,537 samples from a training set and 500 samples from a prediction set. Distribution of test results for the testing model can be learned from the figure, a MARD value of the predicted samples is 11.32%, and most of the samples fall in areas A and B, among which 87.03% of the samples fall in area A and 12.77% of the samples fall in area B, indicating that testing accuracy of the testing model is high.

Fourth embodiment

This embodiment is based on the third embodiment. Infrared light is replaced with visible light, and another non-invasive method for glucose testing is provided, including the following steps.

Imaging: collecting the first image of the imaging area by irradiating visible light on the skin, such as the wrist and the back of the hand, at which the veins are located; and irradiating, by ultraviolet light, a same position in a second wavelength range of 300–390 nm, to obtain the second image of the imaging area.

In the first image, due to the difference between a color of the area at which the venous blood vessels are located and a color of the area at which the non-venous blood vessels are located, the imaging area can be easily divided into the area at which the venous blood vessels are located and the area at which the non-venous blood vessels are located.

In the second image, because it is difficult to distinguish between the area at which the venous blood vessels are located and the area at which the non-venous blood vessels are located, the first image is required for distinguishing. Excitation light in the second wavelength range of 300–390 nm is used to obtain a high-quality effective fluorescence spectral signal. A main response band of the imaging spectrum detection apparatus is 400–800 nm. When the wavelength of the excitation light is less than 300 nm, a main peak of a fluorescence spectrum of the

excited fluorescence radiation signal is in a band <400 nm, and it is difficult for the imaging spectrum detection apparatus to obtain the high-quality effective fluorescence spectral signal. When the wavelength of the excitation light used is >390 nm, the excitation light itself is visible light, the spectral signal of the excitation light and the fluorescence spectral signal are superimposed together, and it is difficult to eliminate the interference of the spectral signal of the excitation light and extract the effective fluorescence spectral signal. After absorbing ultraviolet light in the wavelength range of 300–390 nm, glucose in the venous blood vessels can emit a fluorescence radiation signal in a visible light band of 400–800 nm, and the band is in an effective response range of the imaging spectrum detection apparatus. A characteristic spectral intensity of the fluorescence radiation signal is positively correlated with the concentration of glucose, which has high fluorescence excitation efficiency.

Spectral obtaining: based on grayscale distribution of pixels in the first image, dividing the imaging area into an area at which the venous blood vessels are located and an area at which the non-venous blood vessels are located, selecting a testing point from a corresponding second image in the area at which the venous blood vessels are located, selecting a reference point from a corresponding second image in the area at which the non-venous blood vessels are located, and respectively obtaining spectral data of the testing point and spectral data of the reference point. Specifically, based on a grayscale value of the pixel in the second image, a pixel whose grayscale value meets preset requirements is selected from the area at which the venous blood vessels are located as the testing point, or a combination of the pixel and an adjacent pixel is selected as the testing point, and a pixel whose grayscale value has a deviation from the selected testing point within a preset deviation range is selected from the area at which the non-venous blood vessels are located as the reference point, or a combination of the pixel and a plurality of adjacent pixels is selected as the reference point, and the fluorescence spectral data of the testing point and the fluorescence spectral data of the reference

point are calculated. The grayscale value of the reference point and the grayscale value of the selected testing point are within the preset deviation range because the skin in the imaging area may be influenced by skin colors, pigmentation spots, cosmetics, and the like, which has a direct impact on the spectral data of the reference point, and the first image cannot distinguish the area including all
5 influencing factors. These influencing factors can be effectively excluded by setting the preset deviation range of the grayscale value.

When a combination of a plurality of pixels is selected at the testing point, the fluorescence spectral data at the testing point may be an average of
10 fluorescence spectral data of these pixels. In addition, there may be one or more testing points and reference points. When there is a plurality of testing points and reference points, the average of the fluorescence spectral data of all testing points and the average of the fluorescence spectral data of all reference points can be calculated respectively.

15 analyzing step: preprocessing the obtained spectral data of the testing points and reference points, inputting the preprocessed data into a trained testing model, and outputting the concentration of glucose. When the testing model is trained, it is necessary to obtain spectral data and an accurate test result of a tested object, such as a blood collection test result, the spectral data is used as the input of the testing
20 model, a blood collection test result is used as the output of the testing model, to train the testing model.

The testing model may be a convolutional neural network model, including an input layer, at least two convolutional layers, at least two activation function layers, a Flatten layer, a fully connected layer, and an output layer in sequence, and
25 the convolutional layer and the activation function layer are spaced apart. An activation function used for the activation function layer is a Relu function.

In the convolutional neural network model, a size of each layer of convolutional kernels is 1, the number of convolutional kernels of a first convolutional layer is 32, and the number of convolutional kernels of a second

layer is 64, which are both used to extract blood glucose features, and the output of the convolutional layer is transformed nonlinearly by the activation function. The Flatten layer flattens the output of the convolutional layer into a one-dimensional vector, to connect the subsequent fully connected layers, resulting in a final output dimension of 1. The Adam optimizer is used for model training during model training, a mean square error is used as a loss function, and a mean absolute error is calculated as a performance indicator of model evaluation.

If an error between the output result of the testing model and a standard glucose concentration meets a preset condition, training is stopped, to obtain the testing model.

Different parameters need to be set for a training degree of the testing model according to the needs, and a plurality of extracted glucose eigenvalues are continuously learned based on setting of different parameters, until an error between an output result and a standard glucose value of the above label value meets the requirements, and then training is stopped, to obtain the testing model.

Through a plurality of iterations of training, neurons can learn corresponding changes between different glucose concentrations and glucose spectral characteristics of different sampled objects, thereby improving the universality of the testing model and implementing prediction of glucose concentrations for different users.

In the whole glucose testing process, there is no need to collect blood or pierce the skin, and spectral information of a person to be tested is obtained based on the fluorescence spectrum, and a glucose test result of the person to be tested is obtained based on the spectral information, preventing pain and discomfort, and improving testing comfort and convenience. In the method, a spectral signal for blood vessels and a spectral signal for the skin can be finely distinguished, which provides a possibility for subsequent accurate extraction of a glucose signal, and also enables the spectral signal to be strongly correlated with the glucose concentration, implementing accurate measurement of the glucose concentration, so

that a test result is more accurate, and processing is more easily performed.

Fifth embodiment

This embodiment provides a system for testing an analyte based on the first embodiment. The system for testing an analyte can be implemented by performing
5 flow steps of the method for testing an analyte. In other words, those skilled in the art can understand the method for testing an analyte as a preferred implementation of the system for testing an analyte. The system for testing an analyte includes the following modules.

An imaging module, configured to provide light within a preset wavelength
10 range through a light source to irradiate a first area, and image the first area through an imaging spectrum detection apparatus, to obtain an image of an imaging area. The image can demonstrate, during light irradiation within a preset wavelength range, distribution data and spectral data in the imaging area of a reflection signal or an excitation signal generated by the analyte when irradiated by
15 light. Because different wavelength ranges are required to obtain distribution data and spectral data of the analyte, the light may be either light corresponding to two wavelength ranges or light with a larger wavelength range that covers the two desired wavelength ranges. When there are two pieces of light, there are two obtained images. To facilitate processing, it is usually required that imaging areas
20 of the two images be the same.

In this application, the analyte may be glucose, ketones, alcohol, lactate, oxygen, hemoglobin A1C, acetylcholine, amylase, bilirubin, cholesterol, chorionic gonadotropin, creatine kinase (such as CK-MB), creatine, creatinine, DNA, fructosamine, glutamine, growth hormone, hormone, peroxide, prostate-specific
25 antigen, prothrombin, RNA, thyroid-stimulating hormone, or troponin in the blood vessel of an animal, or may be a drug such as antibiotics (such as gentamicin, vancomycin, or the like), digitoxin, digoxin, drugs of abuse, theophylline, and warfarin. In an implementation in which one or more analytes are tested, the analytes may be tested at the same or different time. In other embodiments, the

analyte may alternatively be another substance in liquid.

A spectral obtaining module, configured to obtain, from the image by the imaging spectrum detection apparatus, spectral data that indicate uneven distribution in the imaging area of the reflection signal or the excitation signal generated by the analyte when irradiated by light. Specifically, the imaging area can be partitioned based on different pieces of distribution data, so that a position of the spectral data can be selected from different partitions.

An analysis module, configured to obtain information about the analyte in the imaging area based on the obtained spectral data, where the information about the analyte includes information about the analyte correlated to the spectral data. Due to a difference in distribution of the analyte in different areas, there is a difference in the reflection signal or excitation signal produced by the analytes when irradiated by light. With this feature, the difference between the two pieces of spectral data can be obtained, to accurately demonstrate the information about the analyte correlated to the spectral data, such as the concentration of the analyte.

Those skilled in the art know that, in addition to implementing the system provided in the present invention and each apparatus, module, and unit thereof in a purely computer-readable program code mode, the system provided in the present invention and each apparatus, module, and unit thereof can be enabled to implement same functions in the form of logic gates, switches, application-specific integrated circuits, programmable logic controllers, and embedded microcontrollers by performing logic programming of the method steps. Therefore, the system provided in the present invention and each apparatus, module, and unit thereof may be regarded as hardware components, and each apparatus, module, and unit thereof for implementing various functions may also be regarded as structures within the hardware components; and each apparatus, module, and unit thereof for implementing various functions may alternatively be regarded as software modules for implementing methods or structures within the hardware components.

Sixth embodiment

This embodiment provides a schematic structural diagram of an electronic device based on the first embodiment. As shown in FIG. 12, the electronic device includes at least one processor 501 and a memory 502 that is in communication connection with the at least one processor 501. The memory 502 stores instructions that can be executed by the at least one processor 501. The instructions are executed by the at least one processor 501, so that the at least one processor 501 can perform the above method for testing an analyte.

The memory 502 and the processor 501 are connected using a bus. The bus may include interconnected buses and bridges of any quantities. The bus connects various circuits of one or more processors 501 and memories 502. The bus may further connect a peripheral device, a voltage regulator, and various other circuits such as a power management circuit, which are all well known in the art and are not further described in the present invention. A bus interface provides an interface between the bus and a transceiver. The transceiver may be one component or a plurality of components, for example, a plurality of receivers and transmitters, to provide a unit that is configured to communicate with various other apparatuses on a transmission medium. Data processed by the processor 501 is transmitted on a wireless medium by using the antenna. Further, the antenna further receives data and transmits the data to the processor 501.

The processor 501 is responsible for managing the bus and general processing, and may further provide various functions, including timing, peripheral interfacing, voltage regulation, power management, and another control function. The memory 502 may be configured to store data used by the processor 501 when performing an operation.

The present invention also provides a computer-readable storage medium that stores a computer program, and when the computer program is executed by a processor, the above method for testing an analyte is implemented.

To be specific, those skilled in the art can understand that all or some of steps in the method of the above embodiments can be completed by instructing relevant

hardware through a program. The program is stored in a storage medium and includes several instructions to enable a device (which may be a single-chip microcontroller, a chip, or the like) or a processor (processor) to perform all or some of the steps of the method described in various embodiments of this application. The above storage medium includes any medium that can store program code, such as a USB flash drive, a removable hard disk, a read-only memory (ROM, Read-Only Memory), a random access memory (RAM, Random Access Memory), a magnetic disk, or an optical disc.

Those skilled in the art can understand that the above implementations are specific embodiments for implementing the present invention, and in actual application, various changes may be made thereto in form and detail without departing from the spirit and scope of the present invention.

In the descriptions of this application, it should be understood that an orientation or a position relationship indicated by the terms "above", "below", "front", "back", "left", "right", "vertical", "horizontal", "top", "bottom", "inside", "outside", and the like is based on an orientation or a position relationship shown in the accompanying drawings, and is merely intended for ease of describing this application and simplifying description, but does not indicate or imply that a described apparatus or element needs to have a specific orientation or be constructed and operated in a specific orientation. Therefore, such terms shall not be understood as a limitation on this application.

Specific embodiments of the present invention are described above. It should be understood that the present invention is not limited to the foregoing specific implementations. Those skilled in the art can make various variations or modifications within the scope of the claims, which does not affect the essence of the present invention. Embodiments in this application and the features in embodiments may be arbitrarily and mutually combined in the case of no conflict.

CLAIMS

1. A system for analyte spectral collection, comprising a shell and an imaging spectrum detection apparatus (202), wherein the shell is capable of fitting a tested part of a tested object and forming an imaging area (100) at a fitting position;

5 the imaging spectrum detection apparatus obtains a light signal from the imaging area (100), the imaging spectrum detection apparatus comprises a sensor and a periodic pixel-level light filtering structure, and the periodic pixel-level light filtering structure is disposed on a surface of the sensor; and

 the periodic pixel-level light filtering structure performs spectral modulation on an
10 incoming light signal, and the sensor generates an image comprising spectral information to be tested.

2. The system for analyte spectral collection according to claim 1, wherein the periodic pixel-level light filtering structure comprises a plurality of light filtering image
15 element channels with pixel-level light filtering structures of different shapes, the light filtering image element channels with pixel-level light filtering structures of different shapes correspond to different spectral filter coefficients, and the pixel-level light filtering structures with different spectral filter coefficients are combined in a fixed order and then arranged periodically.

20

3. The system for analyte spectral collection according to claim 2, wherein specifications and sizes of all light filtering image element channels are the same and evenly arranged.

4. The system for analyte spectral collection according to claim 2, wherein a length or width of any light filtering image element channel is an integer multiple of a pixel size within the sensor.

5 5. The system for analyte spectral collection according to claim 1, further comprising a lens (205), wherein the light signal from the imaging area (100) enters the imaging spectrum detection apparatus after passing through the lens (205).

6. The system for analyte spectral collection according to claim 5, further
10 comprising a second bandpass filter (206), which is located between the lens (205) and the imaging spectrum detection apparatus (202); and

the second bandpass filter (206) allows light within a preset wavelength range to pass through and light outside the preset wavelength range to be cut off.

15 7. The system for analyte spectral collection according to claim 1, wherein light signals in the imaging area (100) comprise a reflection signal generated by the analyte when irradiated by light and an excitation signal generated by the analyte when irradiated by light.

20 8. The system for analyte spectral collection according to claim 1, wherein an image generated by the sensor and comprising spectral information to be tested comprises spectral data that indicate uneven distribution of a reflection signal in the imaging area (100) and/or spectral data that indicate uneven distribution of an excitation signal in the imaging area (100).

9. A system for testing an analyte, comprising the system for analyte spectral collection according to any one of claims 1 to 8.

5 10. The system for testing an analyte according to claim 9, further comprising a portable apparatus, wherein the system for analyte spectral collection is integrated in the portable apparatus.