



- (51) **International Patent Classification:**
G06T 1/40 (2006.01)
- (21) **International Application Number:**
PCT/US2014/033106
- (22) **International Filing Date:**
5 April 2014 (05.04.2014)
- (25) **Filing Language:** English
- (26) **Publication Language:** English
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- (81) **Designated States** (*unless otherwise indicated, for every kind of national protection available*): AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY,

BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KN, KP, KR, KZ, LA, LC, LK, LR, LS, LT, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

- (84) **Designated States** (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— with international search report (Art. 21(3))

(54) **Title:** IDENTIFICATION SYSTEM AND METHOD

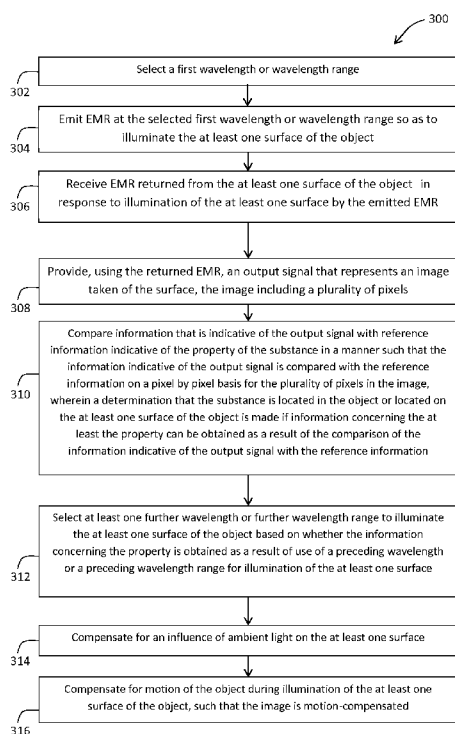


FIG 3

(57) **Abstract:** A system to identify at least a property of a substance located in an object, or located on a surface of the object, is generally described. The system may include an electromagnetic radiation (EMR) source arranged to selectively emit EMR at more than one wavelength to illuminate the surface of the object.

IDENTIFICATION SYSTEM AND METHOD

BACKGROUND

[0001] Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

[0002] Hyperspectral cameras can be used in areas including agriculture, mineralogy, physics, medicine and surveillance, for example, to image objects. The imaging, which uses a large range of the electromagnetic (EM) spectrum, can provide spectral information regarding the object, and the spectral information can be compared to spectral signatures of known substances to identify the object.

[0003] Hyperspectral cameras may be, however, expensive and bulky, and may acquire data at very high volumes which may involve significant processing to extract information. The complexity of doing so may result in low frame rates and may limit the refresh rate or the number of images a hyperspectral camera can capture in a given time frame..

SUMMARY

[0004] In some embodiments, a system to identify at least a property of a substance located in an object or located on at least one surface of the object is generally described.

[0005] An example system includes an electromagnetic radiation (EMR) source arranged to selectively emit EMR at more than one wavelength or wavelength range to illuminate the at least one surface of the object.

[0006] The system may also include an EMR sensor arranged to sense EMR returned from the at least one surface and to use the returned EMR to provide an output signal that represents an image taken of the surface, the image including a plurality of pixels.

[0007] The system may also include a processor system arranged to compare information that is indicative of the output signal of the EMR sensor with reference information indicative of the property of the substance in a manner such that the information indicative of the output signal is compared with the reference information on a pixel by pixel basis for the plurality of pixels in the image.

[0008] The processor system may be arranged to determine that the substance is located in the object or located on the at least one surface of the object if information concerning the at least the property can be obtained as a result of the comparison of the information indicative of the output signal with the reference information.

[0009] The processor system may further be arranged to select a first wavelength or first wavelength range to illuminate the at least one surface by the EMR source, and subsequently select at least one further wavelength or further wavelength range to illuminate the at least one surface by the EMR source, wherein the selection of the at least one further wavelength or the further wavelength range is based on whether the information concerning the property is obtained as a result of use of a preceding wavelength or a preceding wavelength range for illumination of the at least one surface.

[0010] The processor system may further be arranged to compensate for an influence of ambient light on the at least one surface.

[0011] The processor system may further be arranged to compensate for motion of the object relative to the EMR sensor during illumination of the at least one surface of the object, such that the image is motion-compensated.

[0012] In some embodiments, a method to identify at least a property of a substance located in an object or located on at least one surface of the object is generally described.

[0013] An example method includes selecting a first wavelength or wavelength range. The method may include emitting EMR at the selected first wavelength or wavelength range so as to illuminate the at least one surface of the object.

[0014] The method may include receiving EMR returned from the at least one surface of the object in response to illumination of the at least one surface by the emitted EMR.

[0015] The method may include providing, using the returned EMR, an output signal that represents an image taken of the surface, the image including a plurality of pixels.

[0016] The method may include comparing information that is indicative of the output signal with reference information indicative of the property of the substance in a manner such that the information indicative of the output signal is compared with the reference information on a pixel by pixel basis for the plurality of pixels in the image, wherein a determination that the substance is located in the object or located on the at least one surface of the object is made if information concerning the at least the property can be obtained as a result of the comparison of the information indicative of the output signal with the reference information.

[0017] The method may include selecting at least one further wavelength or further wavelength range to illuminate the at least one surface of the object based on whether the information concerning the property is obtained as a result of use of a preceding wavelength or a preceding wavelength range for illumination of the at least one surface.

[0018] The method may further include compensating for an influence of ambient light on the at least one surface, and compensating for motion of the object relative to an EMR sensor at which the EMR returned from the at least one surface of the object is received during illumination of the at least one surface of the object, such that the image is motion-compensated.

[0019] In some embodiments, a non-transitory computer-readable medium that includes computer-readable instructions stored thereon that are executable by a processor is generally described.

[0020] An example non-transitory computer-readable medium is arranged such that the computer-readable instructions stored thereon are executable by a processor to perform the example method described above.

[0021] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features described above, further aspects, embodiments, and features will become apparent by reference to the drawings and the following detailed description.

BRIEF DESCRIPTION OF THE FIGURES

[0022] The foregoing and other features of this disclosure will become more fully apparent from the following description and appended claims, taken in conjunction with the accompanying drawings. Understanding that these drawings depict only several embodiments in accordance with the disclosure and are, therefore, not to be considered limiting of its scope, the disclosure will be described with additional specificity and detail through use of the accompanying drawings. In the drawings:

FIG 1 is a block diagram of an example identification system;

FIG 2 is a block diagram of an example EMR source of the identification system of Figure 1;

FIG 3 is an example identification method; and

FIG 4 is a block diagram illustrating an example computing device that is arranged to process images in connection with substance identification;

all arranged according to at least some embodiments presented herein.

DETAILED DESCRIPTION

[0023] In the following detailed description, reference is made to the accompanying drawings, which form a part hereof. In the drawings, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the

detailed description, drawings, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the spirit or scope of the subject matter presented herein. The aspects of the present disclosure, as generally described herein, and illustrated in the Figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are explicitly contemplated herein.

[0024] This disclosure is generally drawn, inter alia, to methods, apparatus, systems, devices, and computer programs related to identifying a substance located in an object, or located on at least one surface of the object.

[0025] Briefly stated, a system to identify at least a property of a substance located in an object, or located on a surface of the object, may include an electromagnetic radiation (EMR) source arranged to selectively emit EMR at more than one wavelength to illuminate the surface of the object. The system may include an EMR sensor arranged to sense EMR returned from the surface and to use the returned EMR to provide an output signal that represents an image taken of the surface, the image including a plurality of pixels. The system may include a processor system arranged to compare information that is indicative of the output signal of the EMR sensor with reference information indicative of the property of the substance. The processor system may be arranged to select a first wavelength to illuminate the surface by the EMR source, and subsequently select at least one further wavelength based on whether the information concerning the property is obtained as a result of use of a preceding wavelength. The processor system may further be arranged to compensate for an influence of ambient light on the at least one surface, and may be further arranged to compensate for motion of the object relative to the EMR sensor during illumination of the at least one surface of the object, such that the image is motion-compensated.

[0026] Figure 1 is a block diagram of an example identification system 100 that is arranged according to at least some embodiments described herein. The system 100 may be

arranged to identify a property of a substance 102 located in an object 104, or located on a surface 106 of the object 104.

[0027] It will be appreciated that having the capability to identify the property of the substance can facilitate the system positively identifying the substance itself as being located in or on the object. For example, a property of the substance may be a spectral characteristic of radiation that is reflected, or otherwise returned, from the substance. Identifying the spectral characteristic of radiation that is returned from the substance may facilitate positively identifying the substance.

[0028] The system 100 may include an electromagnetic radiation (EMR) source 110, an EMR sensor 112, and a processor system 114.

[0029] The EMR source 110 may be arranged to selectively emit EMR 116 at more than one wavelength or wavelength range to illuminate the surface 106 of the object 104.

[0030] The EMR sensor 112 may be arranged to sense EMR 118 returned, such as by reflection, from the surface 106 and to use the returned EMR 118 to provide an output signal 120 (such as in the form of an electrical signal, wireless signal, optical signal, and/or other signal format) that represents an image taken of the surface 106 of the object 104. The image, in this example, may include a plurality of pixels.

In this example, the processor system 114 may be arranged to compare information that is indicative of the output signal 120 of the EMR sensor 112 with reference information that is indicative of the property of the substance 102. The processor system 114 may be arranged to perform the comparison in a manner such that the information indicative of the output signal 120 is compared with the reference information on a pixel by pixel basis for the plurality of pixels in the image. The processor system 114 may be arranged to determine that the substance 102 is located in the object 104, or located on the surface 106 of the object 104, if information concerning the property can be obtained as a result of the comparison of the information that is indicative of the output signal 120 with the reference information. For example, the comparison

may indicate that there is a match between the information that is indicative of the output signal 120 and the reference information.

[0031] In this example, the processor system 114 may be also arranged to select a first wavelength or first wavelength range to illuminate the surface 106 by the EMR source 110, and subsequently select a further wavelength or further wavelength range to illuminate the surface 106 by the EMR source 110. The selection of the further wavelength or the further wavelength range may be based on whether the information concerning the property is obtained as a result of use of a preceding wavelength or a preceding wavelength range for illuminating the surface 106.

[0032] In one embodiment, the first wavelength or first wavelength range may correspond to a first spectrum that can be used to identify a first group of related substances, such as a group comprising drugs. If it is determined, based on the comparison between the returned EMR 118 and reference information indicative of the first group of substances, that the substance 102 does not belong to the first group, then a second wavelength or second wavelength range that corresponds to a second spectrum that can be used to identify a second group of related substances, such as a group of explosives, can be selected and used to illuminate the surface 106. This process can continue until the group of substances has been identified.

[0033] In some embodiments, the first, second, third, etc. wavelengths or wavelength ranges can be used for identification within the same group of related substances. For instance, if the first wavelength or the first wavelength range is intending to identify drug “A”, and such identification is unsuccessful, then the second wavelength or second wavelength range can be used to try to identify drug “A”. This process can be repeated for all of the available wavelengths and wavelength ranges, in an attempt to identify drug “A”, and then repeated again (if appropriate) to try to identify drug “B” and/or any other drug, until a match or other positive identification occurs for a particular drug type.

[0034] The first spectrum and the second spectrum (and any further spectra utilised to identify further groups of related substances) can be mutually exclusive to one another. In this way, the system 100 can select further spectra with which to illuminate the surface 106 based on

the result of illuminating the surface 106 with previously selected spectra rather than illuminating the surface 106 with all possible spectra in order to identify the group of the substance 102.

[0035] If it is determined, based on the comparison between the returned EMR 118 and reference information indicative of the first group, that the substance 102 belongs to the first group, then a further wavelength or further wavelength range that corresponds to a spectrum that can be used to identify one of a subset of the first group can be selected and used to illuminate the surface 106.

[0036] The subset of the first group can be determined in a manner similar to that in which the identity of the first group was determined. For example, a first subset spectrum corresponding to a first subset of the first group can be selected and used to illuminate the surface 106. If it is determined, based on the comparison between the returned EMR 118 and reference information indicative of the first subset of the first group, that the substance 102 does not belong to the first subset, then a second wavelength or second wavelength range that corresponds to a second subset spectrum that can be used to identify a second subset of the first group can be selected and used to illuminate the surface 106. This process can continue until the subset of the substance 102 has been identified.

[0037] Similar to before, the first subset spectrum and the second subset spectrum (and any further spectra utilised to identify the subset of the substance) can be mutually exclusive to one another. In this way, the system 100 can select further spectra with which to illuminate the surface 106 based on the result of illuminating the surface 106 with previously selected spectra rather than illuminating the surface 106 with all possible spectra in order to identify the subset of the substance 102.

[0038] The subsets of the first group may be different groups of drugs that share spectral reflection characteristics and/or other spectral characteristics, and the system 100 can be used to identify a further subset of an already identified subset. A subset of a group may be a particular substance.

[0039] In some embodiments, the first, second, third, etc. wavelengths or wavelength ranges can be used for identification within the same group of related substances. For instance, if the first wavelength or the first wavelength range is intending to identify drug “A”, and such identification is unsuccessful, then the second wavelength or second wavelength range can be used to try to identify drug “A”. This process can be repeated for all of the available wavelengths and wavelength ranges, in an attempt to identify drug “A”, and then repeated again (if appropriate) to try to identify drug “B” and/or any other drug, until a match or other positive identification occurs for a particular drug type. In this manner, the various available wavelengths or wavelength ranges can be cycled through for various possible substances.

[0040] The returned EMR 118 may typically include a component of the emitted EMR 116, and a component of ambient light. In the example system 100 of Figure 1, the processor system 114 may be arranged to compensate for an influence of ambient light on the surface 106 and/or on the returned EMR 118.

[0041] In one example, EMR that is generated by the EMR source 110 may be relatively intense and of short duration, thereby increasing the signal to noise ratio of the emitted EMR 116 to the ambient light (considering the ambient light as noise).

[0042] Further, or alternatively, the system 100 may comprise a polariser 122 arranged such that EMR generated by the EMR source 110 passes therethrough and is polarised. The system 100 may further comprise a polarisation filter 124 arranged in front of the EMR sensor 112 so as to filter out EMR that does not have the same polarisation as EMR that has been polarised by the polariser 122, thereby improving the signal to noise ratio of the received EMR 118 to the ambient light.

[0043] In another embodiment, the spectra of the ambient light can be determined so as to allow for the influence thereof to be removed from information that is indicative of the output signal 120 by, for example, software correction performed or controlled by processor system 114.

[0044] The spectra of the ambient light can be determined using any appropriate method. In one example, a spectrophotometer can be used to determine the spectra of the ambient light by direct measurement. The spectra of the ambient light can also be determined indirectly, such as by performing a colour calibration measurement using a colour calibration card; providing a user of the system 100 with manual selection of ambient light spectra based on known lighting conditions (such as lighting conditions that correspond to the presence of fluorescent light, sunlight or incandescent light for example); or by using a target card having a specific reflectance spectra and determining the spectra of the ambient light based on a measurement of ambient light reflected from the target card. Other techniques or combination(s) thereof may be used.

[0045] During imaging of the surface 106, the object 104 may move, or the EMR sensor 112 may move, and/or both may move. The processor system 114 may be arranged to compensate for motion of the object 104 relative to the EMR sensor 112 when the surface 106 of the object 104 is being illuminated such that the image is motion-compensated.

[0046] The influence of such movement may be reduced by using, for example, an inertial measurement unit (which may include an accelerometer and a gyroscope) attached to, or otherwise associated with, the EMR sensor 112 to measure movement of the EMR sensor 112. Further, or alternatively, the system 100 may be arranged to determine features of an imaged scene that includes the surface 106, and to align the determined features between images of the scenes so as to compensate for movement of the object 104 and/or the EMR sensor 112.

[0047] Examples of EMR source 110 arrangements will now be described in more detail.

[0048] Figure 2 is a block diagram of an example EMR source 110 of the identification system 100 of Figure 1. In one example, shown in Figure 2, the EMR source 110 may comprise a broadband EMR source 202 for generating light having a broad spectrum. The EMR source 110 may also comprise a spectral dispersion component 204 that is arranged to divide the generated broad spectrum light into its spectral components. The EMR source 110 may further comprise a

selective attenuation component 206 for attenuating spectral components of the generated broad spectrum light as appropriate, and a spectral combination component 208 for recombining spectral components that were not attenuated into EMR having a specific, selected spectrum.

[0049] In the above example, the spectral dispersion component 204 may comprise a first prism, for example a glass prism, arranged to disperse EMR generated by the broadband EMR source 202. The selective attenuation component 206 may comprise a liquid crystal display (LCD) system arranged to facilitate selective attenuation of spectral components that are directed into the LCD system. The spectral combination component 208 in this example may comprise a second prism, the second prism being substantially similar to the first prism. An output from the LCD system may be directed through the second prism and the selectively attenuated spectral components may be combined to provide the emitted EMR 116 which is used to illuminate the surface 106 of the object 104.

[0050] Alternative embodiments for producing the emitted EMR 116 are envisaged. For example, a diffraction grating can be used in place of a prism so as to provide finer spectral control, or a micro-mirror array can be used to selectively attenuate the spectral components.

[0051] The source of EMR may not be a broadband EMR source, and a selected spectra can be generated by measuring the spectra of the EMR source 202 and then determining which bands of the spectra are to be attenuated to create the selected spectra.

[0052] In another example, the EMR source 110 may be arranged to facilitate generation of EMR having a specific, selected spectrum by temporal smearing. In this example, a pulse of light can be generated using a supercontinuum source before dispersing the pulse of light on a temporal basis, by using either material dispersion, or waveguide dispersion. The temporally dispersed pulse of light may be then passed through an electro-optic modulator so as to modulate the amplitude of the beam at that instant, and therefore the spectra of the EMR source 110.

[0053] In another example, a plurality of light sources, each having a different spectra, can be combined to generate a light source having a desired spectra. Each light source will

typically provide a spectrum that is orthogonal to any other light source's spectrum. In one example, each light source produces light at a unique, discrete band.

[0054] In the example system 100, the EMR sensor 112 may be arranged to capture the image of the surface 106 of the object 104 when illuminated by the EMR source 110. The EMR sensor 112 may be a CCD/CMOS sensor that does not include a colour filter array. The image can be formed on the EMR sensor 112 using optics, and filters/diffraction gratings may not typically be used for the image sensing.

[0055] Once each image has been exposed on the EMR sensor 112, the charge count of each pixel may be digitized and output to the processor system 114. The image can now be thought of, for example, as an array of numbers, stored on the processor system 114.

[0056] The processor system 114 may then process the image data to determine the identity of the substance 102. The processor system 114 may be, in this example, a computing device, such as a personal computer, arranged to carry out the processing functions of the processor system 114.

[0057] Once one or more images of the substance 102 have been obtained, using particular spectra, information concerning each pixel may be compared to known information in respect of one or more different target groups of substances and/or individual substance. For example, target groups could be groups of explosives, cocaine, cancer, or any other appropriate group of substances a user of the system 100 wants to detect.

[0058] An appropriate algorithm, for example an algorithm implemented as software running on and/or executable by the processor system 114, can be used to carry out the comparison. For example, a distance between the measured vector and each possible substance group vector can be measured, and the pixel can be assigned to the closest group.

[0059] For example, if flour has a laboratory measured vector of:

[3,5,22,1,32,-1,2,1];

(e.g., in a first image the pixel value was measured to have a value of 3, in a second image the pixel value was measured to have a value of 5, in a third image the pixel value was measured to have a value of 22, and so on)

and cocaine has a laboratory measured vector of:

[4,7,14,2,32,-4,4,2];

and a pixel of an image of the substance 102 taken by the system 100 is determined to have a vector of:

[5,6,14,3,34,-5,3,2];

then the distance, using a Euclidian measure from the flour vector, is:

$$\begin{aligned} & (5-3)^2 + (6-5)^2 + (14-22)^2 + (3-1)^2 + (34-32)^2 + (-5+1)^2 + (3-2)^2 + (2-1)^2 \\ &= 4 + 1 + 64 + 4 + 4 + 16 + 1 + 1 \\ &= 95; \end{aligned}$$

and the distance, using a Euclidian measure from the cocaine vector, is:

$$\begin{aligned} & (5-4)^2 + (6-7)^2 + (14-14)^2 + (3-2)^2 + (34-32)^2 + (-5+4)^2 + (3-4)^2 + (2-2)^2 \\ &= 1 + 1 + 0 + 1 + 4 + 1 + 1 + 0 \\ &= 9. \end{aligned}$$

[0060] From the above, because the pixel vector is closer to the vector which corresponds to cocaine, it can be concluded that the contents of the pixel of the image obtained using the system 100 may be more likely to be cocaine than flour.

[0061] This process may be carried out for each pixel in the image, and the image captured by the system 100 can then be shown to an operator, and an alarm can be raised if necessary.

[0062] In this example, the system 100 may be arranged to select a spectra to illuminate the surface 106 of the object 104 based on an analysis of an image of the surface 106 of the object 104 that has been captured while being illuminated by a previously selected spectra.

[0063] The system 100, and in particular the processor system 114, can be arranged to perform the spectra selection in an appropriate way, such as by using a binary space partitioning tree, which can facilitate determination by the system 100 of the identity of the substance 102 from a number of substances that may be present in the image. Using a binary space tree as a tool in selecting the spectra, rather than linearly searching a set of possible substances for example, can reduce the time taken to identify the substance 102.

[0064] In this particular example, nodes of the binary space tree may correspond to the spectra of substances of interest that may possibly be observed in the image, and hyperplanes that separate nodes of the binary space tree may correspond to the illumination spectra.

[0065] At each stage of illumination, the processor system 114 may decide which spectra to use based on what the system 100 has observed so far and may use the binary space tree to determine which spectra (corresponding to a particular hyperplane of the binary space tree), to use next to most efficiently determine the identity of the substance 102 in the image.

[0066] As a result of selecting a spectrum for illuminating the object 104 based on analysis of an image captured using a previously selected spectrum, the total imaging time may be a function of the number of different substances in the image, rather than the number of

possible different substances of interest that may be observed. The system 100 can therefore identify the substance 102 in a shorter period of time compared to if an approach of linearly searching a set of possible substances is used. Consequently, the system 100 can operate at a higher frame rate, and can be used to detect substances more efficiently compared to if some other approach has been taken.

[0067] For example, using a method of linearly searching a set of possible substances one at a time may be sufficient if a user of the system 100 has some knowledge of what substances the user is attempting to detect, for example one of cocaine, semtex, ricin, ammonium nitrate, or baking flour. However, using the such method, if a user of the system 100 wants to detect one of the five different substances mentioned, the system 100 may take five different sets of images (for example 5*20 images), to linearly determine if any of the substances of interest are in the scene. Under this method, because imaging time may be proportional or otherwise related to the number of substances of interest, it can be seen that there may be a limit to the number of substances of interest which may be efficiently detected.

[0068] In comparison, the system 100 of one embodiment may be arranged to determine the identity of the substance 102 by illuminating the surface 106 of the object 104 with spectra that have been selected based on the result of analysing images captured when the surface 106 of the object 104 has been illuminated with previously selected spectra. In this example, each substance, or group of substances, may have a spectral characteristic that is mutually exclusive to the other substances, or group of substances. For example, there may be a known spectrum for the group of explosive substances that may be present in one or many forms of explosives, but that is not present in the group of drug substances. Further, each type of explosive substance may have a spectrum that is not present in every type of explosive substance.

[0069] If, as a result of illuminating the surface 106 with a spectrum that is specific to the group of explosive substances, it is determined that no explosive substances are present, the system 100 may select a different spectrum that is exclusive to a further group of substances, for example the group of drug substances, until one spectrum is identified that is unique in that group of substances.

[0070] Once a particular group of substances has been identified, the system 100 may then select spectra that are present in substances of the identified group of substances until the actual substance is identified.

[0071] Figure 3 is an example identification method. More specifically, a method 300 to identify the substance 102 using the system 100 will now be described with reference to Figure 3.

[0072] In some examples, the process in Figure 3 could be implemented using system 100 discussed above. An example process may include one or more operations, actions, or functions as illustrated by one or more of blocks 302-316. Although illustrated as discrete blocks, various blocks may be divided into additional blocks, combined into fewer blocks, or eliminated, depending on the particular implementation. Blocks may be supplemented with additional blocks representing other operations, actions, or functions.

[0073] The example method 300 may include a block 302 of selecting a first wavelength or wavelength range. In a block 304, which may follow the block 302, the EMR source 110 may emit EMR at the selected first wavelength or wavelength range so as to illuminate at least one surface 106 of the object 104. In a block 306, which may follow the block 304, EMR returned from the at least one surface 106 of the object 102 may be received by the EMR sensor 112 in response to illumination of the at least one surface by the emitted EMR.

[0074] The output signal 120, which may represent an image taken of the surface 106, may be provided in a block 308 that may follow the block 306. In the block 308, the returned EMR may be used to provide the output signal 120. The image may typically include a plurality of pixels.

[0075] In a block 310, which may follow the block 308, information that is indicative of the output signal 120 may be compared with reference information that is indicative of the property of the substance 102. The comparison of the block 310 may be performed in a manner

such that the information indicative of the output signal 120 is compared with the reference information on a pixel by pixel basis for the plurality of pixels in the image.

[0076] The block 310 may be performed by the processor system 114 and, in this example, the processor system 114 may be arranged to determine that the substance 102 is located in the object 104, or located on the surface 106 of the object 104, if information concerning the property can be obtained as a result of the comparison of the information indicative of the output signal 120 with the reference information.

[0077] In a block 312, which may follow the block 310, at least one further wavelength or further wavelength range may be selected to illuminate the surface 106 of the object 104 by the EMR source 110 based on whether the information concerning the property is obtained as a result of use of a preceding wavelength or a preceding wavelength range for illumination of the surface 106.

[0078] A block 314 of the method 300 may follow the block 312 and may include compensating for an influence of ambient light on the surface 106 of the object 104.

[0079] A block 316 may follow the block 314 and may include compensating for motion of the object during illumination of the at least one surface of the object, such that the image is motion-compensated.

[0080] While security applications have been described by way of example, the system 100 can be used in other appropriate applications, for example medical segmentation, wherein the system 100 may be arranged to determine what parts of a scene are liver, kidney, connective tissue, biofilm, etc. The object 104 may include a person or a piece of clothing of the person. Further, the substance 102 may include, in solid form or in liquid form, at least one of a drug, an explosive, a radioactive material, or a food product.

[0081] The present disclosure is not to be limited in terms of the particular embodiments described in this application, which are intended as illustrations of various aspects. Many

modifications and variations can be made without departing from its spirit and scope. Functionally equivalent methods and apparatuses within the scope of the disclosure, in addition to those enumerated herein, are possible from the foregoing descriptions. Such modifications and variations are intended to fall within the scope of the appended claims. The present disclosure is to be limited only by the terms of the appended claims, along with the full scope of equivalents to which such claims are entitled. This disclosure is not limited to particular methods, reagents, compounds, compositions or biological systems, which can, of course, vary. The used herein is for the purpose of describing particular embodiments only, and is not intended to be limiting.

[0082] In an illustrative embodiment, any of the operations, processes, etc. described herein can be implemented as computer-readable instructions stored on a non-transitory computer-readable medium. The computer-readable instructions can be executed by a processor of a mobile unit, a network element, and/or any other computing device.

[0083] Figure 4 shows an example of one such computing device. Specifically, Figure 4 is a block diagram illustrating an example computing device 400 that is arranged to process images in connection with substance identification in accordance with the present disclosure. In one embodiment, at least some of the elements of the system 100 of Figure 1 can be implemented in or by the computing device 400 of Figure 4.

[0084] In a very basic configuration 401, computing device 400 typically includes one or more processors 410 and system memory 420. A memory bus 430 can be used for communicating between the processor 410 and the system memory 420. In one embodiment, the processor system 114 of Figure 1 can be implemented in whole or in part by the processor 410 of Figure 4.

[0085] Depending on the desired configuration, processor 410 can be of any type including but not limited to a microprocessor (μ P), a microcontroller (μ C), a digital signal processor (DSP), or any combination thereof. Processor 410 can include one or more levels of caching, such as a level one cache 411 and a level two cache 412, a processor core 413, and registers 414. The processor core 413 can include an arithmetic logic unit (ALU), a floating

point unit (FPU), a digital signal processing core (DSP Core), or any combination thereof. A memory controller 415 can also be used with the processor 410, or in some implementations the memory controller 415 can be an internal part of the processor 410.

[0086] Depending on the desired configuration, the system memory 420 can be of any type including but not limited to volatile memory (such as RAM), non-volatile memory (such as ROM, flash memory, etc.) or any combination thereof. System memory 420 typically includes an operating system 421, one or more applications 422, and program data 424. Application 422 may include an identification algorithm 423 that may cooperate with the processor 410 to perform one or more of: control the EMR 116 to illuminate the object 104, process the returned EMR 118 to provide the output signal 120, process image(s) represented by the output signal 120 (including comparing information contained in or represented by the output signal 120 with reference information), perform the binary space tree operations, compensate for ambient light and motion, and/or other operations described above that pertain to illumination and identification of a substance in or on the object 104. Program Data 424 may include identification data 425 that is usable for performing the algorithm 423, including but not limited to reference information, vector values, binary space tree values, settings for EMR spectra, calculation results, and/or other data. In some embodiments, application 422 can be arranged to operate with program data 424 on an operating system 421 such that the illumination and identification as described above is performed. This described basic configuration is illustrated in Figure 4 by those components within dashed line 401.

[0087] Computing device 400 can have additional features or functionality, and additional interfaces to facilitate communications between the basic configuration 401 and any required devices and interfaces. For example, a bus/interface controller 440 can be used to facilitate communications between the basic configuration 401 and one or more data storage devices 450 via a storage interface bus 441. The data storage devices 450 can be removable storage devices 451, non-removable storage devices 452, or a combination thereof. Examples of removable storage and non-removable storage devices include magnetic disk devices such as flexible disk drives and hard-disk drives (HDD), optical disk drives such as compact disk (CD) drives or digital versatile disk (DVD) drives, solid state drives (SSDs), and tape drives to name a

few. Example computer storage media can include volatile and nonvolatile, removable and non-removable media implemented in any method or technology for storage of information, such as computer readable instructions, data structures, program modules, or other data.

[0088] System memory 420, removable storage 451 and non-removable storage 452 are all examples of computer storage media. Computer storage media includes, but is not limited to, RAM, ROM, EEPROM, flash memory or other memory technology, CD-ROM, digital versatile disks (DVDs) or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information and which can be accessed by computing device 400. Any such computer storage media can be part of device 400.

[0089] Computing device 400 can also include an interface bus 442 for facilitating communication from various interface devices (e.g., output interfaces, peripheral interfaces, and communication interfaces) to the basic configuration 401 via the bus/interface controller 440. Example output devices 460 include a graphics processing unit 461 and an audio processing unit 462, which can be configured to communicate to various external devices such as a display or speakers via one or more A/V ports 463. Example peripheral interfaces 470 include a serial interface controller 471 or a parallel interface controller 472, which can be configured to communicate with external devices such as input devices (e.g., keyboard, mouse, pen, voice input device, touch input device, etc.) or other peripheral devices (e.g., printer, scanner, etc.) via one or more I/O ports 473. An example communication device 480 includes a network controller 481, which can be arranged to facilitate communications with one or more other computing devices 490 over a network communication via one or more communication ports 482. The communication connection is one example of a communication media. Communication media may typically be embodied by computer readable instructions, data structures, program modules, or other data in a modulated data signal, such as a carrier wave or other transport mechanism, and includes any information delivery media. A “modulated data signal” can be a signal that has one or more of its characteristics set or changed in such a manner as to encode information in the signal. By way of example, and not limitation, communication media can include wired media such as a wired network or direct-wired connection, and wireless

media such as acoustic, radio frequency (RF), infrared (IR) and other wireless media. The term computer readable media as used herein can include both storage media and communication media.

Computing device 400 can be implemented as a portion of a small-form factor portable (or mobile) electronic device such as a cell phone, a personal data assistant (PDA), a personal media player device, a wireless web-watch device, a personal headset device, an application specific device, or a hybrid device that include any of the above functions. Computing device 400 can also be implemented as a personal computer including both laptop computer and non-laptop computer configurations.

[0090] The use of hardware or software is generally (but not always, in that in certain contexts the choice between hardware and software can become significant) a design choice representing cost vs. efficiency tradeoffs. There are various vehicles by which processes and/or systems and/or other technologies described herein can be effected (e.g., hardware, software, and/or firmware), and that the preferred vehicle will vary with the context in which the processes and/or systems and/or other technologies are deployed. For example, if an implementer determines that speed and accuracy are paramount, the implementer may opt for a mainly hardware and/or firmware vehicle; if flexibility is paramount, the implementer may opt for a mainly software implementation; or, yet again alternatively, the implementer may opt for some combination of hardware, software, and/or firmware.

[0091] The foregoing detailed description has set forth various embodiments of the devices and/or processes via the use of block diagrams, flowcharts, and/or examples. Insofar as such block diagrams, flowcharts, and/or examples contain one or more functions and/or operations, each function and/or operation within such block diagrams, flowcharts, or examples can be implemented, individually and/or collectively, by a wide range of hardware, software, firmware, or virtually any combination thereof. In one embodiment, several portions of the subject matter described herein may be implemented via Application Specific Integrated Circuits (ASICs), Field Programmable Gate Arrays (FPGAs), digital signal processors (DSPs), or other integrated formats. However, some aspects of the embodiments disclosed herein, in whole or in part, can be equivalently implemented in integrated circuits, as one or more computer programs

running on one or more computers (e.g., as one or more programs running on one or more computer systems), as one or more programs running on one or more processors (e.g., as one or more programs running on one or more microprocessors), as firmware, or as virtually any combination thereof, and designing the circuitry and/or writing the code for the software and or firmware would be possible in light of this disclosure. In addition, the mechanisms of the subject matter described herein are capable of being distributed as a program product in a variety of forms, and that an illustrative embodiment of the subject matter described herein applies regardless of the particular type of signal bearing medium used to actually carry out the distribution. Examples of a signal bearing medium include, but are not limited to, the following: a recordable type medium such as a floppy disk, a hard disk drive, a CD, a DVD, a digital tape, a computer memory, etc.; and a transmission type medium such as a digital and/or an analog communication medium (e.g., a fiber optic cable, a waveguide, a wired communications link, a wireless communication link, etc.).

[0092] Those skilled in the art will recognize that it is common within the art to describe devices and/or processes in the fashion set forth herein, and thereafter use engineering practices to integrate such described devices and/or processes into data processing systems. That is, at least a portion of the devices and/or processes described herein can be integrated into a data processing system via a reasonable amount of experimentation. A typical data processing system generally includes one or more of a system unit housing, a video display device, a memory such as volatile and non-volatile memory, processors such as microprocessors and digital signal processors, computational entities such as operating systems, drivers, graphical user interfaces, and applications programs, one or more interaction devices, such as a touch pad or screen, and/or control systems including feedback loops and control motors (e.g., feedback for sensing position and/or velocity; control motors for moving and/or adjusting components and/or quantities). A typical data processing system may be implemented utilizing any suitable commercially available components, such as those typically found in data computing/communication and/or network computing/communication systems.

[0093] The herein described subject matter sometimes illustrates different components contained within, or connected with, different other components. Such depicted architectures are

merely examples, and in fact many other architectures can be implemented which achieve the same functionality. In a conceptual sense, any arrangement of components to achieve the same functionality is effectively "associated" such that the desired functionality is achieved. Hence, any two components herein combined to achieve a particular functionality can be seen as "associated with" each other such that the desired functionality is achieved, irrespective of architectures or intermedial components. Likewise, any two components so associated can also be viewed as being "operably connected", or "operably coupled", to each other to achieve the desired functionality, and any two components capable of being so associated can also be viewed as being "operably couplable", to each other to achieve the desired functionality. Specific examples of operably couplable include but are not limited to physically mateable and/or physically interacting components and/or wirelessly interactable and/or wirelessly interacting components and/or logically interacting and/or logically interactable components.

[0094] With respect to the use of substantially any plural and/or singular terms herein, those having skill in the art can translate from the plural to the singular and/or from the singular to the plural as is appropriate to the context and/or application. The various singular/plural permutations may be expressly set forth herein for sake of clarity.

[0095] It will be understood by those within the art that, in general, terms used herein, and especially in the appended claims (*e.g.*, bodies of the appended claims) are generally intended as "open" terms (*e.g.*, the term "including" should be interpreted as "including but not limited to," the term "having" should be interpreted as "having at least," the term "includes" should be interpreted as "includes but is not limited to," etc.). It will be further understood by those within the art that if a specific number of an introduced claim recitation is intended, such an intent will be explicitly recited in the claim, and in the absence of such recitation no such intent is present. For example, as an aid to understanding, the following appended claims may contain usage of the introductory phrases "at least one" and "one or more" to introduce claim recitations. However, the use of such phrases should not be construed to imply that the introduction of a claim recitation by the indefinite articles "a" or "an" limits any particular claim containing such introduced claim recitation to embodiments containing only one such recitation, even when the same claim includes the introductory phrases "one or more" or "at least one" and

indefinite articles such as "a" or "an" (*e.g.*, "a" and/or "an" should be interpreted to mean "at least one" or "one or more"); the same holds true for the use of definite articles used to introduce claim recitations. In addition, even if a specific number of an introduced claim recitation is explicitly recited, those skilled in the art will recognize that such recitation should be interpreted to mean at least the recited number (*e.g.*, the bare recitation of "two recitations," without other modifiers, means at least two recitations, or two or more recitations). Furthermore, in those instances where a convention analogous to "at least one of A, B, and C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*e.g.*, "a system having at least one of A, B, and C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). In those instances where a convention analogous to "at least one of A, B, or C, etc." is used, in general such a construction is intended in the sense one having skill in the art would understand the convention (*e.g.*, "a system having at least one of A, B, or C" would include but not be limited to systems that have A alone, B alone, C alone, A and B together, A and C together, B and C together, and/or A, B, and C together, etc.). It will be further understood by those within the art that virtually any disjunctive word and/or phrase presenting two or more alternative terms, whether in the description, claims, or drawings, should be understood to contemplate the possibilities of including one of the terms, either of the terms, or both terms. For example, the phrase "A or B" will be understood to include the possibilities of "A" or "B" or "A and B."

[0096] In addition, where features or aspects of the disclosure are described in terms of Markush groups, those skilled in the art will recognize that the disclosure is also thereby described in terms of any individual member or subgroup of members of the Markush group.

[0097] As will be understood by one skilled in the art, for any and all purposes, such as in terms of providing a written description, all ranges disclosed herein also encompass any and all possible subranges and combinations of subranges thereof. Any listed range can be easily recognized as sufficiently describing and enabling the same range being broken down into at least equal halves, thirds, quarters, fifths, tenths, etc. As a non-limiting example, each range discussed herein can be readily broken down into a lower third, middle third and upper third, etc.

As will also be understood by one skilled in the art all language such as “up to,” “at least,” and the like include the number recited and refer to ranges which can be subsequently broken down into subranges as discussed above. Finally, as will be understood by one skilled in the art, a range includes each individual member. Thus, for example, a group having 1-3 cells refers to groups having 1, 2, or 3 cells. Similarly, a group having 1-5 cells refers to groups having 1, 2, 3, 4, or 5 cells, and so forth.

[0098] From the foregoing, various embodiments of the present disclosure have been described herein for purposes of illustration, and various modifications may be made without departing from the scope and spirit of the present disclosure. Accordingly, the various embodiments disclosed herein are not intended to be limiting, with the true scope and spirit being indicated by the following claims.

CLAIMS

WHAT IS CLAIMED IS:

1. A system to identify at least a property of a substance located in an object or located on at least one surface of the object, the system comprising:
 - an electromagnetic radiation (EMR) source arranged to selectively emit EMR at more than one wavelength or wavelength range to illuminate the at least one surface of the object;
 - an EMR sensor arranged to sense EMR returned from the at least one surface and to use the returned EMR to provide an output signal that represents an image taken of the surface, the image including a plurality of pixels; and
 - a processor system arranged to compare information that is indicative of the output signal of the EMR sensor with reference information indicative of the property of the substance in a manner such that the information indicative of the output signal is compared with the reference information on a pixel by pixel basis for the plurality of pixels in the image, wherein the processor system is arranged to determine that the substance is located in the object or located on the at least one surface of the object if information concerning the at least the property can be obtained as a result of the comparison of the information indicative of the output signal with the reference information, the processor system being further arranged to:
 - select a first wavelength or first wavelength range to illuminate the at least one surface by the EMR source, and subsequently select at least one further wavelength or further wavelength range to illuminate the at least one surface by the EMR source, wherein the selection of the at least one further wavelength or the further wavelength range is based on whether the information concerning the property is obtained as a result of use of a preceding wavelength or a preceding wavelength range for illumination of the at least one surface;
 - compensate for an influence of ambient light on the at least one surface; and

compensate for motion of the object relative to the EMR sensor during illumination of the at least one surface of the object, such that the image is motion-compensated.

2. The system of claim 1, wherein the object includes a person or a piece of clothing of the person.
3. The system of claim 1, wherein the substance includes, in solid form or in liquid form, at least one of a drug, an explosive, a radioactive material, or a food product.
4. The system of any one of claims 1 to 3, wherein the processor system is arranged to select a plurality of further wavelengths or further wavelength ranges to illuminate the at least one surface by the EMR source based on whether the information concerning the at least a property is obtained in preceding wavelengths or preceding wavelength ranges.
5. The system of any one of the preceding claims, wherein the first wavelength or first wavelength range corresponds to a first spectrum that can be used to identify a first group of related substances and wherein, if it is determined, based on the comparison between information that is indicative of the output signal of the EMR sensor and reference information indicative of the property of the first group of substances, that the substance does not belong to the first group, then the processor system is arranged to select a second wavelength or second wavelength range that corresponds to a second spectrum that can be used to identify a second group of related substances to illuminate the surface.
6. The system of claim 5, wherein the first spectrum and the second spectrum are mutually exclusive to one another.
7. The system of claim 5 or claim 6, wherein if it is determined, based on the comparison between information that is indicative of the output signal of the EMR sensor and reference information indicative of the property of the first group, that the substance belongs to the first group, then the processor system is arranged to select a further

wavelength or further wavelength range that corresponds to a first subset spectrum that can be used to identify one of a subset of the first group to illuminate the surface.

8. The system of claim 7, wherein if, in response to illuminating the surface of the object with the first subset spectrum, it is determined, based on the comparison between information that is indicative of the output signal of the EMR sensor and reference information indicative of the first subset of the first group, that the substance does not belong to the first subset, then the processor system is arranged to select a second wavelength or second wavelength range that corresponds to a second subset spectrum that can be used to identify a second subset of the first group.
9. The system of claim 8, wherein the first subset spectrum and the second subset spectrum are mutually exclusive to one another.
10. The system of any one of claims 1 to 9, wherein the processor system is arranged to select the at least one further wavelength or further wavelength range based on binary space partitioning of a binary space, the binary space comprising a plurality of nodes and hyperplanes that separate nodes of the plurality of nodes, wherein each node of the binary space is indicative of an EMR spectrum associated with a known substance, and each hyperplane of the binary space is indicative of a wavelength or wavelength range that is selectable by the processor system.
11. The system of claim 10, wherein the processor system is arranged to select the at least one further wavelength or wavelength range based on a binary space tree, the binary space tree comprising a plurality of nodes and hyperplanes that separate nodes of the plurality of nodes wherein:
 - each node of the binary space tree comprises information that is indicative of an EMR spectrum associated with a known substance; and
 - each hyperplane of the binary space tree comprises information that is indicative of a wavelength or wavelength range that can be selected by the processor system.

12. The system of any one of the preceding claims, wherein, to compensate for the influence of the ambient light, the processor system is arranged to control the EMR source such that the influence of the ambient light returned from the at least one surface is adjusted compared to a selected wavelength or selected wavelength range generated by the EMR source and returned from the at least one surface.
13. The system of claim 12, wherein the EMR source is arranged to generate the selected wavelength or selected wavelength range so as to have an intensity that is greater than that of the ambient light.
14. The system of claim 12, further comprising a polariser that is arranged to polarise the at least one wavelength or wavelength range, and a filter that is arranged to filter EMR that has a different polarisation to that of the polarised wavelength or wavelength range prior to being received by the EMR sensor.
15. The system of any one of claims 1 to 11, wherein, to compensate for the influence of the ambient light, the EMR sensor or a further EMR sensor is arranged so as to determine a spectrum of the ambient light, and wherein the processor system is arranged to filter at least a portion of the ambient light spectrum from information that is indicative of the EMR returned from the at least one surface.
16. The system of claim 15, wherein the processor system is arranged to determine the ambient light spectrum from a colour calibration measurement performed using the EMR sensor or the further EMR sensor.
17. The system of claim 15, wherein the processor system is arranged to determine the ambient light spectrum by determination of a spectrum of EMR returned from an object having a known reflectance characteristic.
18. The system of any one of the preceding claims, wherein, to compensate for the motion of the object, the processor system is arranged to determine a movement of the at least one

- surface of the object relative to the EMR sensor to correct the output signal based on the EMR as received by the EMR sensor over a period of time while the at least one surface moves.
19. The system of claim 18, further comprising an inertial movement unit, the inertial movement unit being associated with the object or the EMR sensor and being arranged to determine a relative movement of the at least one surface of the object and the EMR sensor.
 20. The system of claim 18, wherein to compensate for the motion of the object the processor system is arranged to determine relative movement of the at least one surface of the object and the EMR sensor by comparison of at least one feature of EMR returned from the at least one surface and received by the EMR sensor at a first time with the at least one feature of EMR returned from the at least one surface and received by the EMR sensor at a second time.
 21. The system of any one of the preceding claims, wherein the EMR source is arranged to generate wavelengths or wavelength ranges within a visible spectrum, and wherein the EMR sensor is sensitive to wavelengths or wavelength ranges within the visible spectrum.
 22. The system of claim 21, wherein the EMR sensor includes an image sensor.
 23. The system of claim 22, wherein the image sensor includes a charge-coupled device (CCD) sensor or a complementary metal–oxide–semiconductor (CMOS) sensor.
 24. A method to identify at least a property of a substance located in an object or located on at least one surface of the object, the method comprising:
 - selecting a first wavelength or wavelength range;
 - emitting EMR at the selected first wavelength or wavelength range so as to illuminate the at least one surface of the object;

receiving EMR returned from the at least one surface of the object in response to illumination of the at least one surface by the emitted EMR;

providing, using the returned EMR, an output signal that represents an image taken of the surface, the image including a plurality of pixels;

comparing information that is indicative of the output signal with reference information indicative of the property of the substance in a manner such that the information indicative of the output signal is compared with the reference information on a pixel by pixel basis for the plurality of pixels in the image, wherein a determination that the substance is located in the object or located on the at least one surface of the object is made if information concerning the at least the property can be obtained as a result of the comparison of the information indicative of the output signal with the reference information;

selecting at least one further wavelength or further wavelength range to illuminate the at least one surface of the object based on whether the information concerning the property is obtained as a result of use of a preceding wavelength or a preceding wavelength range for illumination of the at least one surface;

compensating for an influence of ambient light on the at least one surface; and

compensating for motion of the object relative to an EMR sensor at which the EMR returned from the at least one surface of the object is received during illumination of the at least one surface of the object, such that the image is motion-compensated.

25. The method of claim 24, wherein the object includes a person or a piece of clothing of the person.
26. The method of claim 24, wherein the substance includes, in solid form or in liquid form, at least one of a drug, an explosive, a radioactive material, or a food product.
27. The method of any one of claims 24 to 26, further comprising selecting a plurality of further wavelengths or further wavelength ranges to illuminate the at least one surface by EMR based on whether the information concerning the property is obtained in preceding wavelengths or preceding wavelength ranges.

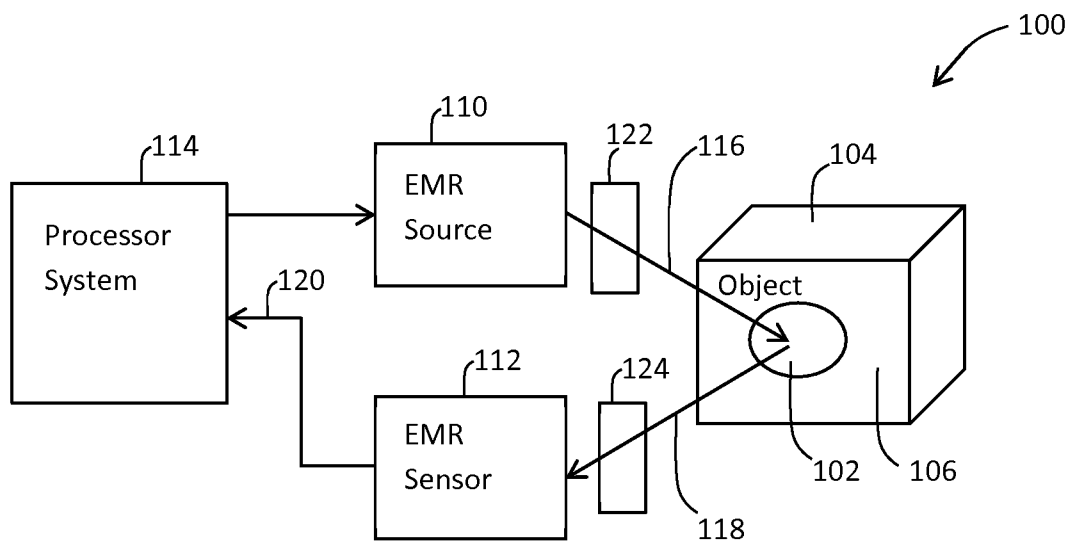
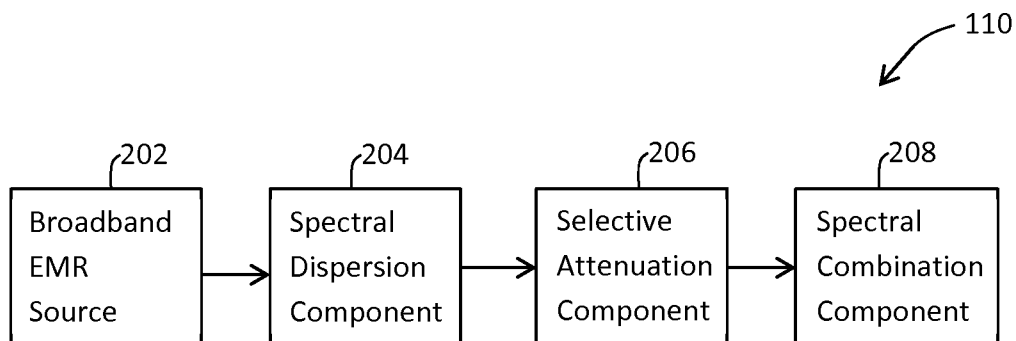
28. The method of any one of claims 24 to 27, wherein the first wavelength or first wavelength range corresponds to a first spectrum that can be used to identify a first group of related substances and wherein, if it is determined, based on the comparison between information that is indicative of the output signal and reference information indicative of the property of the first group of substances, that the substance does not belong to the first group, then a second wavelength or second wavelength range that corresponds to a second spectrum that can be used to identify a second group of related substances is selected to illuminate the surface.
29. The method of claim 28, wherein the first spectrum and the second spectrum are mutually exclusive to one another.
30. The method of claim 28 or claim 29, wherein if it is determined, based on the comparison between information that is indicative of the output signal and reference information indicative of the property of the first group, that the substance belongs to the first group, then a further wavelength or further wavelength range that corresponds to a first subset spectrum that can be used to identify one of a subset of the first group is selected to illuminate the surface.
31. The method of claim 30, wherein if, in response to illuminating the surface of the object with the first subset spectrum, it is determined, based on the comparison between information that is indicative of the output signal of the EMR sensor and reference information indicative of the first subset of the first group, that the substance does not belong to the first subset, then the processor system is arranged to select a second wavelength or second wavelength range that corresponds to a second subset spectrum that can be used to identify a second subset of the first group.
32. The method of claim 31, wherein the first subset spectrum and the second subset spectrum are mutually exclusive to one another.

33. The method of any one of claims 24 to 32, wherein selecting the at least one further wavelength or further wavelength range is based on binary space partitioning of a binary space, the binary space comprising a plurality of nodes and hyperplanes that separate nodes of the plurality of nodes, wherein each node of the binary space is indicative of an EMR spectrum associated with a known substance, and each hyperplane of the binary space is indicative of a wavelength or wavelength range that is selectable.
34. The method of claim 33, wherein selecting the at least one further wavelength or wavelength range is based on a binary space tree, the binary space tree comprising a plurality of nodes and hyperplanes that separate nodes of the plurality of nodes wherein:
each node of the binary space tree comprises information that is indicative of an EMR spectrum associated with a known substance; and
each hyperplane of the binary space tree comprises information that is indicative of a wavelength or wavelength range that is selectable.
35. The method of any one of claims 24 to 34, wherein, to compensate for the influence of the ambient light, the method comprises controlling emission of the EMR such that the influence of the ambient light returned from the at least one surface is adjusted compared to a selected wavelength or selected wavelength range of EMR emitted and subsequently returned from the at least one surface.
36. The method of claim 35, wherein compensating for the influence of the ambient light comprises generating the selected wavelength or selected wavelength range so that the EMR emitted and subsequently returned from the at least one surface is greater than that of the ambient light.
37. The method of claim 35, wherein compensating for the influence of the ambient light comprises:
polarising the emitted EMR; and
filtering EMR that has a polarisation that is different to that of the emitted polarised EMR prior to being received.

38. The method of any one of claims 24 to 34, wherein compensating for the influence of the ambient light comprises:
- determining a spectrum of the ambient light; and
 - filtering at least a portion of the ambient light spectrum from information that is indicative of the EMR returned from the at least one surface.
39. The method of claim 38, wherein determining the ambient light spectrum comprises measuring the spectrum of the ambient light.
40. The method of claim 38, wherein determining the ambient light spectrum comprises performing a colour calibration measurement.
41. The method of claim 38, wherein the ambient light spectrum is determined by determination of a spectrum of EMR returned from an object having a known reflectance characteristic.
42. The method of any one of claims 24 to 41, wherein compensating for the motion of the object comprises:
- determining a movement of the at least one surface of the object relative to an EMR sensor used to receive the EMR reflected from the at least one object; and
 - correcting the output signal based on the EMR as received by the EMR sensor over a period of time while the at least one surface moves.
43. The method of claim 42, wherein determining the movement of the at least one surface of the object relative to the EMR sensor comprises using an inertial movement unit associated with the at least one object or the EMR sensor.
44. The method of claim 42, wherein determining the movement of the at least one surface of the object relative to an EMR sensor comprises:

comparing at least one feature of received EMR returned from the at least one surface at a first time with the at least one feature of received EMR returned from the at least one surface at a second time.

45. The method of any one of claims 24 to 44, wherein the emitted EMR is visible EMR.
46. A non-transitory computer-readable medium that includes computer-readable instructions stored thereon that are executable by a processor to perform the method of any of claims 24 to 44.

**FIG 1****Fig 2**

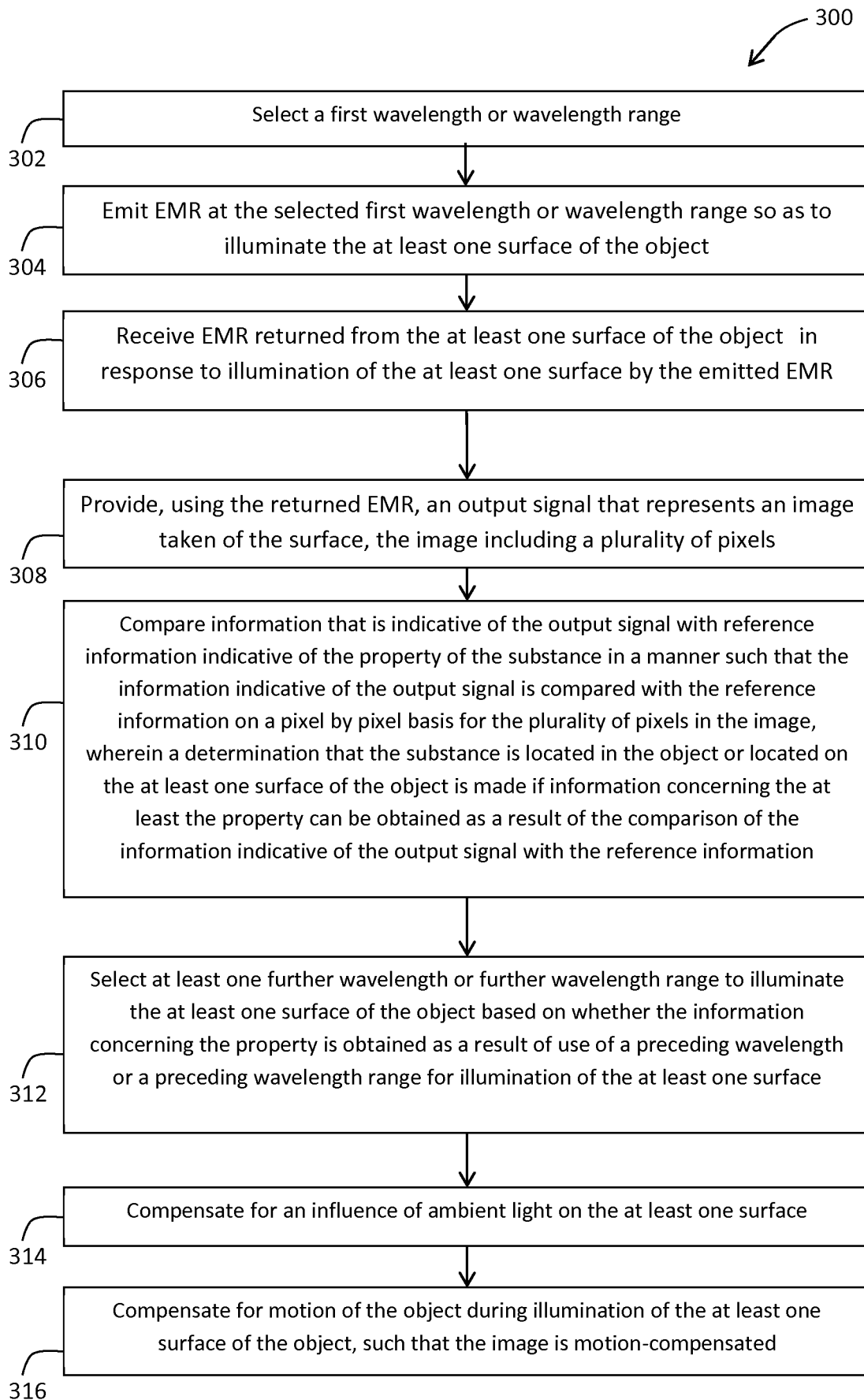


FIG 3

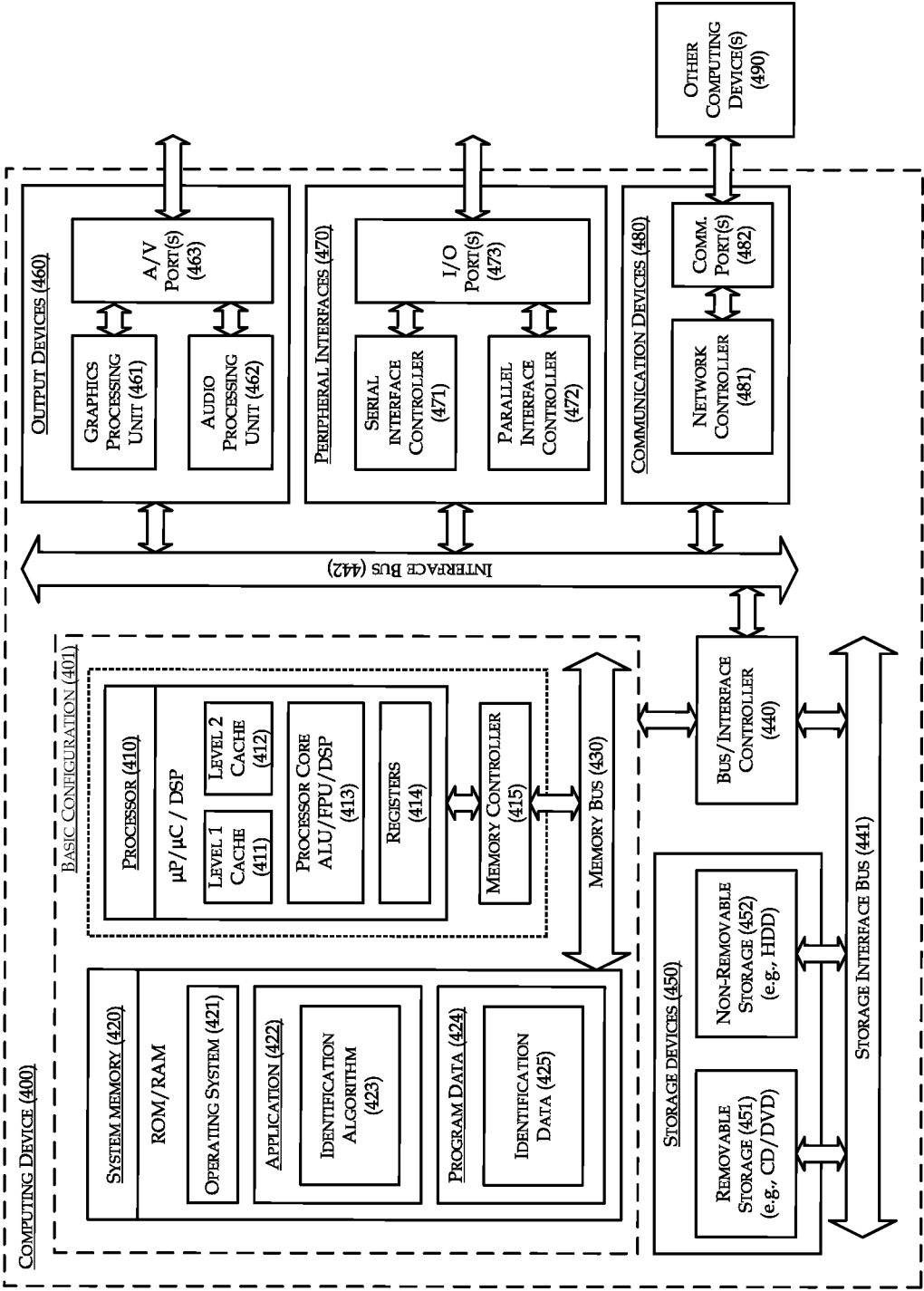


FIG 4

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/033106

A. CLASSIFICATION OF SUBJECT MATTER

IPC(8) - G06T 1/40 (2014.01)

USPC - 382/191

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC(8) - G06K 9/00, 02, 62, 78; G06T 7/00, 40 (2014.01)

USPC - 382/103, 190, 191

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

CPC - G06K 9/00, 02, 62, 78; G06T 7/00, 40 (2014.02)

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

PatBase, Google Patents, Google Scholar

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2002/0092989 A1 (TOOMEY) 18 July 2002 (18.07.2002) entire document	1-4, 24-27
Y	US 2007/0024946 A1 (PANASYUK et al) 01 February 2007 (01.02.2007) entire document	1-4, 24-27
Y	US 2013/0236073 A1 (PIRATLA et al) 12 September 2013 (12.09.2013) entire document	2, 3, 25, 26
A	US 8,571,325 B1 (ROBINSON et al) 29 October 2013 (29.10.2013) entire document	1-4, 24-27
A	US 2012/0134582 A1 (TREADO et al) 31 May 2012 (31.05.2012) entire document	1-4, 24-27

☐ Further documents are listed in the continuation of Box C.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

"P" document published prior to the international filing date but later than the priority date claimed

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

28 July 2014

Date of mailing of the international search report

20 AUG 2014

Name and mailing address of the ISA/US

Mail Stop PCT, Attn: ISA/US, Commissioner for Patents
P.O. Box 1450, Alexandria, Virginia 22313-1450

Facsimile No. 571-273-3201

Authorized officer:

Blaine R. Copenheaver

PCT Helpdesk: 571-272-4300
PCT OSP: 571-272-7774

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2014/033106

Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:
2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:
3. ☒ Claims Nos.: 5-23, 28-46
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.