application, the latter being only possible if data loads are small. When edge computing is used with heavy processing, the devices operating the systems get bulkier and limit ease of use and therefore implementation.

Thus, a need exists for systems and methods that are suitable for improving object recognition capabilities for computer vision applications.

Summary

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

In an aspect, there is provided a system for object recognition via a computer vision application is provided, the system comprising at least the following components:

- at least one object to be recognized, the object having an object specific reflectance spectral pattern and an object specific luminescence spectral pattern,
- a natural and/or artificial light source which is configured to illuminate a scene including the at least one object, the light source being designed to omit at least one spectral band of a spectral range of light when illuminating the scene, the at least one omitted spectral band being in the luminescence spectral pattern of the at least one object,
- a sensor which is configured to measure radiance data of the scene including the at least one object when the scene is illuminated by the light source, and to read at the at least one omitted spectral band,
- a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- a data processing unit which is configured to calculate/extract/derive the object specific luminescence spectral pattern of the at least one object to be recognized from the measured radiance data of the scene

within the at least one omitted spectral band and to match the calculated/extracted/derived object specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit, and to identify a best matching luminescence spectral pattern and, thus, its assigned object.

According to one possible embodiment of the system, the light source is a LED light source which is configured to intentionally and intrinsically leave out (omit) the at least one individual spectral band of the spectral range of light when illuminating the scene. The LED light source can be composed of a plurality of narrow band LEDs, each LED being configured to emit light in a narrow spectral band, the spectral bands of the LEDs being spaced apart from each other with omitted individual spectral bands in between them.

In a further example of the proposed system, the light source is equipped with at least one light filter, the at least one light filter being designed to block the at least one individual spectral band of the spectral range of light from entering the scene.

The term "individual spectral band", in the following also simply called "spectral band", indicates a spectral band spanning only one or a comparatively small number of successive wavelengths of light within the spectral range of light which span a comparatively higher number of successive wavelengths of light.

Within the scope of the present disclosure ambient light can be either natural light or artificial/room light, but normally not both. In some cases, it can be both and both can be filtered at the same spectral bands. One of such cases is given when sun is shining through a window of a room and the room is further illuminated by a light bulb. Natural light can be, for example, sun light, moon light, light of stars, etc. Artificial light may be light from bulbs, etc.

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 example of the present disclosure, the at least one light filter is designed as a dynamic light filter which is configured to block at least one spectral band of light from entering the scene at a time and to change the at least one spectral band which is to be blocked dynamically, thus blocking at least one portion of the spectral range of light over time.

It is possible to pre-give a plurality of individual spectral bands, each spectral band being in the luminescence spectral pattern of the at least one object, and to let the system randomly choose which spectral band(s) to be omitted/blocked when illuminating the scene. Such selection is performed by choosing and/or activating at least one suitable light source among a plurality of light sources, each light source of the plurality of light sources being configured to omit a spectral band of the plurality of spectral bands, and/or to control a light source which is configured to omit/block all the spectral bands of the plurality of spectral bands selectively, so that the light source omits one or more of the spectral bands randomly (activating/deactivating a filter with which the light source is equipped and/or to activating/choosing one or more single LEDs of a LED light source).

Further, the dynamic light filter is configured to continuously operate over the light spectral range of interest and to provide blocking of at least one band of interest on demand, particularly at wavelengths covered by the luminescence spectral pattern of the at least one object.

According to a further embodiment of the proposed system, the system comprises a plurality of dynamic light filters on the same natural and/or artificial light source and/or on multiple natural or artificial light sources illuminating the

multispectral camera, or a hyperspectral camera. The sensor may be a combination of any of the above, or the combination of any of the above with a tuneable or selectable filter set, such as, for example, a monochrome sensor with specific filters. The sensor may measure a single pixel of the scene, or measure many pixels at once. The optical sensor may be configured to count photons in a specific range of spectrum, particularly in more than three bands. It may be a camera with multiple pixels for a large field of view, particularly simultaneously reading all bands or different bands at different times.

A multispectral camera captures image data within specific wavelength ranges across the electromagnetic spectrum. The wavelengths may be separated by filters or by the use of instruments that are sensitive to particular wavelengths, including light from frequencies beyond the visible light range, i.e. infrared and ultra-violet. Spectral imaging can allow extraction of additional information the human eye fails to capture with its receptors for red, green and blue. A multispectral camera measures light in a small number (typically 3 to 15) of spectral bands. A hyperspectral camera is a special case of spectral camera where often hundreds of contiguous spectral bands are available.

In a further example, the data processing unit is configured to calculate the object specific luminescence spectral pattern of the at least one object to be recognized based on the radiance data of the scene within the spectral bands that are omitted/blocked/filtered, e. g. based on the spectral distribution of the at least one light filter, and to match the calculated object specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit, and to identify a best matching luminescence spectral pattern and, thus, its assigned object.

In another aspect, the present disclosure further refers to a method for object recognition via a computer vision application, the method comprising at least the following steps:

- providing an object to be recognized, the object having object specific reflectance and luminescence spectral patterns,

- illuminating a scene including the object using a natural and/or artificial light source, the light source being designed to omit at least one individual spectral band of a spectral range of light from when illuminating the scene, the at least one spectral band being adapted to the luminescence spectral pattern of the at least one object and covering at least one wavelength of the luminescence spectral pattern, i.e. the at least one filtered spectral band being in the luminescent spectral range of the object,
- measuring, by means of a sensor, radiance data of the scene including the object when the scene is illuminated by the light source, and reading at the at least one omitted spectral band,
- providing a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- extracting, by means of a data processing unit, the object specific luminescence spectral pattern of the object to be recognized out of the measured radiance data of the scene,
- matching the extracted object specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit, and
- identifying a best matching luminescence spectral pattern and, thus, its assigned object.

According to one example of the proposed method, the light source is equipped with at least one light filter which is designed to block the at least one individual spectral band. Alternatively, the light source is chosen as a LED light source with one or more LEDs, each LED being configured to emit light in a narrow spectral band, the spectral bands of the LEDs being spaced apart from each other with omitted individual spectral bands in between them.

In a further example, the method further comprises choosing the at least one light filter as a dynamic filter and scanning the light spectral range of interest and providing blocking at a wavelength/spectral band of interest on demand,

particularly at wavelengths covered by the luminescence spectral pattern of the at least one object.

According to still a further example, the proposed method comprises choosing the at least one light filter as a notch filter which is configured to block at least one distinct spectral band permanently, particularly to block a plurality of distinct spectral bands within the spectral range of light. The notch filter may be configured to block light entering the scene from a window as in natural lighting or an artificial lighting element at at least one distinct spectral band continuously.

According to still another example of the proposed method, extracting the object specific luminescence spectral pattern comprises calculating the object specific luminescence spectral pattern of the at least one object to be recognized based on the radiance data of the scene within the at least one spectral band that is omitted, e. g. based on the spectral distribution of the at least one light filter and the measured radiance data of the scene and matching the calculated object specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit, and identifying a best matching luminescence spectral pattern and, thus, its assigned object.

Generally, at least the light source, the sensor, the data processing unit and the data storage unit (the database) are networked among each other via respective communicative connections. Thus, each of the communicative connections between the different components of the monitoring device may be a direct connection or an indirect connection, respectively. Each communicative connection may be a wired or a wireless connection. Each suitable communication technology may be used. The data processing unit, the sensor, the data storage unit, the light source, each may include one or more communications interfaces 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.

The data processing unit may include or may be 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 data processing unit may include or may be in communication, i. e. in communicative connection 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 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-transistory computer readable medium. Within the scope of the present disclosure the database may be part of the data storage unit or may represent the data storage unit itself. The terms "database" and "data storage unit" are used synonymously.

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:

- provide an object to be recognized, the object having object specific reflectance and luminescence spectral patterns,

- illuminate a scene including the object using a light source, the light source being designed to omit at least one spectral band of a spectral range of light when illuminating the scene, the at least one omitted spectral band being in the luminescence spectral pattern of the at least one object,
- measure radiance data of the scene exclusively at the at least one omitted spectral band when the scene is illuminated by the light source,
- provide a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- extract the object specific luminescence spectral pattern of the object to be recognized out of the measured radiance data of the scene, and
- match the extracted object specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit, and
- identify a best matching luminescence spectral pattern and, thus, its assigned object.

The present disclosure further refers to a computer program product having instructions that are executable by a computer, the computer program product comprising instructions to:

- provide an object to be recognized, the object having object specific reflectance and luminescence spectral patterns,
- illuminate a scene including the object using a natural and/or artificial light source, the light source being designed to omit at least one individual spectral band of a spectral range of light when illuminating the scene, the at least one spectral band being adapted to the luminescence spectral pattern of the at least one object and covering at least one wavelength of the luminescence spectral pattern, i. e. the at least one omitted spectral band being in the luminescent spectral range of the object,
- measure radiance data of the scene including the object when the scene is illuminated by the light source, and to read at the at least one filtered spectral band,
- provide a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- extract the object specific luminescence spectral pattern of the object to be recognized out of the measured radiance data of the scene, and
- match the extracted object specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit, and
- identify a best matching luminescence spectral pattern and, thus, its assigned object.

The light source may be equipped with at least one light filter that is designed to block the at least one individual spectral band from entring the scene.

In one example, the computer program product further having instructions to calculate the object specific luminescence spectral pattern of the at least one object to be recognized based on the radiance data of the scene within the at least one spectral band and to match the calculated object specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit, and to identify a best matching luminescence spectral pattern and, thus, its assigned object.

The present disclosure describes a system and a method to detect a fluorescence emission spectrum of an object/material within a scene under unchanging (steady state) ambient lighting conditions. The system may comprise notch filters applied to sources of light in an indoor space (light bulbs of various types and/or windows, etc.), or dark or low ambient light conditions outdoor using the same filtered light sources, a sensor/camera capable of scanning the scene and recording responses over the scene at different wavelength ranges, and a data processing unit configured to calculate the fluorescence emission spectrum based on the spectral distribution of the notch filters, i. e. based on the measured radiance data from the sensor/camera which has been measured within the omitted spectral bands of the light source. Alternatively, the system can be built using dynamic light filters placed on sources of light for a scene that can block portions of the light spectrum at a time and scan the spectral range over time. If multiple dynamic light filters are used for the system, each filter can be synchronized to block the same spectral band(s) simultaneously for accommodating luminescence readings of the target object at that blocked spectral band(s). It is also possible that multiple different spectral bands are blocked simultaneously. Alternatively, the light source is chosen as a LED light source with one or more LEDs, each LED being configured to emit light in a narrow spectral band, the spectral bands of the LEDs being spaced apart from each other with omitted individual spectral bands in between them. The system further includes a data storage unit with a database of luminescent materials/objects and a data/computer processing unit that computes the spectral match of such luminescent objects using various algorithms. The proposed system and method enable color space-based object recognition using luminescent objects/materials for indoor environments as well as low light outdoor environments with or without sunlight entering the scene and without the need for high frequency variable illumination source.

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

Fig. 1a shows a schematic diagram of an unfiltered illuminant spectrum and a notch filter transmission spectrum;

Fig. 1b shows a schematic diagram of a resulting illuminant spectrum after filtration, i.e. a superimposing of the unfiltered illuminant spectrum and the notch filter transmission spectrum of Fig. 1a.

Fig. 2 shows a schematic diagram of a notch filter transmission spectrum and one sensor band being located within each notch filter blocking band,

Fig. 3 shows a schematic diagram of a notch filter transmission spectrum and multiple sensor bands being located within each notch filter blocking band

Fig. 4 shows schematically one embodiment of the proposed system.

Detailed description of the drawings

Figure 1a shows a diagram with a horizontal axis 101 and two vertical axes 102 and 103. The diagram is shown for an embodiment of the proposed system for object recognition via a computer vision application. The system comprises at least a natural and/or artificial light source which comprises at least one illuminant to illuminate a scene including at least one object to be recognized.