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[Continued on next page]

(54) **Title**: VITAL SIGN MONITORING

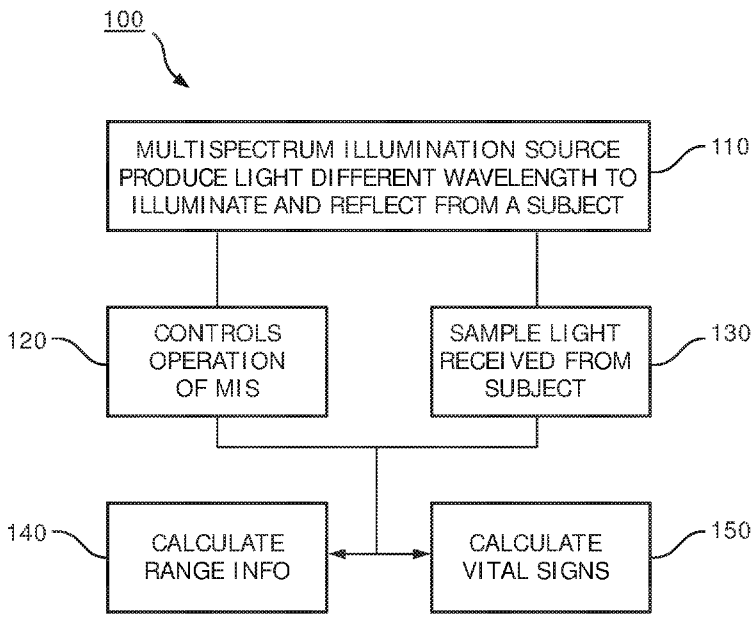

FIG. 7

(57) **Abstract**: Apparatus and methods to monitor vital signs. A multispectral illumination source produces light having a plurality of wavelengths that illuminate a subject. A processing component, such as a time-of-flight camera system, measures the time the light has taken to travel from the multispectral illumination source to the subject and from the subject to the processing component, calculates range information to localize the subject, and calculates vital signs of the subject utilizing photoplethysmographic (PPG) information derived from the light received from the subject and the range information.

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VITAL SIGN MONITORING

TECHNICAL FIELD

[001] The present invention generally relates to the monitoring of human vital signs and, more specifically, to obtaining human vital sign measurements from a photoplethysmogram utilizing multispectral illumination and a time-of-flight sensing system.

BACKGROUND

[002] In photoplethysmographic (PPG) imaging portions of human tissues are exposed to light. The illuminating light penetrates the skin and is partially scattered back. The amount of light backscattered shows a time dependent behavior. These temporal changes in the PPG signal are caused by the time dependent absorption of light by oxygenated hemoglobin and deoxyhemoglobin. Because the oxyhemoglobin and deoxyhemoglobin have different absorption spectra, changes in their relative concentration in the blood change the overall amount of light transmitted and reflected by body tissue.

[003] Vital sign measurements can be obtained from a PPG signal. For example, heart rate can be obtained by measuring the time interval between two consecutive peaks of a PPG waveform. An estimate of peripheral arterial oxygen saturation (SpO_2) can be obtained by measuring the PPG signal at two wavelengths. The use of light sources with different light spectra and in combination with optical filters has enabled blood oxygenation imaging techniques. One prior art arrangement teaches the use of multiple cameras and multiple LED light sources to image the oxygenation content in tissue blood vessels. This prior art imaging system uses three light sources each having a peak emitted frequency at three different wavelengths.

SUMMARY

[004] Embodiments of the present invention relate generally to the monitoring of human vital signs, and more specifically, to obtaining improved measurements of vital signs utilizing multispectral illumination and a time-of-flight sensing system.

[005] It is to be understood that the invention is not limited in its application to the details of the construction and arrangement of parts illustrated in the accompanying drawings and discussed herein below. The invention is capable of other embodiments and of being practiced or carried out in a variety of ways. It is to be understood that the phraseology and terminology employed herein are for the purpose of description and not of limitation.

[006] One aspect of an embodiment of the present invention includes an apparatus to monitor a physiological parameter. The apparatus includes a multispectral illumination source in combination with a processing component. The multispectral illumination source produces light having a plurality of wavelengths that illuminates a subject. In one embodiment, the multispectral illumination source includes a plurality of LEDs, wherein a first LED in the plurality of LEDs is capable of emitting light having a first wavelength and a second LED in the plurality of LEDs is capable of emitting light having a second wavelength, wherein the first and second wavelength are different. In another embodiment, the multispectral illumination source is a single element multi-color LED. Additionally, the light produced can be in the form of light pulses, modulated light, or both.

[007] The processing component measures the time the light has taken to travel from the multispectral illumination source to the subject and from the subject to the processing component. It also has the capability to calculate range information to localize the subject and to calculate a physiological parameter of the subject utilizing photoplethysmographic (PPG) information derived from the light received from the subject. In this embodiment, the apparatus includes at least one image sensor to sample the light received from the subject and electronic circuitry to control the operation of the multispectral illumination source.

[008] In one embodiment of the present invention, the apparatus above further comprises a spectral band-pass filter in the optical path of the processing component to suppress wavelengths not emitted by the multispectral illumination source. This will reduce the ambient light levels and result in better signal-to-noise (SNR) ratio and operability.

[009] In one embodiment of the present invention, the apparatus above further comprises at least one image sensor to sense the light received from the subject and electronic circuitry to control the operation of the multispectral illumination source.

[0010] In one embodiment of the present invention, the apparatus above further comprises a plurality of spectral band-pass filters located in proximity to the at least one image sensor, thereby filtering the light received from the subject on a pixel-by-pixel basis. Additionally, the multispectral illumination source can produce light having an illumination spectrum tuned to the plurality of spectral band-pass filters. This will increase the system's ability to filter light thus improving the energy efficiency and robustness of the system.

[0011] In one embodiment of the present invention, the multispectral illumination source can produce light including a subset of wavelengths wherein each of the wavelengths in the subset has a different modulation frequencies and the processing component configured to filter the wavelengths on a pixel-by-pixel basis based on the different modulation frequencies of the plurality of wavelengths.

[0012] One aspect of an embodiment of the present invention includes a method for monitoring a physiological parameter. The method includes producing light having a plurality of wavelengths which illuminates and reflects from a subject. Range information is calculated to localize the subject from the reflected light from the subject. The desired physiological parameter of the subject are calculated utilizing photoplethysmographic (PPG) information derived from the reflected light from the subject.

[0013] In various embodiments, the light is produced from a multispectral illumination source, and the light can be in the form of light pulses, modulated light, or both. One type of multispectral illumination source includes a plurality of LEDs where wavelength first LED in the plurality of LEDs is capable of emitting light having a first wavelength and a second LED in the plurality of LEDs is capable of emitting light having a second wavelength, wherein the first wavelength and second wavelength are different. Another suitable multispectral illumination source is a single element multi-color LED.

[0014] In this embodiment, the method can also include sensing the light received from the subject utilizing at least one image sensor and controlling the operation of the multispectral illumination source using electronic circuitry.

[0015] In another embodiment of the method of the present invention, the method above further comprises suppressing light having wavelengths not emitted by the multispectral illumination source by utilizing a spectral band-pass filter. This reduces ambient light levels and results in a better SNR ratio and operability.

[0016] In another embodiment of the method of the present invention, the method further comprises suppressing light having wavelengths not emitted by the multispectral source on a pixel-by-pixel basis by placing a plurality of spectral band-pass filters in proximity to the at least one image sensor. In a variation of this embodiment, the produced light can be tuned to the plurality of spectral band-pass filters.

[0017] In another embodiment of the inventive method of the present invention, at least a subset of the plurality of wavelengths has a different modulation frequency. The light having wavelengths not emitted by the multispectral illumination source is suppressed on a pixel-by-pixel basis based on the different modulation frequencies of the subset of wavelengths using a plurality of spectral band-pass filters in proximity to the at least one image sensor.

[0018] In another aspect, an embodiment of the present invention concerns an inventive method for monitoring a physiological parameter that includes producing light having a plurality of wavelengths which illuminates and reflects from a subject. A time-of-flight system is utilized to calculate range information to localize the subject from the reflected light from the subject and to calculate a physiological parameter of the subject utilizing photoplethysmographic (PPG) information derived from the reflected light from the subject. In one embodiment, the plurality of wavelengths includes a subset of wavelengths, wherein each of the wavelengths in the subset has a different modulation frequency.

[0019] In another aspect, embodiments of the present invention relate to an apparatus to monitor a physiological parameter of a subject the apparatus comprising a processing component to measure the time light takes to travel from a multispectral illumination source to the subject and from the subject to the processing component. The light produced by a multispectral illumination source has a plurality of wavelengths and a plurality of modulation frequencies. The processing component is capable of calculating range information to localize the subject and calculating a physiological parameter of the subject utilizing photoplethysmographic (PPG) information derived from the light received from the subject. In one embodiment, one of the plurality of wavelengths is associated with a respective modulation frequency.

[0020] Upon reading the above description, various alternative embodiments will become obvious to those skilled in the art. These embodiments are to be considered within the scope and spirit of the subject invention, which is only to be limited by the claims that follow and their equivalents.

BRIEF DESCRIPTION OF DRAWINGS

[0021] Non-limiting and non-exhaustive embodiments are described with reference to the following Figures in which:

[0022] FIG 1 is a graphic representation of PPG amplitude against wavelength;

[0023] FIG 2 is a graphic representation of an exemplary waveform of a green light used for monitoring a physiological parameter, namely, the heart rate;

[0024] FIG 3 is a graphic representation of exemplary PPG waveforms of reflected red and infrared light used for monitoring a physiological parameter, namely, the peripheral arterial oxygen saturation (SpO_2);

[0025] FIG 4 is a schematic of an embodiment of an imaging apparatus according to the present invention;

[0026] FIG 5 is a schematic of an additional embodiment of an imaging apparatus according to the present invention;

[0027] FIG 6 is a schematic of an additional embodiment of an imaging apparatus according to the present invention; and

[0028] FIG 7 is a schematic of an embodiment of a method for determining physiological parameters (i.e., vital signs) according to the present invention.

[0029] In the drawings, like reference characters generally refer to corresponding parts throughout the different views. The drawings are not necessarily to scale, emphasis instead being placed on the principles and concepts of operation.

DETAILED DESCRIPTION

[0030] Various embodiments are described more fully below with reference to the accompanying drawings, which form a part hereof, and which show specific exemplary embodiments. However, embodiments may be implemented in many different forms and should not be construed as limited to the embodiments set forth herein; rather, these embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the embodiments to those skilled in the art. Embodiments may be practiced as methods, systems or devices. Accordingly, embodiments may take the form of a hardware implementation, an entirely software implementation or an implementation combining software and hardware aspects. The following detailed description is, therefore, not to be taken in a limiting sense.

[0031] Reference in the specification to “one embodiment” or to “an embodiment” means that a particular feature, structure, or characteristic described in connection with the embodiments is included in at least one embodiment of the invention. The appearances of the phrase “in one embodiment” in various places in the specification are not necessarily all referring to the same embodiment.

[0032] Some portions of the description that follow are presented in terms of symbolic representations of operations on non-transient signals stored within a computer memory. These descriptions and representations are the means used by those skilled in the data processing arts to most effectively convey the substance of their work to others skilled in the art. Such operations typically require physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical, magnetic or optical signals capable of being stored, transferred, combined, compared and otherwise manipulated. It is convenient at times, principally for reasons of common usage, to refer to these signals as bits, values, elements, symbols, characters, terms, numbers, or the like. Furthermore, it is also convenient at times, to refer to certain arrangements of steps requiring physical manipulations of physical quantities as modules or code devices, without loss of generality.

[0033] However, all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient labels applied to these quantities. Unless specifically stated otherwise as apparent from the following discussion, it is appreciated that throughout the description, discussions utilizing terms such as “processing” or “computing” or “calculating” or “determining” or “displaying” or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and transforms data represented as physical (electronic) quantities within the computer system memories or registers or other such information storage, transmission or display devices.

[0034] Certain aspects of the present invention include process steps and instructions that could be embodied in software, firmware or hardware, and when embodied in software, could be downloaded to reside on and be operated from different platforms used by a variety of operating systems.

[0035] The present invention also relates to an apparatus for performing the operations herein. This apparatus may be specially constructed for the required purposes, or it may comprise a general-purpose computer selectively activated or reconfigured by a computer program stored in the computer. Such a computer program may be stored in a computer readable storage medium, such as, but is not limited to, any type of disk including floppy disks, optical disks, CD-ROMs, magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, application specific integrated circuits (ASICs), or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus. Furthermore, the computers referred to in the specification may include a single processor or may be architectures employing multiple processor designs for increased computing capability.

[0036] The processes and displays presented herein are not inherently related to any particular computer or other apparatus. Various general-purpose systems may also be used with programs in accordance with the teachings herein, or it may prove convenient to construct more specialized apparatus to perform the required method steps. The required structure for a variety of these systems will appear from the description below. In addition, the present invention is not described with reference to any particular programming language. It will be appreciated that a variety of programming languages may be used to implement the teachings of the present invention as described herein, and any references below to specific languages are provided for disclosure of enablement and best mode of the present invention.

[0037] In addition, the language used in the specification has been principally selected for readability and instructional purposes and may not have been selected to delineate or circumscribe the inventive subject matter. Accordingly, the disclosure of the present invention is intended to be illustrative, but not limiting, of the scope of the invention, which is set forth in the claims.

[0038] Embodiments of the present invention generally relate to the monitoring of physiological parameters, such as human vital signs, and more specifically, to obtaining improved measurements of physiological parameters utilizing multispectral illumination and a time-of-flight sensing system.

[0039] Figure 1 presents an overview of wavelengths used for monitoring physiological parameters, such as human vital signs in PPG applications. Figure 1 generally illustrates how the reflectivity of light of various wavelengths changes in response to blood oxygenation levels.

[0040] A first line (green) depicts the amplitude of light versus wavelength reflected from a typical subject having fully-oxygenated blood (i.e., 100% SpO_2). A second line (red) illustrates the amplitude of light versus wavelength from a typical subject having partly oxygenated blood (i.e., 60% SpO_2). A third line (infrared - IR) reflects the amplitude of light versus wavelength reflected from source typical subject having blood that is oxygenated at a value between full and partial oxygenation.

[0041] As the RED arrow indicates, the amplitude of reflected red light varies significantly according the level of oxygenation, reflecting the spectral absorption capacity of oxyhemoglobin and deoxyhemoglobin at various relative concentrations. By way of contrast, the IR arrow indicates that the amplitude of reflected infrared light is relatively constant despite the specific oxygenation of the blood. Accordingly, reflected infrared and red light can be used to establish the level of oxygenation: the infrared light can be used to establish a baseline value and the red light can be used to establish a value relative to that baseline; the relative value can then be compared to a table of predetermined values to determine the subject’s oxygenation level.

[0042] The GREEN arrow indicates that the amplitude of reflected green light is both relatively constant despite the specific oxygenation of the blood and also relatively robust compared to the amplitude of reflected infrared light, which is also relatively independent of oxygenation. Accordingly, green light can be used (although it is not required) to provide an additional channel of information, such as the subject’s heart rate.

[0043] As illustrated in Figure 2, the heart rate of the target can be obtained from reflected green light. The amplitude of the reflected green light varies with time according to the subject's heart rate. Measuring the number of peaks in a given time period (e.g., six seconds, one minute, etc.) enables the direct or indirect measurement of heart rate. Measuring the time between subsequent peaks can also enable the indirect measurement of the subject's heart rate.

[0044] As illustrated in Figure 3, the peripheral arterial oxygen saturation (SpO_2) of the target can be obtained by using the waveforms of the reflected red light and the reflected infrared light. The absorption coefficient of oxygenated hemoglobin (HbO_2) with respect to red light is much lower than that of deoxygenated hemoglobin (Hb). Therefore, the amplitude of the reflected red light varies with time according to the presence of Hb in the subject's blood. Conversely, the absorption coefficient of Hb with respect to infrared light is much lower than that of HbO_2. Accordingly, the amplitude of reflected infrared light varies with time according to the presence of HbO_2 in the subject's blood. Through a comparative measurement of the amplitudes of the reflected red and infrared lights, the ratio of Hb and HbO_2 in the subject's blood can be determined.

[0045] Figure 4 schematically illustrates a vital sign monitoring apparatus 10 in accordance with one embodiment of the invention. Vital sign monitoring apparatus 10 includes a multispectral illumination source 12 and a processing component 14. Other embodiments of the invention feature an illumination source 12 and/or a processing component 14 that is external to the vital sign monitoring apparatus 10. For example, the processing component 14 and/or its functionality can be provided by an application service provider or "cloud" configuration.

[0046] Multispectral illumination source 12 is capable of producing light having a plurality of wavelengths λ_1, λ_2, λ_3, etc., which illuminates a subject 16. In this embodiment, the light produced by multispectral illumination source 12 is generated by a plurality of light emitting diodes (LEDs), where at least two of the LEDs have different wavelength content (e.g., one red LED and one green LED). In other embodiments, the multispectral illumination source 12 may be a single element multi-color LED. In some embodiments, multispectral illumination source 12 may include various focusing and/or collimating optics to facilitate the illumination of and/or subsequent reflection from the subject 16. In embodiments where the multispectral illumination source 12 includes a plurality of LEDs with different wavelength content, the illumination of the

LED may be time-sequentially switched, avoiding the need for spectral filtering in proximity to the imager.

[0047] Processing component 14 is capable of detecting and receiving the light reflected from the subject 16. Processing component 14 is also capable of measuring the time the light has taken to travel from the multispectral illumination source 12 to the subject 16 and from the subject 16 to the processing component 14.

[0048] Processing component 14 is further capable of calculating range information to localize the subject 16. For example, if processing component 14 knows when the illumination source 12 was activated (e.g., because processing component 14 controls the illumination source 12) and the time of receipt of the light, the processing component 14 can calculate the range knowing the speed of light and the time between illumination and receipt. Processing component 14 is also capable of calculating the physiological parameters, such as human vital signs, of the subject 16 utilizing photoplethysmographic (PPG) information derived from the light received from the subject 16 as discussed above. In this embodiment, processing component 14 includes at least one image sensor 18 to sample the light received from the subject 16 along with electronic circuitry 20 to control the operation of the multispectral illumination source 12. In various embodiments, the at least one image sensor 18 may be a single element photosensor, an RGB photosensor, or an array of photosensors.

[0049] An additional embodiment of the inventive apparatus of the present invention, as shown in Figure 5, includes placing a spectral band-pass filter 22 (such as a liquid-crystal tunable filter) in the optical path of the processing component 14. Spectral band-pass filter 22 is capable of suppressing wavelengths that were not emitted by the multispectral illumination source 12. By suppressing these wavelengths, the ambient light levels will be reduced which results in an improved signal to noise ratio and improved operability.

[0050] An additional embodiment of the inventive apparatus of the present invention, as shown in Figure 6, includes a plurality of spectral band-pass filters 24 proximate to the at least one image sensor 18. The plurality of spectral band-pass filters 24 are capable of filtering the light received from the subject on a pixel-by-pixel basis. By filtering the light received on a pixel-by-pixel basis, the motion-robustness of the system will be improved.

[0051] For example, the spectral band-pass filters 24 could be arranged in a manner similar to a Bayer pattern commonly used in standard image sensors. In embodiments where two wavelengths (e.g., red and infrared) are used, the red spectral filters could be placed on the odd columns on the even rows and on the even columns on the odd rows of the pixel elements of the image sensor; the infrared spectral filters will be placed on the remaining pixel elements. The filters may also be oriented at an angular offset relative to the underlying sensor element, promoting pixel binning and increasing dynamic range. In still other embodiments, different wavelength-specific sensors may be stacked or located in a co-planar arrangement.

[0052] In the event additional wavelengths are used, e.g. red and infrared light for SpO_2 measurement and green light for heart rate measurement, additional spectral band-pass filters could be used and arranged accordingly, such as a Bayer pattern, an X-Trans pattern, etc.

[0053] Additionally, multispectral illumination source 12 can produce light tuned to be compatible with the plurality of spectral band-pass filters 24. For example, monochromatic LEDs with appropriate wavelengths may be used. Illumination with monochromatic LEDs enhances the contrast with ambient light levels and results in better SNR ratio and operability. In other embodiments, additional spectral band-pass filters 24 can be placed in proximity to a multispectral illumination source 12 such as one or more white LEDs. This will improve the signal quality due to the suppression of signals of other wavelengths by the optical filters.

[0054] Additionally, at least a subset of the wavelengths (e.g., λ_1, λ_2, λ_3, etc.) may each be associated with a different modulation frequency (e.g. 15 MHz, 20 MHz, 30 MHz, etc.). The light sampled by the image sensor 18 can be processed to extract the signal of each modulated wavelength by filtering in the frequency domain. This may be accomplished through inclusion of a plurality of spectral band-pass filters located in proximity to the at least one image sensor 18 and filtering the wavelengths on a pixel-by-pixel basis. This may also be accomplished by filtering for the different modulation frequencies of the wavelengths.

[0055] Figure 7 is a flowchart of an embodiment of a method for monitoring physiological parameters according to the present invention. In step 710, a multispectral illumination source 12, which in this embodiment can be a plurality of LEDs with at least two LEDs having different wavelengths, illuminates a subject with multiple wavelengths of light λ_1, λ_2, λ_3, etc., that are reflected from the subject 16. The multispectral illumination source 12 is a component of a larger electronic system 10 including processing capabilities 14 and control electronics 20, such as a time-of-flight system.

[0056] In step 120, the system 10 controls the operation of the multispectral illumination source 12 using electronic circuitry 20. In step 130, the system 10, utilizing at least one image sensor 18, samples the light received from the subject 16. In step 140, the system 10 calculates range information to localize the subject 16 based at least in part on the reflected light from the subject 16. In step 150, the system calculates the vital signs of the subject 16 utilizing photoplethysmographic (PPG) information and range information derived from the reflected light from the subject 16.

[0057] Additionally, light having wavelengths not emitted by the multispectral illumination source can be suppressed utilizing a spectral band-pass filter 22. Spectral band-pass filter 22 can be placed in the optical path of the reflected light from the subject 16 or in proximity to the at least one image sensor 18 in order to suppress such light on a pixel-by-pixel basis. Further, the multispectral illumination source 112 can produce light having an illumination spectrum tuned to the plurality of spectral band-pass filters 22 which will improve the signal-to-noise ratio and operability of the system.

[0058] Additionally, the plurality of wavelengths may each have a different modulation frequency. In such case, the light having wavelengths not emitted by the multispectral illumination source can be suppressed on a pixel-by-pixel basis based on the different modulation frequencies of the plurality of wavelengths by using a plurality of spectral band-pass 22 filters in proximity to the at least one image sensor 18.

[0059] While the invention has been described with a certain degree of particularity, it is manifest that many changes may be made in the details of construction and the arrangement of components without departing from the spirit and scope of this disclosure. It is understood that the invention is not limited to the embodiments set forth herein for purposes of exemplification.

[0060] Embodiments of the present disclosure, for example, are described above with reference to block diagrams and/or operational illustrations of methods, systems, and computer program products according to embodiments of the present disclosure. The functions/acts noted in the blocks may occur out of the order as shown in any flowchart. For example, two blocks shown in succession may in fact be executed substantially concurrent or the blocks may sometimes be executed in the reverse order, depending upon the functionality/acts involved. Additionally, not all of the blocks shown in any flowchart need to be performed and/or executed. For example, if a given flowchart has five blocks containing functions/acts, it may be the case that only three of the five blocks are performed and/or executed. In this example, any of the three of the five blocks may be performed and/or executed.

[0061] The description and illustration of one or more embodiments provided in this application are not intended to limit or restrict the scope of the present disclosure as claimed in any way. The embodiments, examples, and details provided in this application are considered sufficient to convey possession and enable others to make and use the best mode of the claimed embodiments. The claimed embodiments should not be construed as being limited to any embodiment, example, or detail provided in this application. Regardless of whether shown and described in combination or separately, the various features (both structural and methodological) are intended to be selectively included or omitted to produce an embodiment with a particular set of features. Having been provided with the description and illustration of the present application, one skilled in the art may envision variations, modifications, and alternate embodiments falling within the spirit of the broader aspects of the general inventive concept embodied in this application that do not depart from the broader scope of the claimed embodiments.

CLAIMS

What is claimed is:

1. An apparatus to monitor a physiological parameter, the apparatus comprising:

a multispectral illumination source to produce light having a plurality of wavelengths that illuminates a subject; and

a processing component to measure the time the light has taken to travel from the multispectral illumination source to the subject and from the subject to the processing component, wherein the processing component is capable of calculating range information to localize the subject and calculating a physiological parameter of the subject utilizing photoplethysmographic (PPG) information derived from the light received from the subject.

2. The apparatus of claim 1, wherein the light produced is at least one of light pulses and modulated light.

3. The apparatus of claim 1, wherein the multispectral illumination source comprises a single element multi-color LED.

4. The apparatus of claim 1, wherein the multispectral illumination source comprises a plurality of LEDs, wherein a first LED in the plurality of LEDs is capable of emitting light having a first wavelength and a second LED in the plurality of LEDs is capable of emitting light having a second wavelength, wherein the first wavelength and second wavelength are different.

5. The apparatus of claim 4, wherein the apparatus further comprises:

a spectral band-pass filter in the optical path of the processing component to suppress wavelengths not emitted by the multispectral illumination source.

6. The apparatus of claim 1, wherein the apparatus further comprises:

at least one image sensor to sense the light received from the subject; and

electronic circuitry to control the operation of the multispectral illumination source.

7. The apparatus of claim 6, wherein the apparatus further comprises:

a plurality of spectral band-pass filters located in proximity to the at least one image sensor and to filter the light received from the subject on a pixel-by-pixel basis.

8. The apparatus of claim 7, wherein the multispectral illumination source produces light having an illumination spectrum tuned to the plurality of spectral band-pass filters.

9. The apparatus of claim 6, wherein the plurality of wavelengths includes a subset of wavelengths, wherein each of the wavelengths in the subset has a different modulation frequency, and

the processing component configured to filter the wavelengths on a pixel-by-pixel basis based on the different modulation frequencies of the plurality of wavelengths.

10. A method for monitoring a physiological parameter comprising:

producing light having a plurality of wavelengths which illuminates and reflects from a subject;

calculating range information to localize the subject based at least in part on the reflected light from the subject; and

calculating the physiological parameter of the subject utilizing photoplethysmographic (PPG) information derived from the reflected light from the subject.

11. The method of claim 10, wherein the produced light is at least one of light pulses and modulated light.

12. The method of claim 10, wherein the produced light is produced from a single element multi-color LED.

13. The method of claim 12, wherein the method further comprises:

suppressing light having wavelengths not emitted by the multispectral illumination source by utilizing a spectral band-pass filter.

14. The method of claim 13, wherein the produced light is produced from a plurality of LEDs, wherein a first LED in the plurality of LEDs is capable of emitting light having a first wavelength and a second LED in the plurality of LEDs is capable of emitting light having a second wavelength, wherein the first wavelength and second wavelength are different.

15. The method of claim 10, wherein the method further comprises:

sensing the light received from the subject utilizing at least one image sensor; and

controlling the operation of the multispectral illumination source using electronic circuitry.

16. The method of claim 10, wherein the method further comprises:

suppressing light having wavelengths not emitted by the multispectral illumination source on a pixel-by-pixel basis by placing a plurality of spectral band-pass filters in proximity to the at least one image sensor.

17. The method of claim 16, wherein the multispectral illumination source produces light having an illumination spectrum tuned to the plurality of spectral band-pass filters.

18. The method of claim 15, wherein at least a subset of the plurality of wavelengths has a different modulation frequency, and further comprising:

suppressing light having wavelengths not emitted by the multispectral illumination source on a pixel-by-pixel basis based on the different modulation frequencies of the subset of wavelengths using a plurality of spectral band-pass filters in proximity to the at least one image sensor.

19. A method for monitoring a physiological parameter comprising:

producing light having a plurality of wavelengths which illuminates and reflects from a subject; and

utilizing a time of flight system to calculate range information to localize the subject from the reflected light from the subject and to calculate a physiological parameter of the subject utilizing photoplethysmographic (PPG) information derived from the reflected light from the subject.

20. The apparatus of claim 19, wherein the plurality of wavelengths includes a subset of wavelengths, wherein each of the wavelengths in the subset has a different modulation frequency.

21. An apparatus to monitor a physiological parameter of a subject, the apparatus comprising:

a processing component to measure the time light takes to travel from a multispectral illumination source to the subject and from the subject to the processing component,

wherein the light produced by the multispectral illumination source has a plurality of wavelengths and a plurality of modulation frequencies, and

wherein the processing component is capable of calculating range information to localize the subject and calculating a physiological parameter of the subject utilizing photoplethysmographic (PPG) information derived from the light received from the subject.

22. The apparatus of claim 21, wherein one of the plurality of wavelengths is associated with a respective modulation frequency.

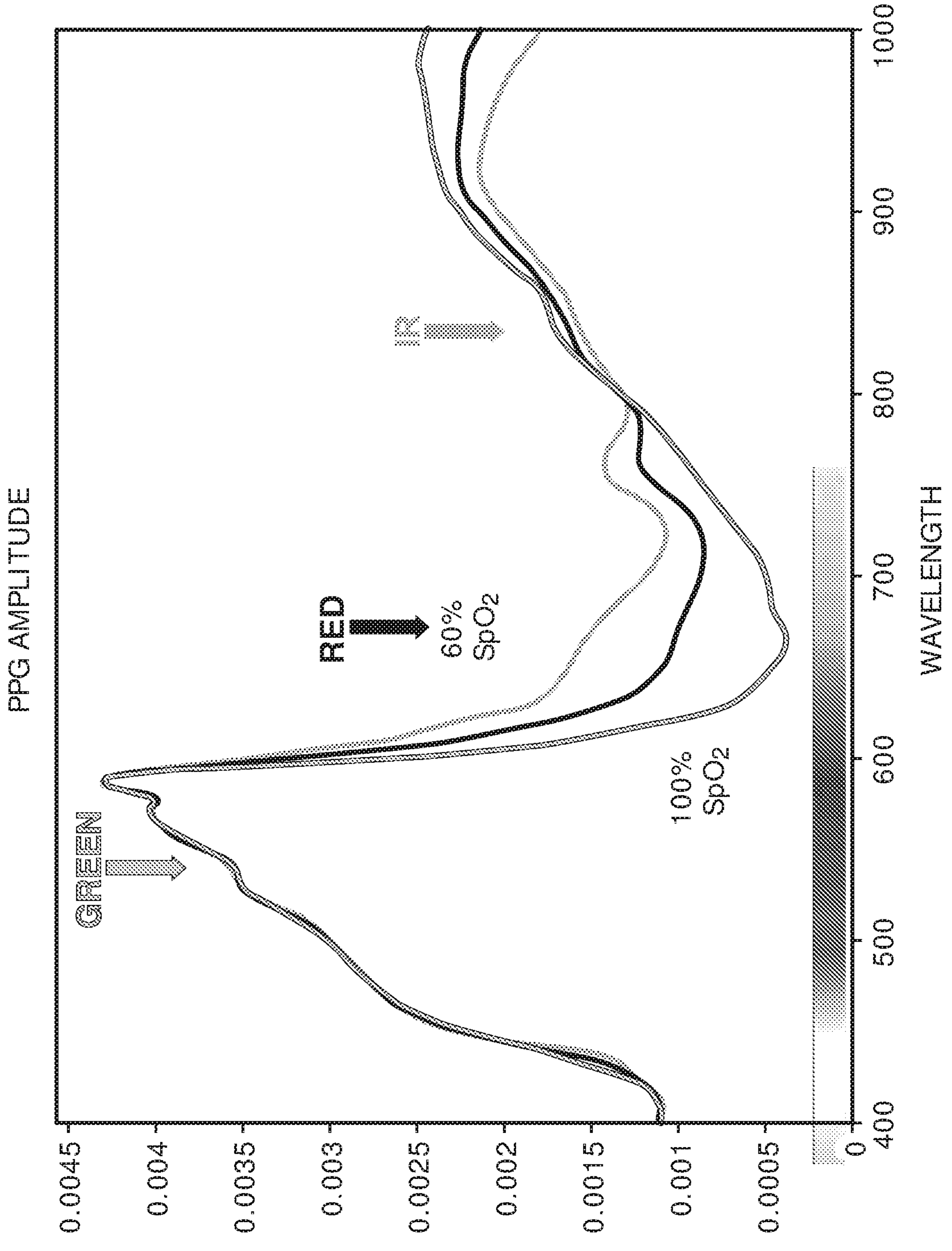
PPG AMPLITUDE
0.0045
0.004
0.0035
0.003
0.0025
0.002
0.0015
0.001
0.0005
0
400
500
600
700
800
900
1000
WAVELENGTH
GREEN
RED
IR
60%
SpO2
100%
SpO2

FIG. 1

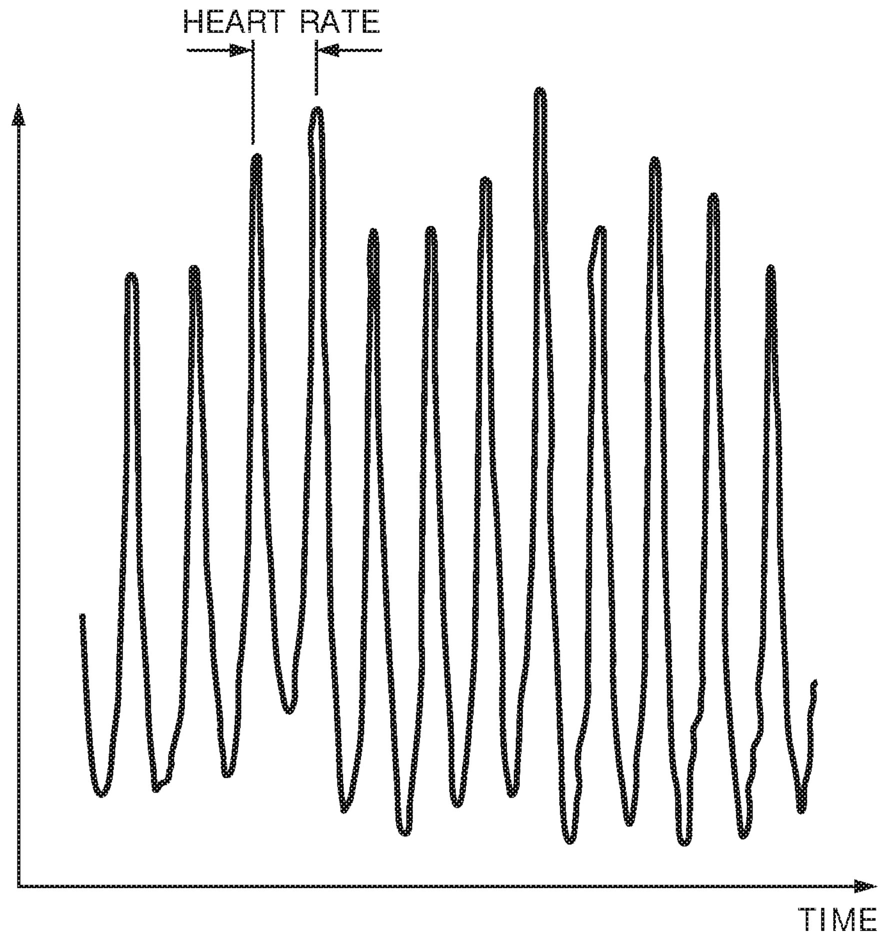
HEART RATE
TIME

FIG. 2

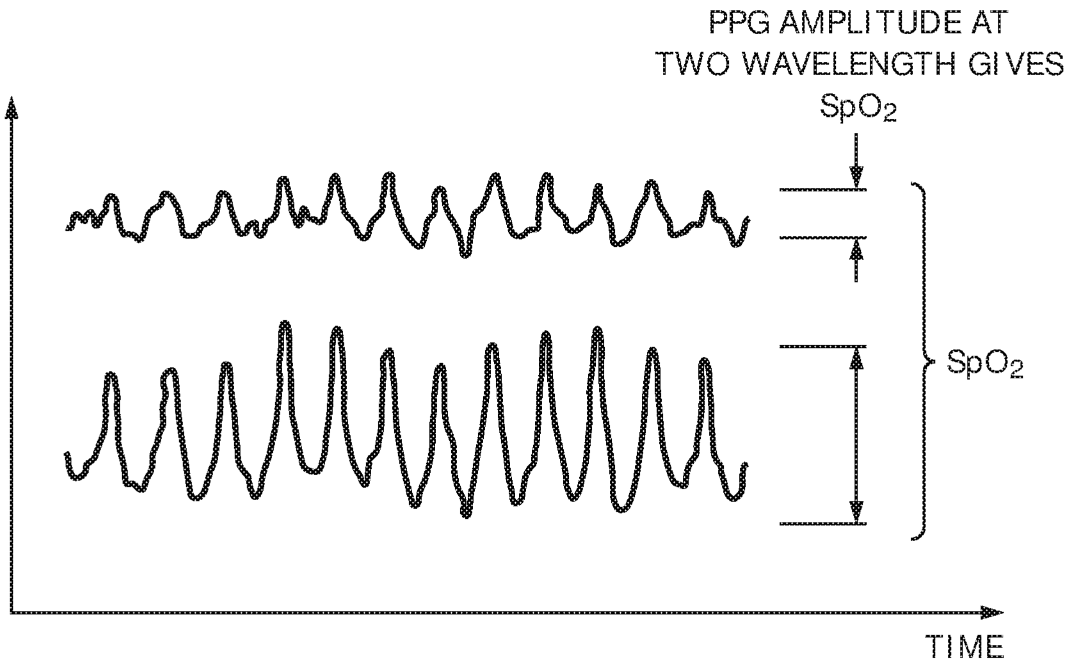
PPG AMPLITUDE AT
TWO WAVELENGTH GIVES
SpO2
SpO2
TIME

FIG. 3

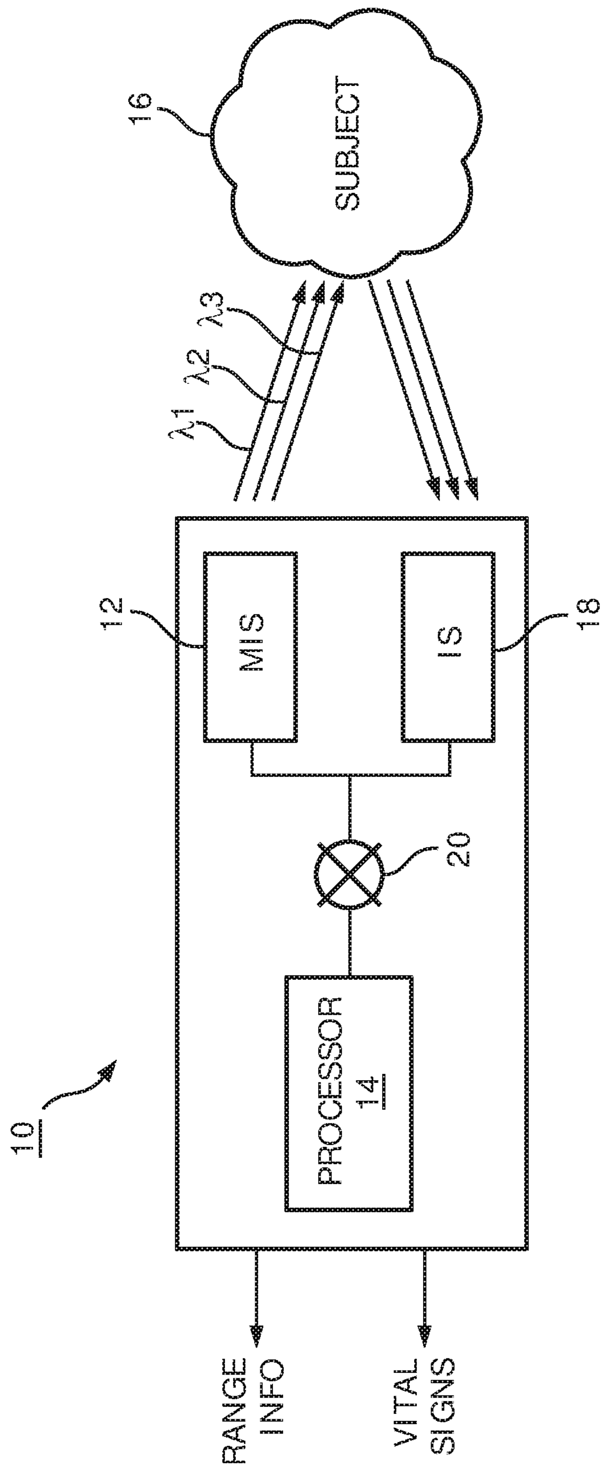
SUBJECT
16
λ1
λ2
λ3
12
MIS
IS
18
20
PROCESSOR
14
10
RANGE INFO
VITAL SIGNS

FIG. 4

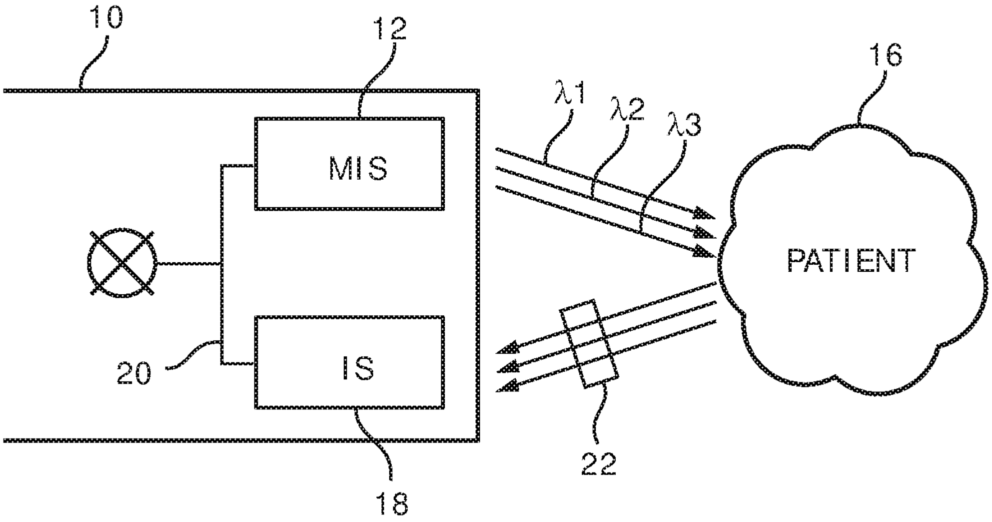
10
12
16
λ1
λ2
λ3
MIS
PATIENT
IS
20
22
18

FIG. 5

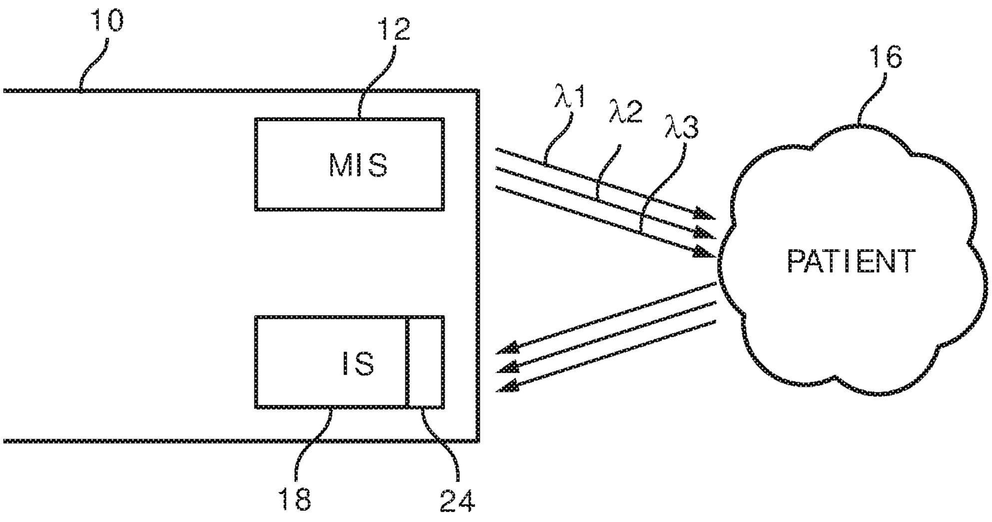
10
12
16
λ1
λ2
λ3
MIS
PATIENT
IS
18
24

FIG. 6

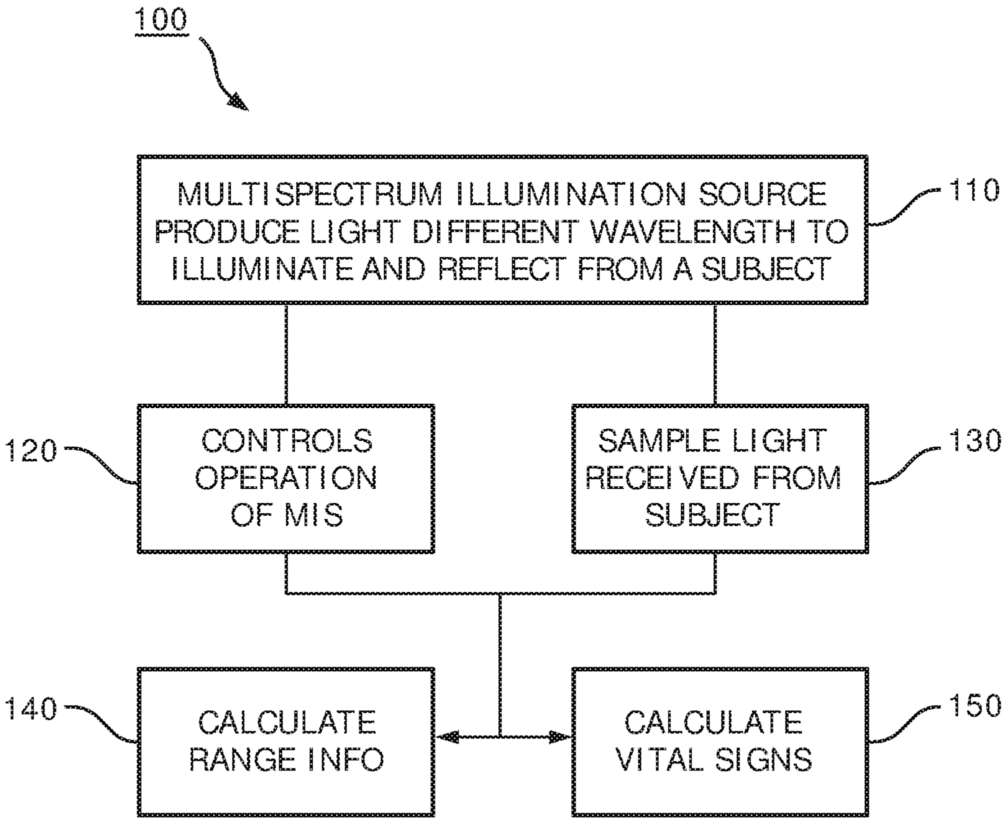
100
MULTISPECTRUM ILLUMINATION SOURCE PRODUCE LIGHT DIFFERENT WAVELENGTH TO ILLUMINATE AND REFLECT FROM A SUBJECT
110
120
CONTROLS OPERATION OF MIS
SAMPLE LIGHT RECEIVED FROM SUBJECT
130
140
CALCULATE RANGE INFO
CALCULATE VITAL SIGNS
150

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/052048

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/024 A61B5/00
ADD.

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)
A61B

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

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

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X Y	WO 2014/055755 A1 (TRANSROBOTICS INC [US]) 10 April 2014 (2014-04-10) paragraph [0002] paragraph [0085] - paragraph [0087] paragraph [0130] - paragraph [0131] paragraph [0136] paragraph [0255] - paragraph [0256] -----	1-6, 10-15,19 7-9, 16-18, 20-22
X	US 2014/316293 A1 (AHMAD ANIS [US] ET AL) 23 October 2014 (2014-10-23) paragraph [0004] paragraph [0018] paragraph [0026] - paragraph [0027] -----	1-6, 10-15,19

-/--

[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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"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	Date of mailing of the international search report
21 June 2016	28/06/2016

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Gooding Arango, J

INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2016/052048

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
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Y	US 2008/027299 A1 (TOBOLA ANDREAS [DE] ET AL) 31 January 2008 (2008-01-31) paragraph [0063] - paragraph [0067] paragraph [0075]	9,18, 20-22
A	US 2008/266564 A1 (THEMELIS GEORGE [GR]) 30 October 2008 (2008-10-30) paragraph [0069] - paragraph [0073] figures 1, 4A	7,8,16, 17

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Information on patent family members

International application No
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			JP	2007524441	A	30-08-2007
			KR	20060002923	A	09-01-2006
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			US	2006210120	A1	21-09-2006
			WO	2004090786	A2	21-10-2004
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			JP	2015523135	A	13-08-2015
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			EP	1909189	A2	09-04-2008
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			EP	2284509	A1	16-02-2011
			US	2008266564	A1	30-10-2008
			US	2012085932	A1	12-04-2012
			WO	2007056102	A1	18-05-2007