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. In particular, recognition or sensing of molecules that are not part of a solid surface pose unique challenges since the computer vision systems utilizing the visible portions of electromagnetic spectrum do not have such capabilities but rely on geometry, 2D or 3D information structures that are more or less static. For fluids that do not present a fixed boundary condition, such as gases and liquids, these shape-based recognition methods and sensing techniques come short.

Summary

Therefore, it was an object of the present disclosure to provide a device and a method that enable the recognition and the monitoring of fluids, e.g. gases and liquids, i.e. of molecules present without a solid-state boundary.

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.

According to an aspect, a device is provided for recognizing and monitoring a fluid in and/or in the surroundings of a system via a computer vision application, the device comprising at least the following components:

- at least one luminescent dye, each luminescent dye having a dye specific reflectance and luminescence spectral pattern and being configured to be added to the fluid,
- a device that is configured to add, e.g. admix, the at least one luminescent dye to the fluid,

- a light source which is composed of at least two illuminants and which is configured to illuminate a scene including the system and/or the surroundings of the system, particularly under ambient lighting conditions, by switching between the at least two illuminants, wherein at least one of the two illuminants is based on at least one solid-state system,
- a sensor which is configured to measure radiance data of the scene including the system when the scene is illuminated by the light source,
- a data processing unit which is configured to inspect whether the dye specific luminescence spectral pattern is detectable out of the radiance data of the scene when the scene is illuminated by the light source, and, in the case that the dye specific luminescence spectral pattern can be detected out of the radiance data, to identify the fluid the dye has been added to.

Within the scope of the present disclosure the terms "fluorescent" and "luminescent" are used synonymously. The same applies to the terms "fluorescence" and "luminescence". The term "fluid" comprises gases and liquids, i. e. a fluid can be a gas or a liquid.

The device can be particularly used for detecting a leak within the system. In that case the system uses the fluid as operating medium which is to be carried continuously through (pipes of) the system. According to an example, the device further comprises a controller which is configured to run the system to circulate the dye throughout the system after the dye has been added to the fluid.

According to said possible example, the device is configured to be used for monitoring the system for leaks via a computer vision application, wherein the system uses the fluid as operating medium which is carried continuously through the system, wherein the data processing unit is further configured to

Thus, a liquid in a glass, bowl, plate, cup or in a transparent glass or plastic container may be monitored.

According to a further example of the proposed device, the device further comprises an output unit which is configured to perform a predefined action, in the case that the dye specific luminescence spectral pattern can be extracted/detected out of the radiance data. Thus, the device can output a notification of the identified fluid, particularly of a leak of the system in the case the device is used for leak detection, and/or it may stop the leaking system and/or start any other preventative action, such as open a window, turn off electricity, etc.

According to still a further example, the device comprises a plurality of different dyes, the different dyes having different dye specific reflectance and/or luminescence spectral patterns and being configured to be added to the fluid in different fluid paths within the system, thus enabling, in the case that one of the dye specific luminescence spectral patterns can be detected/extracted out of the radiance data, a localisation of the identified fluid and, thus, of the identified leak in the case the device is used for leak detection.

According to a further example the device comprises a data storage unit with luminescence spectral patterns together with appropriately assigned respective dyes, wherein the data processing unit is configured to identify the dye specific luminescence spectral pattern of the at least one dye by matching the extracted dye specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit using any number of matching algorithms between the extracted dye specific luminescence spectral pattern and the stored luminescence spectral patterns. The matching algorithms may be chosen from the group comprising at least one of: lowest root mean squared error, lowest mean absolute error, highest coefficient of determination, matching of maximum wavelength value.

switched between illuminants at a rate that is not visible to the human eye. Sinusoidal like illuminants may also be created with LEDs or other light sources, which is useful for some of the proposed computer vision algorithms.

The sensor which is configured to measure the radiance data of the scene is linked and synchronized with the switching of the light source between illuminants. According to a further example of the proposed device, the sensor is synchronized to the switching of the light source to only issue at one time the radiance data from the scene under one of the at least two illuminants. That means that the sensor may be configured to only capture information during the time period one illuminant is active. It may be configured to capture/measure information during one or more illuminants being active and use various algorithms to calculate and issue the radiance for a subset of the illuminants. It may be configured to capture the scene radiance at a particular period before, after or during the activation of the light source and may last longer or shorter than the light pulse. That means that the sensor is linked to the switching, but it does not necessarily need to capture radiance data during the time period only one illuminant is active. This procedure could be advantageous in some systems to reduce noise, or due to sensor timing limitations.

It is possible that the sensor is synchronized to the light source and that the sensor tracks the illuminants' status during the sensor integration time. The spectral changes of the light source are managed by a control unit via a network, working in sync with the sensor´s integration times. Multiple light sources connected to the network can be synced to have the same temporal and spectral change frequencies amplifying the effect.

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 computing device 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 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.

According to a further aspect, examples of the disclosure are directed to a method for recognizing and monitoring a fluid in a system and/or in surroundings of the system via a computer vision application, the method comprising at least the following steps:

- adding a luminescent dye to the fluid, the luminescent dye having a dye specific reflectance and luminescence spectral pattern,
- illuminating a scene including the system and/or surroundings of the system, preferably under ambient lighting conditions, with an additional light source which is composed of at least two illuminants, by switching between the at least two illuminants, wherein at least one of the two illuminants is based on at least one solid-state system,
- measuring, by means of a sensor, radiance data of the scene when the scene is illuminated by the light source,
- inspecting, by a data processing unit, whether the dye specific luminescence spectral pattern is detectable out of the radiance data of the scene, and
- in the case that the dye specific luminescence spectral pattern can be detected out of the radiance data, identifying, by the data processing unit, the fluid.

In another example of the disclosure are directed to a method for monitoring a system for leaks via a computer vision application, the system using a fluid as operating medium, e. g. as coolant, which is to be carried continuously through (pipes of) the system, the method comprising at least the following steps:

- adding a luminescent dye to the fluid, the luminescent dye having a dye specific reflectance and luminescence spectral pattern,

- running the system to circulate the dye together with the fluid throughout the system,
- illuminating a scene including the system and/or surroundings of the system, preferably under ambient lighting conditions, with an additional light source which is composed of at least two illuminants, by switching between the at least two illuminants, wherein at least one of the two illuminants is based on at least one solid-state system,
- measuring, by means of a sensor, radiance data of the scene when the scene is illuminated by the light source,
- inspecting, by a data processing unit, whether the dye specific luminescence spectral pattern is extractable/detectable out of the radiance data of the scene, and
- in the case that the dye specific luminescence spectral pattern can be extracted/detected out of the radiance data, identifying, by the data processing unit, a leak of the system.

According to one example of the proposed method, the method further comprises providing a data storage unit with luminescence spectral patterns together with appropriately assigned respective dyes, and identifying the dye specific luminescence spectral pattern of the at least one dye by matching the extracted dye specific luminescence spectral pattern with the luminescence spectral patterns stored in the data storage unit using any number of matching algorithms between the extracted dye specific luminescence spectral pattern and the stored luminescence spectral patterns. The matching algorithms may be chosen from the group comprising at least one of: lowest root mean squared error, lowest mean absolute error, highest coefficient of determination, matching of maximum wavelength value.

In a further example, the method further comprises performing a predefined action, e. g. outputting, in the case that the dye specific luminescence spectral pattern can be extracted out of the radiance data, a notification of the identified leak of the system via an output unit. Additionally or alternatively, the leaking

system can be stopped and/or any other preventative action, such as opening a window or turning off electricity can be performed.

In still a further example of the proposed method, a plurality of different dyes is provided, the different dyes having different dye specific reflectance and luminescence spectral patterns, and different dyes are added to the fluid in different fluid paths within the system, thus enabling, in the case that one of the dye specific luminescence spectral patterns can be extracted out of the radiance data, a localisation of the fluid and, thus, of the identified leak, in the case the method is performed for leak detection.

The light source may be chosen as a switchable light source with two illuminants each comprised of one or more LEDs and with a short switchover time between the two illuminants.

In another aspect, examples of the disclosure are directed to a computer program product having instructions for recognizing and monitoring a fluid in a system and/or in surroundings of the system via a computer vision application, wherein the instructions are executable by a computer, particularly by a data processing unit as described before, and, when executed, cause a machine to:

- add a luminescent dye to the fluid, the luminescent dye having a dye specific reflectance and luminescence spectral pattern,
- illuminate a scene which includes the system and/or the surroundings of the system, preferably under ambient lighting conditions, with an additional light source which is composed of at least two illuminants, by switching between the at least two illuminants, wherein at least one of the two illuminants is based on at least one solid-state system,
- measure, by means of a sensor, radiance data of the scene when the scene is illuminated by the light source,

- determine/inspect whether the dye specific luminescence spectral pattern is detectable/extractable out of the radiance data of the scene, and
- identify the fluid in the case that the dye specific luminescence spectral pattern can be detected/extracted out of the radiance data.

In another example of the disclosure are directed to a computer program product having instructions for monitoring a system for leaks via a computer vision application, the system using a fluid as operating medium, e. g. as coolant, which is to be carried continuously through (pipes of) the system, the instructions being executable by a computer, particularly a data processing unit as described before, and causing, when executed, a machine to:

- add a luminescent dye to the fluid, the luminescent dye having a dye specific reflectance and luminescence spectral pattern,
- run the system, using the fluid as operating medium, to circulate the dye together with the fluid throughout the system,
- illuminate a scene including the system and/or surroundings of the system, preferably under ambient lighting conditions, with an additional light source which is composed of at least two illuminants, by switching between the at least two illuminants, wherein at least one of the two illuminants is based on at least one solid-state system,
- measure, by means of a sensor, radiance data of the scene when the scene is illuminated by the light source,
- inspect whether the dye specific luminescence spectral pattern is detectable/extractable out of the radiance data of the scene, and
- identify a leak of the system in the case that the dye specific luminescence spectral pattern can be detected/extracted out of the radiance data.

The computer program product may further comprise instructions to identify the dye specific luminescence spectral pattern of the at least one dye by matching the extracted/detected dye specific luminescence spectral pattern with

luminescence spectral patterns stored in a data storage unit using any number of matching algorithms between the extracted/detected dye specific luminescence spectral pattern and the stored luminescence spectral patterns. The matching algorithms may be chosen from the group comprising at least one of: lowest root mean squared error, lowest mean absolute error, highest coefficient of determination, matching of maximum wavelength value.

The computer program product may further comprise instructions to perform a predefined action, e. g. to output via an output unit, in the case that the dye specific luminescence spectral pattern can be extracted/detected out of the radiance data, a notification of the identified fluid and/or the identified leak of the system.

The present disclosure further refers to a non-transitory computer-readable medium storing instructions that, when executed by one or more processors, cause a machine to:

- add a luminescent dye to a fluid, the luminescent dye having a dye specific reflectance and luminescence spectral pattern,
- illuminate a scene, preferably under ambient lighting conditions, with an additional light source which is composed of at least two illuminants, by switching between the at least two illuminants, wherein at least one of the two illuminants is based on at least one solid-state system,
- measure, by means of a sensor, radiance data of the scene when the scene is illuminated by the light source,
- inspect whether the dye specific luminescence spectral pattern is detectable/extractable out of the radiance data of the scene, and
- in the case that the dye specific luminescence spectral pattern can be detected/extracted out of the radiance data, to identify the fluid.

In 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:

- add a luminescent dye to a fluid, the luminescent dye having a dye specific reflectance and luminescence spectral pattern,
- run a system, using the fluid as operating medium, to circulate the dye together with the fluid throughout the system,
- illuminate a scene including the system and/or surroundings of the system, preferably under ambient lighting conditions, with an additional light source which is composed of at least two illuminants, by switching between the at least two illuminants, wherein at least one of the two illuminants is based on at least one solid-state system,
- measure, by means of a sensor, radiance data of the scene when the scene is illuminated by the light source,
- inspect whether the dye specific luminescence spectral pattern is detectable/extractable out of the radiance data of the scene, and
- in the case that the dye specific luminescence spectral pattern can be detected/extracted out of the radiance data, to identify a leak of the system.

The terms "data processing unit", "processor", "computer" are used synonymously and are to be interpreted broadly.

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 invention and without departing from the spirit and scope thereof, can make various changes and modifications of the invention to adapt it to various uses and conditions.

Brief description of the drawings

Fig. 1 shows schematically an embodiment of the proposed device executing an embodiment of the proposed method.