

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.

5

Thus, a need exists for systems and methods that are suitable for improving object recognition capabilities for computer vision applications. One of the challenges with color space-based object recognition techniques is the unknown lighting conditions in a scene. Since most the environments of interest
10 did not have controlled lighting conditions, 3D maps or networking capabilities, the dynamic modelling of lighting conditions in a scene was not possible. With the advances in IoT devices including lighting elements and 3D scanners along with improved processing power such light modelling techniques can be utilized for chemistry-based object recognition system designs.

15

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
20 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:

- 25 - at least one object to be recognized, the object having an object specific reflectance spectral pattern and an object specific luminescence spectral pattern,
- at least one light source which is configured to illuminate a scene which includes the at least one object under ambient light conditions,
- 30 the at least one light source having light source specific radiance values,

The light source can be designed to connect automatically to at least one of the further components of the system such as the sensor, the scene mapping tool, the data storage unit and/or the data processing unit. However, the light source does not have to be linked to and/or networked with the other components of the system (if light source has predefined and known parameters, e. g. radiance values, pulse rates and timing, etc.), but need to be synchronized with the other components. This synchronization may be accomplished with measurements from the other components of the system, such as a spectral camera. It is also possible that the radiance of the light source is measured by at least one spectroradiometer, i.e. the system may be initialized with a spectroradiometer. However, generally this is only done for a setup of the system, but generally not in real time, i.e. not in operating mode of the system.

The light source specific radiance values comprise spectral characteristics, power and/or an emission angle profile (light output profile) of the at least one light source in the scene. Radiance of the at least one light source at points of the at least one object in the scene is calculated by using the light source specific radiance values, particularly the spectral characteristics, the power and/or the emission angle profile of the at least one light source in the scene and mapping a distance from the at least one light source to the at least one object in the scene.

According to a further example of the system, the sensor is a multispectral or hyperspectral 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
5 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
10 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.

According to a further example of the proposed system, the scene mapping tool is
15 configured to perform a scene mapping by using a technique based on time of flight
(TOF), stereovision and/or structured light. The scene mapping tool may comprise
at least one of a time of flight system, such as TOF-cameras, a stereovision-based
system, a light probe which emits structured light or any combination thereof. The
structured light may be, for example, infrared light. Time of flight measurements can
20 use infrared light, visible light or radar. Alternative scene mapping tools are
(ultra)sound-based systems.

In still another example, the system is configured to use physical location (received
via GPS), compass orientation, time of day, and/or weather conditions to model an
25 effect of solar radiation on the illumination of the at least one object in the scene.
Those influencing factors are considered in the model, i.e. incorporated into the
model.

In a further example, the system is configured to use information of reflective and
30 fluorescence properties of not only the at least one object but also of other items
in the scene to improve radiance mapping of the scene by means of bidirectional
reflectance distribution functions (BRDFs) and bidirectional

fluorescence distribution functions (BPDFs) to account for interreflections of reflected and fluoresced light throughout the scene.

- According to another example of the proposed system, the system comprises at least one white tile located at least one point in the scene, the white tile being configured to be used to measure radiance of the light source at the at least one point in the scene, wherein the measured radiance of the light source at the at least one point in the scene is used in conjunction with the 3D map and the light output profile of the light source to estimate radiance at other points in the scene. Highly reflective white tile(s) in the scene can be used to measure radiance from the light source at that point in the scene. This will also give the spectral characteristics of the light source. In conjunction with the 3D map of the scene, and assumptions/calculations about the light output profile of the light source, estimates of the radiance at other points in the scene can then be made. This may be most useful for systems that are not networked with information about the light source. The white tile(s) could also be used for "smart" systems that are networked with information about the light source to validate the calculations in addition to determining contributions from light sources outside of the system described.
- In another aspect, the present disclosure also 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, by at least one light source, a scene which includes the at least one object under ambient light conditions, the light source having light source specific radiance values,
 - measuring, using a sensor, radiance data of the scene which includes the at least one object when the scene is illuminated by the light source,
 - mapping, using a scene mapping tool, the scene rendering an at least partial 3D map of the scene,

- providing a data storage unit which comprises luminescence and/or reflectance spectral patterns together with appropriately assigned respective objects,
 - providing a data processing unit which is programmed to analyze data received from the scene mapping tool and merge the analysed data with the light source specific radiance values to calculate radiance of light incident at points in the scene, particularly at points of the at least one object, and to combine the calculated radiance of light incident at the points in the scene with the measured radiance of light returned to the sensor from points in the scene, particularly from the at least one object, thus forming a model of light spectral distribution and intensity at the at least one object in the scene, and to extract/detect the object specific luminescence and/or reflectance spectral pattern of the at least one object to be recognized out of the model of light spectral distribution and intensity and to match the extracted/detected object specific luminescence and/or reflectance spectral pattern with the luminescence and/or reflectance spectral patterns stored in the data storage unit, and to identify a best matching luminescence and/or reflectance spectral pattern and, thus, its assigned object,
- wherein the sensor, the scene mapping tool, the data storage unit and the data processing unit are communicating with each other wirelessly and/or through wires and synchronized with the light source by default, thus forming an integrated system.
- According to one example of the proposed method a scene mapping is performed by using a technique based on time of flight (TOF) and/or structured light and/or stereocameras wherein at least one of a time of flight system, a sound-based system, a stereovision-based system or any combination thereof is used. Infrared, visible, UV light can be used. Also radar, stereovision and/or ultrasound can be used here.

In a further example, radiance of the at least one light source at the at least one object in the scene is calculated using the light source specific radiance values, such as spectral characteristics, power and/or an emission angle profile of the at least one light source in the scene, and mapping a distance from the at least one
5 light source to the at least one object in the scene.

Further, physical location (determined via GPS), compass orientation, time of day, and/or weather conditions may be used to model an effect of solar radiation on the illumination of the scene, thus adapting the model accordingly.

10

In still a further example, information of the reflective and fluorescence properties of items (not only of the at least one object) in the scene is used to improve radiance mapping of the scene by means of bidirectional reflectance distribution functions (BRDFs) and bidirectional fluorescence distribution functions (BFDFs) to account
15 for interreflections of reflected and fluoresced light throughout the scene.

20

The model of light spectral distribution and intensity can be analyzed and displayed on a 2D map or as a 3D view via a respective output device, such as a display or a screen configured to issue a 3D map/view.

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
25 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
30 data storage unit or may represent

the data storage unit itself. The terms "database" and "data storage unit" are used synonymously.

The present disclosure further refers to a computer program product having
 5 instructions that are executable by a data processing unit as provided as component/part of the proposed system, the instructions cause the system to:

- analyse data received from the scene mapping tool,
- merge the analysed data with the light source specific radiance data,
- 10 - calculate radiance of light incident at points in a scene, particularly at points of at least one object to be recognized, based on the merged data,
- combine the calculated radiance of light incident at the points in the scene with the measured radiance of light returned to the sensor from
 15 points in the scene, particularly from points of the at least one object, thus forming a model of light spectral distribution and intensity at the at least one object in the scene,
- extract an object specific luminescence and/or reflectance spectral pattern of the at least one object to be recognized out of the model of
 20 light spectral distribution and intensity,
- match the extracted object specific luminescence and/or reflectance spectral pattern with luminescence and/or reflectance spectral patterns stored in the data storage unit, and,
- identify a best matching luminescence and/or reflectance spectral
 25 pattern and, thus, its assigned object.

In another aspect, the present disclosure also refers to a non-transitory computer-readable medium storing instructions that, when executed by one or more data processing units as component(s) of the proposed system, cause the
 30 system to:

- analyse data received from the scene mapping tool,
- merge the analysed data with the light source specific radiance data,

- calculate radiance of light incident at points in a scene, particularly at points of at least one object to be recognized, based on the merged data,
- combine the calculated radiance of light incident at the points in the scene with the measured radiance of light returned to the sensor from points in the scene, particularly from points of the at least one object, thus forming a model of light spectral distribution and intensity at the at least one object in the scene,
- extract an object specific luminescence and/or reflectance spectral pattern of the at least one object to be recognized out of the model of light spectral distribution and intensity,
- match the extracted object specific luminescence and/or reflectance spectral pattern with luminescence and/or reflectance spectral patterns stored in the data storage unit, and,
- identify a best matching luminescence and/or reflectance spectral pattern and, thus, its assigned object.

The present disclosure describes a method for object recognition and a chemistry-based object recognition system comprising a light source(s), a sensor, particularly a camera, a database of luminescence and/or reflectance spectral patterns of different objects and a computer/data processing unit that is configured to compute a spectral match of such luminescent and/or reflective objects of the database using various algorithms, a 3D map of scenes and a model of light spectral distribution and intensity (illuminance) at target objects in the field of view of the sensor. By incorporating the 3D maps of scenes and simple models of illuminance in the respective scenes with the rest of the network connected / synchronized system, luminescent/chemistry-based object recognition techniques are simplified and improved.

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.

5

Brief description of the drawings

Fig. 1 shows schematically an arrangement of an embodiment of the system according to the invention.

10

Detailed description of the drawings

Figure 1 shows an embodiment of the system 100 for object recognition via a computer vision application. The system 100 comprises at least one object 110 which is to be recognized. The object 110 has an object-specific reflectance spectral pattern and an object-specific luminescence spectral pattern. The object 110 is further located in a scene 130. The system 100 further comprises a first light source 121 and a second light source 122. Both light sources are configured to illuminate the scene 130 including the at least one object 110, preferably under ambient light conditions. The system 100 further comprises a sensor 140 which is configured to measure radiance data of the scene 130 including the at least one object 110 when the scene 130 is illuminated by at least one of the light sources 121 and 122. In the case shown here, the sensor 140 is a multispectral or a hyperspectral camera. The system 100 further comprises a scene mapping tool 150 which is configured to map the scene 130 rendering at least a partial 3D map of the scene 130. Further shown is a data storage unit 160 which comprises luminescence and/or reflectance spectral patterns together with appropriately assigned respective objects. The system 100 further comprises a data processing unit 170 which is configured to analyze data received from the scene mapping tool 150, merge the analyzed data with light source specific radiance parameters/values and calculate radiance of light incident at points in the scene 130, particularly at points of the object 110. The