to be processed determines if edge or cloud computing is appropriate for the 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.

Accordingly, the present disclosure refers to 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 object specific reflectance and luminescence spectral patterns,
- a light source which is configured to illuminate a scene which includes the at least one object, preferably under ambient lighting conditions,
- 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,
- a linear polarizer coupled with a quarter waveplate, the quarter waveplate being oriented with its fast and slow axes at an angle in the range of 40 to 50 degrees, preferably of 42 to 48 degrees, more preferably of 44 to 46 degrees relative to the linear polarizer, the linear polarizer and the quarter waveplate being positioned between the light source and the at least one object and between the sensor and the at least one object,

- a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- a data processing unit which is configured to extract/detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to match the extracted/detected 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 one aspect, the present disclosure refers to a system for object recognition via a computer vision application, the system comprising at least the following components:

- at least one object (110) to be recognized, the object having object specific reflectance and luminescence spectral patterns,
- a light source (140) which is configured to illuminate a scene including the at least one object under ambient lighting conditions,
- a sensor (150) 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,
- a linear polarizer (120) coupled with a quarter waveplate (130), the quarter waveplate (130) being oriented with its fast and slow axes at an angle in the range of 40 to 50 degrees, preferably of 42 to 48 degrees, more preferably of 44 to 46 degrees relative to the linear polarizer (120), the linear polarizer (120) and the quarter waveplate (130) being positioned between the sensor (150) and the at least one object (110), and between the light source (140) and the at least one object (110),
- a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- a data processing unit which is configured to detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to

- match the detected 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.

Technically the construct of linear polarizer and quarter waveplate needs to be between the light source and the object AND between the object and the sensor, i.e. the light must travel through the linear polarizer on the way to the object and then travel through it again on its way to the sensor.

In one example of the proposed system, the linear polarizer and the quarter waveplate are fused together forming one optical component. The linear polarizer and the quarter waveplate are applied directly on top of the at least one object, preferably as a coating or wrap, to form a 3-layer construct. Preferably, the at least one object has an essentially flat surface to which the linear polarizer and the quarter waveplate as one optical component can be applied.

Within the scope of the present disclosure the terms "fluorescent" and "luminescent" and the terms "fluorescence" and "luminescence" are used synonymously. Within the scope of the present disclosure, the terms "data processing unit", "processor", "computer" and "data processor" are to be interpreted broadly and are used synonymously.

Examples of the disclosure are directed to a system for object recognition via a computer vision application, the system comprising at least the following components:

- at least one object to be recognized, the object being at least semi-transparent and having object specific transmission and luminescence spectral patterns,
- a light source which is configured to illuminate a scene which includes the at least one object, preferably under ambient lighting conditions,
- two linear polarizers which are aligned at about 0 degrees relative to each other or rotated at about 90 degrees to each other and which are sandwiching the at least one object between them,
- 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,
- a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- a data processing unit which is configured to extract/detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to match the extracted/detected 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 refers to a system for object recognition via a computer vision application, the system comprising at least the following components:

- at least one object (210, 310) to be recognized, the object being at least semi-transparent and having object specific transmission and luminescence spectral patterns,
- a light source (240, 340) which is configured to illuminate a scene including the at least one object under ambient lighting conditions,
- two linear polarizers (220, 225, 320, 325) which are aligned at an angle in the range of -5 to 5 degrees, preferably of -3 to 2 degrees, more preferably of -1 to 1 degrees relative to each other or rotated at an

angle in the range of 85 to 95 degrees, particularly of 87 to 92 degrees, more preferably of 89 to 91 degrees to each other and which are sandwiching the at least one object between them,

- a sensor (250, 350) 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,
- a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- a data processing unit which is configured to detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to match the detected 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 example of the proposed system the linear polarizers are applied directly on either side of the at least one object.

In one example, each of the two linear polarizers is coupled with a quarter waveplate (lambda quarter plate). In this case the linear polarizers need to be aligned at about 0 degrees relative to each other, i. e. at an angle in the range of -5 to 5 degrees, preferably of -3 to 2 degrees, more preferably of -1 to 1 degrees relative to each other. Each of the quarter waveplates is oriented with its fast and slow axes at about 45 degrees relative to the respective linear polarizer, i. e. at an angle in the range of 40 to 50 degrees, preferably of 42 to 48 degrees, more preferably of 44 to 46 degrees, and each quarter waveplate

being oriented at about 0 degrees relative to the other quarter waveplate, i. e. at an angle in the range of -5 to 5 degrees, preferably of -3 to 2 degrees, more preferably of -1 to 1 degrees relative to the other quarter waveplate.

Generally, there are two different alternatives for an arrangement with two linear polarizers, the linear polarizers may be crossed (being oriented at about 90 degrees) relative to each other or aligned (being oriented at about 0 degrees) relative to each other.

In another example of the proposed system, the two linear polarizers and the respective two quarter waveplates each coupled with one of the two linear polarizers are applied directly, preferably as respective coating or wrap, on either side of the at least one object, thus forming a 5-layer construct with each layer directly on top of the other. Preferably, the at least one object has two essentially flat surfaces on two opposite sides, to each of which a linear polarizer and a quarter waveplate can be applied as one component to form a 5-layer construct in total.

In a further example, the sensor is a hyperspectral camera or a multispectral camera. The sensor is generally an optical sensor with photon counting capabilities. More specifically, it may be a monochrome camera, or an RGB camera, or a 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

eliminates the ambient light dependency for color space-based recognition techniques for computer vision applications since the chroma observed by the sensor will be independent on the ambient light conditions but only dependent on the chemistry of the luminescent layer (of the object to be recognized). By decoupling the reflectance and luminescence of a surface construct as described, it is possible to use the chroma of luminescence for chemistry-based object recognition since the luminescence is an intrinsic property of the chemical moieties present in the luminescent material/object.

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

- providing at least one object to be recognized, the object having object specific reflectance and luminescence spectral patterns,
- illuminating a scene which includes the at least one object under ambient lighting conditions using a light source,
- providing a linear polarizer coupled with a quarter waveplate, the quarter waveplate being oriented with its fast and slow axes at about 45 degrees relative to the linear polarizer, i. e. at an angle in the range of 40 to 50 degrees, preferably of 42 to 48 degrees, more preferably of 44 to 46 degrees relative to the linear polarizer, and
- positioning the linear polarizer and the quarter waveplate between the light source and the at least one object and between a sensor and the at least one object,
- measuring, using the sensor, radiance data of the scene including the at least one object,
- providing a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- extracting/detecting the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene,

- matching the extracted/detected 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.

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

- providing at least one object to be recognized, the object having object specific reflectance and luminescence spectral patterns,
- illuminating a scene including the at least one object under ambient lighting conditions using a light source,
- providing a linear polarizer coupled with a quarter waveplate, the quarter waveplate being oriented with its fast and slow axes at an angle in the range of 40 to 50 degrees, preferably of 42 to 48 degrees, more preferably of 44 to 46 degrees relative to the linear polarizer, and
- positioning the linear polarizer and the quarter waveplate between a sensor and the at least one object, and between the light source and the at least one object,
- measuring, using the sensor, radiance data of the scene including the at least one object,
- providing a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- detecting the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene,
- matching the detected 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.

In one example, the linear polarizer and the quarter waveplate are applied directly on top of the at least one object to form a 3-layer construct.

Examples of the disclosure are directed to a method for object recognition via a computer vision application, the method comprising at least the following steps:

- providing at least one object to be recognized, the object being at least semi-transparent and having object specific transmission and luminescence spectral patterns,
- illuminating, using a light source, a scene which includes the at least one object under ambient lighting conditions,
- providing two linear polarizers which are aligned at about 0 degrees relative to each other or rotated at about 90 degrees to each other and which are sandwiching the at least one object between them,
- measuring, using a sensor, radiance data of the scene including the at least one object,
- providing a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- providing a data processing unit which is programmed to extract/detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to match the extracted/detected 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 yet another aspect, the present disclosure refers to a method for object recognition via a computer vision application, the method comprising at least the following steps:

- providing at least one object to be recognized, the object being at least semi-transparent and having object specific transmission and luminescence spectral patterns,

- illuminating, using a light source, a scene including the at least one object under ambient lighting conditions,
- providing two linear polarizers which are aligned at an angle in the range of -5 to 5 degrees, preferably of -3 to 2 degrees, more preferably of -1 to 1 degrees relative to each other or rotated at an angle in the range of 85 to 95 degrees, particularly of 87 to 92 degrees, more preferably of 89 to 91 degrees to each other and which are sandwiching the at least one object between them,
- measuring, using a sensor, radiance data of the scene including the at least one object,
- providing a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- providing a data processing unit which is programmed to detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to match the detected 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 linear polarizers may be applied directly on either side of the at least one object

Each of the two linear polarizers may be coupled with a quarter waveplate. In this case the two linear polarizers need to be aligned relative to each other and each quarter waveplate needs to be rotated at about 45 degrees relative to the respective linear polarizers while the quarter waveplates are aligned relative to each other.

The wording "to be aligned" means to be aligned at about 0 degrees relative to each other, i. e. at an angle in the range of -5 to 5 degrees, preferably of -3 to 2 degrees, more preferably of -1 to 1 degrees relative to each other.

According to one possible example of the proposed method, the two linear polarizers and the respective two quarter waveplates each coupled with one of the two linear polarizers are applied directly on either side of the at least one object, thus forming a 5-layer construct with each layer directly on top of the other.

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-transitory 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.

Some or all technical components of the proposed system, namely the light source, the sensor, the linear polarizer(s), the data storage unit and the data processing unit may be in communicative connection with each other. A communicative connection between any of the components may be a wired or a wireless connection. Each suitable communication technology may be used. The respective components, each may include one or more communications 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.

In still a further example, the disclosure is directed to a computer program product having instructions that are executable by one or more data processing units as described before, the instructions cause a machine to:

- provide at least one object to be recognized, the object being at least semi-transparent and having object specific transmission and luminescence spectral patterns,
- illuminate, using a light source, a scene including the at least one object under ambient lighting conditions,
- provide two linear polarizers which are aligned at an angle in the range of -5 to 5 degrees, preferably of -3 to 2 degrees, more preferably of -1 to 1 degrees relative to each other or rotated at an angle in the range of 85 to 95 degrees, particularly of 87 to 92 degrees, more preferably of 89 to 91 degrees to each other, and which are sandwiching the at least one object between them,

- measure, using a sensor, radiance data of the scene including the at least one object,

- provide a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to match the detected 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 still a further example, the present disclosure refers to a non-transitory computer-readable medium storing instructions that, when executed by one or more processors, particularly by one or more data processing units as described before, cause a machine to:

- provide at least one object to be recognized, the object being at least semi-transparent and having object specific transmission and luminescence spectral patterns,
- illuminate, using a light source, a scene which includes the at least one object under ambient lighting conditions,
- provide two linear polarizers which are aligned at an angle in the range of -5 to 5 degrees, preferably of -3 to 2 degrees, more preferably of -1 to 1 degrees relative to each other or rotated at an angle in the range of 85 to 95 degrees, particularly of 87 to 92 degrees, more preferably of 89 to 91 degrees to each other, and which are sandwiching the at least one object between them,
- measure, using a sensor, radiance data of the scene including the at least one object,
- provide a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to match the detected 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 yet another aspect, the present disclosure refers to a non-transitory computer-readable medium storing instructions that when executed by one or more processors, cause a machine to:

- provide at least one object to be recognized, the object being at least semi-transparent and having object specific transmission and luminescence spectral patterns,
- illuminate, using a light source, a scene including the at least one object under ambient lighting conditions,
- provide two linear polarizers which are aligned at an angle in the range of -5 to 5 degrees, preferably of -3 to 2 degrees, more preferably of -1 to 1 degrees relative to each other or rotated at an angle in the range of 85 to 95 degrees, particularly of 87 to 92 degrees, more preferably of 89 to 91 degrees to each other, and which are sandwiching the at least one object between them,
- measure, using a sensor, radiance data of the scene including the at least one object,
- provide a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene and to match the detected 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 still another example, the present disclosure refers to a non-transitory computer-readable medium storing instructions that when executed by one or more processors, cause a machine to:

- provide at least one object to be recognized, the object having object specific reflectance and luminescence spectral patterns,
- illuminate a scene which includes the at least one object under ambient lighting conditions using a light source,
- provide a linear polarizer coupled with a quarter waveplate, the quarter waveplate being oriented with its fast and slow axes at an angle in the range of 40 to 50 degrees, preferably of 42 to 48 degrees, more preferably of 44 to 46 degrees relative to the linear polarizer, and
- position the linear polarizer and the quarter waveplate between a sensor and the at least one object, and between the light source and the at least one object,
- measure, using the sensor, radiance data of the scene including the at least one object,
- provide a data storage unit which comprises luminescence spectral patterns together with appropriately assigned respective objects,
- detect the object specific luminescence spectral pattern of the at least one object to be recognized out of the measured radiance data of the scene,
- match the detected 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 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. 1 shows schematically a section of a first embodiment of the system according to the present disclosure.

Fig. 2 shows schematically a section of a second embodiment of the system according to the present disclosure.

Fig. 3 shows schematically a section of a third embodiment of the system according to the present disclosure.

Fig. 4 shows a diagram of measured radiance and emission data which have been received using an embodiment of the system according to the present disclosure.

Detailed description of the drawings

Figure 1 shows a first embodiment of a system according to the present invention. The system comprises an object 110 which is to be recognized and which is provided/imparted with a fluorescent material as indicated by reference sign 105. Further, the object 110 has also a specular reflective surface 106. The system further comprises a linear polarizer 120 and a quarter waveplate 130. Furthermore, the system comprises a light source 140 which is configured to illuminate a scene including the object 110. Between the light source 140 and the object 110 and between the object 110 and a sensor 150 the linear polarizer 120 and the quarter waveplate 130 are arranged. The linear polarizer 120 can be in any position. The quarter waveplate 130 must have its fast and slow axes as indicated by the respective double arrows at about 45 degrees (ideally, small deviations are acceptable) to the linear polarizer orientation, but otherwise the