Summary

Therefore, it was an object of the present disclosure to provide a device and a method for forming at least one ground truth database for an object recognition system and for keeping the at least one ground truth database current.

The present disclosure provides a device and a method with the features of the independent claims. Examples are subject of the dependent claims and the description and drawings.

Therefore, in an aspect, a device is provided for forming at least one ground truth database for an object recognition system and for keeping the at least one ground truth database current, the device comprising at least the following components:

a) at least one data storage unit configured to store color space positions/coordinates and/or reflectance spectra and/or luminescence spectra of different objects; and
b) a processor programmed for communication with the data storage unit, i. e. the processor is in a communicative connection with the data storage unit, and with the object recognition system, the processor programmed for:

- receiving, via a communication interface, color space positions/coordinates and/or reflectance spectra and/or luminescence spectra of different objects,
- assigning each received color space position and/or reflectance and/or luminescence spectrum to one of the different objects as a tag,
- storing the color space positions and/or reflectance and/or luminescence spectra together with the respective different objects the color space positions and/or reflectance and/or luminescence spectra are assigned to, respectively, in the at least one data storage unit, thus forming the at least one ground truth database,
- monitoring, by using at least one sensor and/or artificial intelligence tools, both being connected with or integrated in the processor, a

database. Online order/confirmation email of a new household item could be a triggering event to add the item to the at least one ground truth database. A new item (object) that is visible entering through the door enabled with a camera (as sensor means) would induce the processor to recognize the entry and add the item to the at least one ground truth database. Similarly an item (object) exiting through the door would trigger to remove that item from the at least one ground truth database. When a shopping list item is added to the list on an AI (artificial intelligence) device such as a smart speaker, that item can be added to the at least one ground database, i. e. the addition of the shopping list item is the triggering event. The AI device functions as all-in-one device suitable for detecting and identifying a triggering and/or recognition event.

The proposed device provides at least one ground truth database for a surface chemistry/color-based object recognition system. The disclosure addresses issues relating to color fading or shifting in ground truth database formation for chemistry/color space-based object recognition systems in computer vision applications. It is proposed to utilize luminescent or color space-based object recognition techniques and specifically to manage the color space or reflective/luminescent spectra that are used as respective tags for objects of interest by specifically designing color space specifications to include not only the original color space position of each object and its standard deviation but also a degradation path and a surrounding space with the associated standard deviation. Furthermore, the proposed device describes how the computer vision system utilizing color/chemistry-based recognition techniques can be used to update the ground truth database dynamically to increase recognition performance.

It is further possible to include use of 3D location clusters of the objects of interest to improve the accuracy of object recognition predictions by continuously monitoring any shifts of color in recognition articles (objects) of interest.

Within the scope of the present disclosure the terms "fluorescent" and "luminescent" are used synonymously. The same applies to the terms "fluorescence" and "luminescence".

According to one further example, the proposed device comprises the processor programmed for providing as the at least one ground truth database a master database and a local database, the local database being in conjunction, i. e. in communicative connection with the master database. Further, the color space positions and/or the reflectance spectra and/or luminescence spectra stored in the local database are updated and/or supplemented over time by receiving from the object recognition system re-measured respective color space positions and/or reflectance spectra and/or luminescence spectra for the different objects in the scene and, thus, small and continuous changes of the respective objects are at least tracked in the local database.

Specifically, the local database is stored locally in the scene or on a cloud server, the local database being only accessible for the object recognition system which is locally used in the scene. The master database is accessible for all object recognition systems which have subscribed to use any of the ground truth databases formed by the proposed device, i.e. which have been authorized to use those databases by subscription.

According to one further example the device comprises the processor programmed for tracking the small and continuous changes of the respective objects by monitoring changes in fluorescence emission magnitude and/or fluorescence emission spectral shapes of the respective objects.

The device further comprises the processor programmed for supplementing the local database by a color space position and/or a reflectance spectrum and/or luminescence spectrum of an object by using the master database when the object is new in the scene (newly entering the scene) and the new object's color

Similarly, the object may be "retired" by removing it from the local database when it is disposed of at the end of its useful life. Alternatively or additionally, another database can be formed to track the color positions of the objects that are discarded in a recycling bin, trash bin or other physical space that may be used in future tasks such as sorting / separation of recyclables and / or different types of waste for efficient processing.

According to a further example of the disclosure, the master database comprises for each of the different objects color space position and/or reflectance spectrum and/or luminescence spectrum of the original object and color space position and/or reflectance spectrum and/or luminescence spectrum of at least one degraded/aged object descending from the original object.

An object can be imparted, i. e. provided with luminescent, particularly fluorescent materials in a variety of methods. Fluorescent materials may be dispersed in a coating that may be applied through methods such as spray coating, dip coating, coil coating, roll-to-roll coating, and others. The fluorescent material may be printed onto the object. The fluorescent material may be dispersed into the object and extruded, molded, or cast. Some materials and objects are naturally fluorescent and may be recognized with the proposed system and/or method. Some biological materials (vegetables, fruits, bacteria, tissue, proteins, etc.) may be genetically engineered to be fluorescent. Some objects may be made fluorescent by the addition of fluorescent proteins in any of the ways mentioned herein. The color positions and/or the reflectance and fluorescence spectra of different objects may be measured by at least one camera and/or at least one spectrophotometer or a combination thereof, and provided to the processor for forming the at least one ground truth database.

Many fluorescent and reflective materials degrade over time with exposure to light (particularly ultraviolet light) or oxygen. Most of these materials have their fluorescence emission reduced in magnitude, but some may undergo changes in their fluorescence emission spectral shapes, i.e. in their fluorescence spectra.

In the first case, beyond the difficulty of measuring lower amounts of fluorescence emission amounts, difficulties of matching a known fluorescence spectrum in a database may occur if multiple fluorescent materials with different degradation rates are present in the scene. In the second case, the problem of matching a changed fluorescence spectrum to a database of original spectra is obvious. Therefore, it is proposed that the master database comprises for each original object at least color space position and/or reflectance spectrum and/or luminescence spectrum of at least one degraded/aged object descending from the original object.

The disclosure proposes to include a local database in conjunction (in communicative connection) with a master database. A new object in the scene would initially be classified with the master database on the assumption that the object has a non-degraded spectrum. Once detected, the object can be included in the local database for quicker identification in the future. Additionally, the spectra of the object measured by the object recognition system can be updated over time, so that small and continuous changes of the object are tracked in the local database. At the end of an object's useful life (end of use recognition event), it may be identified correctly by the local database despite its current emission spectra better matching (in the meantime) another object's original emission spectra in the master database.

An object need not always be in view of the sensor. For example, the sensor may be located in a kitchen pantry where an object is first identified. The object may be removed for a period of time (i.e. dinner preparation) and then replaced. The object would not be removed from the local database while it was out of view of the sensor, so it would still be recognized when returned. It will only be removed from the local database when it is absent from the scene (out of view of the sensor) for a predefined period of time. Such period of time can be defined with respect to normal habits.

It is to be stated that the local database need not be stored locally, it may still be cloud based, but only the local scene, i. e. the object recognition system locally used, will have access to it. There may be multiple local databases in various locations / areas and these local databases may overlap in some cases.

As mentioned above, another possible example of the proposed device is for the master database to include aged/included samples of respective objects. The master database will first match to the original samples of the respective objects. However, over time, the master database will make comparisons to the aged/degraded samples that are the approximate age of the observed objects. Therefore, an exchange between the local database and the master database is necessary.

Each communicative connection between any of above mentioned components, such as between the processor and the data storage unit, between the processor and the object recognition system, between the processor and the measuring device, between the processor and the sensor means and between the local database and the master database, may be a wired or a wireless connection. Each suitable communication technology may be used. The respective component, such as the local database and the master database, each may include one or more communication interface for communicating with each other. Such communication may be executed using a wired data transmission protocol, such as fiber distributed data interface (FDDI), digital subscriber line (DSL), Ethernet, asynchronous transfer mode (ATM), or any other wired transmission protocol. Alternatively, the communication may be wirelessly via wireless communication networks using any of a variety of protocols, such as General Packet Radio Service (GPRS), Universal Mobile Telecommunications System (UMTS), Code Division Multiple Access (CDMA), Long Term Evolution (LTE), wireless Universal Serial Bus (USB), and/or any other wireless protocol. The respective communication may be a combination of a wireless and a wired communication.

To realize such matching algorithm between a spectrum observed in a scene and a spectrum in the local database and/or the master database, confidence threshold and error thresholds are required. For example, a match between a spectrum observed in a scene and a spectrum in the local database and/or in the master database must meet the confidence threshold to enable an identification of the object associated with the measured spectrum. However, there may still be some error between the measured/observed spectrum and the assigned/stored spectrum for one and the same object. If this error is greater than the error threshold, then the spectra in the local database and/or in the master database may need to be updated.

Other improvements may also be added to the device by asking a user to select from possible object recognitions/identifications (either in the local database and/or in the master database) via a user interface coupled with the processor. The user interface may be realized by an input and output device, e.g. a graphical user interface or an acoustic interface. There may be a display for displaying the respective inquiries. Alternatively, a loudspeaker could output any selection from which a user is asked to select one or more of the possible identifications. The respective user input can be realized via a GUI and/or a microphone. The user feedback is used to improve the accuracy of future identifications within the databases, particularly within the local database. Alternatively, the device may ask via the user interface the user if a specific chosen identification is correct and use the feedback to improve future identifications with the local database.

In another aspect, there is provided a computer-implemented method for forming at least one ground truth database for an object recognition system and for keeping the at least one ground truth database current, the method comprising at least the following steps:

- providing via a communications interface color space positions/coordinates and/or reflectance spectra and/or luminescence

The triggering and/or recognition event may be realized by one or more new objects visibly entering the scene and/or by changed respective color space positions and/or spectra for one or more of the different objects located in the scene which have been re-measured by the object recognition system.

For the monitoring step, sensor means, particularly a camera, and artificial intelligence tools may be provided, both, the sensor means and the artificial intelligence tools are in communicative connection with or integrated in the processor, thus enabling the processor to detect, by means of the sensor means, and to identify, by means of respective artificial intelligence tools, the triggering event. The artificial intelligence tools are trained and configured to use input from the sensor means, such as cameras, microphones, wireless signals, to deduce the triggering and/or recognition event. Thus, the processor is configured to announce at least one object which is to be added to or deleted from at least one of the at least one ground truth database as a direct or indirect result of the triggering and/or recognition event. The artificial intelligence tools comprise or may have access to triggering and/or recognition events or at least basic information about them which have been trained before and rules for conclusions. The artificial intelligence tools and/or the sensor means can be integrated in the processor. The artificial intelligence tools may be realized via an accordingly trained neural network.

According to an example of the proposed method, the method further comprises providing as the at least one ground truth database a master database and a local database, the local database being in conjunction (in communicative connection) with the master database. The color space positions and/or the reflectance spectra and/or luminescence spectra stored in the local database are updated and/or supplemented over time by re-measuring, by the object recognition system, the respective color space positions and/or the reflectance spectra and/or luminescence spectra for the different objects in the scene or by monitoring the scene for new objects entering the scene or by recognizing the occurrence of a further triggering

and/or recognition event, and, thus, small and continuous changes in the scene are at least tracked in the local database.

The local database may be stored locally in the scene or on a cloud server, the local database being only accessible for the object recognition system which is locally used in the scene.

According to a further example of the proposed method, the small and continuous changes of the respective objects are tracked by monitoring changes in fluorescence emission magnitude/amplitude and/or fluorescence emission spectral shape of the fluorescence spectrum of the respective objects.

The local database may be supplemented by a color space position and/or a reflectance spectrum and/or luminescence spectrum of an object by using the master database when the object is new in the scene and the new object's color space position and/or reflectance spectrum and/or luminescence spectrum measured by the locally used object recognition system can be matched to a color space position and/or a reflectance spectrum and/or luminescence spectrum of an object stored in the master database.

The master database and the local database are synchronized regarding the different objects in the scene within predefined time intervals or when at least one of a number of predefined events occurs. Such time intervals for updates can be hours, days, weeks or months depending on the object.

The master database comprises for each of the different objects color space position and/or reflectance spectrum and/or luminescence spectrum of the original object and color space position and/or reflectance spectrum and/or luminescence spectrum of at least one degraded/aged object descending from the original object.

In another aspect, there is provided a non-transitory computer-readable medium storing instructions that, when executed by one or more processors, cause a machine to:

- receive, via a communication interface, color space positions/coordinates and/or reflectance spectra and/or luminescence spectra of different objects,
- assign each color space position and/or reflectance spectrum and/or luminescence spectrum to one of the different objects as a tag,
- store the color space positions and/or reflectance spectra and/or luminescence spectra together with the respective different objects the color space positions and/or reflectance spectra and/or luminescence spectra are assigned to, respectively, in a data storage unit, thus forming at least one ground truth database,
- monitor, by using at least one sensor and/or artificial intelligence tools, a scene which includes at least some of the different objects for the occurrence of a triggering and/or recognition event,
- update and/or supplement dynamically, if necessary, in at least one of the at least one database the color space positions and/or the reflectance spectra and/or luminescence spectra stored in the at least one database in the case the triggering and/or recognition event occurs, thus, tracking small and continuous changes in the scene in the at least one of the at least one database, and
- provide immediate access to the up-to-date color positions and/or reflectance spectra and/or luminescence spectra.

Such triggering and/or recognition event can be given by new objects visibly entering the scene and/or by receiving respective re-measured color positions and/or spectra for the different objects located in the scene.

Further, a respective computer program product having instructions that are executable by one or more processors, is provided, the instructions cause a machine to perform the above mentioned method steps.

The processor may include or may be in communication, i. e. in communicative connection with one or more input units, such as a touch screen, an audio input, a movement input, a mouse, a keypad input and/or the like. Further the processor may include or may be in communication with one or more output units, such as an audio output, a video output, screen/display output, and/or the like.

Examples of the disclosure may be used with or incorporated in a computer system that may be a standalone unit or include one or more remote terminals or devices in communication with a central computer, located, for example, in a cloud, via a network such as, for example, the Internet or an intranet. As such, the data processing unit/processor described herein and related components may be a portion of a local computer system or a remote computer or an online system or a combination thereof. The database, i.e. the data storage unit and software described herein may be stored in computer internal memory or in a non-transitory computer readable medium.

The disclosure is further defined in the following examples. It should be understood that these examples, by indicating preferred examples of the disclosure, are given by way of illustration only. From the above discussion and the examples, one skilled in the art can ascertain the essential characteristics of this disclosure and without departing from the spirit and scope thereof, can make various changes and modifications of the disclosure to adapt it to various uses and conditions.

Brief description of the drawings

Figure 1 shows schematically a flowchart of method for object recognition using at least one ground truth database formed and updated using one embodiment of the proposed device and/or of the proposed method.