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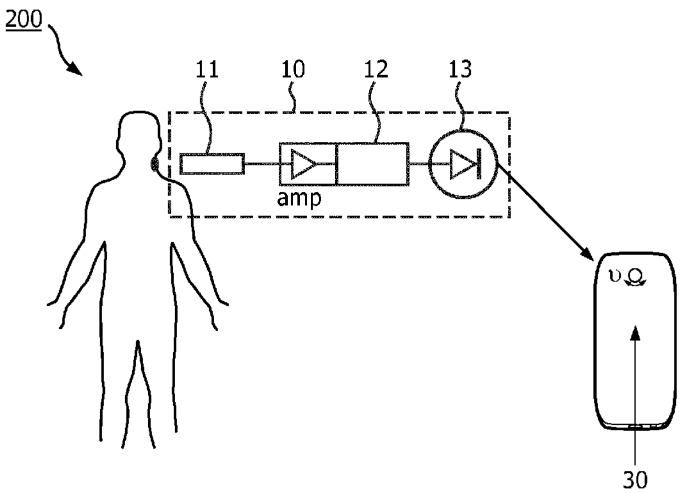

FIG. 2

(57) **Abstract**: The present invention provides method, apparatus and system for physiological signal acquisition by utilizing portable device. According to an aspect of the present invention, it proposes a system for deriving a physiological signal of a subject, comprising: an apparatus for emitting an optical signal representing a physiological signal of a subject, comprising: a physiological sensor placed on the subject, for acquiring an electrical signal representing the physiological signal of the subject; a light source for emitting the optical signal; and a modulator for modulating the intensity of the optical signal in accordance with the amplitude of the electrical signal. The system further comprises a portable device, comprising: a camera for acquiring an optical image sequence of the optical signal emitted from the apparatus; and a processor for deriving the physiological signal from the optical image sequence of the optical signal. The novel method is featured in low-cost, ease-of-use and portability. These features aim to increase patients' awareness of their own risks of diseases, such as arteriosclerosis, and help them improve their compliance. In addition, this device provides desired advantages of instant data assessment functionality, which is of high value for patients caring at home, instant consult service from medical professionals, and convenient data communication and data storing.

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PHYSIOLOGICAL SIGNAL ACQUISITION USING PORTABLE DEVICE

FIELD OF THE INVENTION

The present invention relates to physiological signal acquisition, and more particularly, to method, apparatus and system for physiological signal acquisition by utilizing portable device. The invention in particular relates to an apparatus for converting a physiological signal of a subject to an optical signal, a device for converting an optical signal to a physiological signal of a subject, a system for deriving a physiological signal of a subject, a method of converting a physiological signal of a subject to an optical signal and a method of converting an optical signal to a physiological signal of a subject.

BACKGROUND OF THE INVENTION

Physiological signal acquisition is quite important for a subject's health condition or potential risk in terms of particular diseases. However, conventionally, the acquisition of the physiological signal involves the professional medical instruments, which makes the cost high and the acquisition procedure not that convenient for the subject.

For example, the PWV (pulse wave velocity) is a key feature for Arteriosclerosis. Conventional PWV assessment modalities use analog-digital convertor (ADC) devices for pulse wave signal conversion and utilize the powerful computing ability of computer for signal processing. These typical PWV modalities had already been commonly used in hospitals for medical professionals to assess subject's arteriosclerosis.

On the other hand, these conventional PWV assessment modalities and the corresponding implementations, which particularly using ADC device, usually induce high price, large system dimension, requirements of professional operation, training for signal acquisition and results interpretation. These requirements exclude the applicability of PWV assessment for basic home care, which constitutes the crucial part of chronic disease management (CDM) in perspective of long-term CVD risk monitoring and behavior self-management. In China in particular, the PWV assessment is recommended by the CVD guideline, but patient's medical check-up expense on their PWV assessment is currently not covered by the medical insurance. People with low-income and under-awareness of healthcare are reluctant to go through routine PWV check-up. This situation increases the difficulty of prevalent CVD management. For patient, the insufficient awareness of CVD risk is not favorable for improving their healthcare and their compliance.

SUMMARY OF THE INVENTION

Therefore, there is a need for a novel solution for physiological signal acquisition which is low-cost and provides ease-of-use for the user.

In accordance with an aspect of the present invention, it proposes a system for deriving a physiological signal of a subject, which comprises an apparatus for emitting an optical signal representing a physiological signal of a subject and a portable device for deriving the physiological signal from the optical signal.

Specifically, the apparatus in the system for converting a physiological signal of a subject to an optical signal comprises a physiological sensor attachable to the subject, for generating an electrical signal in dependence of a measured physiological signal of the subject, an amplitude or a frequency of the electrical signal being indicative of a value of the physiological signal measured by the physiological sensor, a light source for emitting the optical signal having an intensity and one or more wavelength within the visible range and a modulator for modulating the intensity of the optical signal in accordance with the amplitude or frequency of the electrical signal.

The intensity of the optical signal corresponds to the luminance (e.g. candela per square metre) of the optical signal emitted, which is controlled by the modulator.

In an embodiment, a light emitting diode (LED) may be used as light source, in which case an LED driver can be used to modulate the intensity of the optical signal. The skilled person knows of several other alternatives for light sources capable to emit an intensity modulated optical signal.

In an embodiment of the present invention, the physiological sensor in the apparatus is one of thermistor for measuring body temperature, an SpO2 sensor for measuring Oxygen saturation (SpO2), a deformation-sensitive sensor for measuring the deformation of the surface and an accelerometer for motion detection. The deformation-sensitive sensor is a sensor having a shape that may be deformed by a force acting on it, wherein the sensor provides an electrical signal in response to a force causing a change of the shape. Examples of a deformation sensitive sensor are strain sensor, piezoelectric sensor or piezoresistive sensor. The output of a physiological sensor is an electrical signal having an amplitude or frequency varying over time, where the amplitude or frequency at a particular time indicates the corresponding value of physiological signal detected by the physiological sensor. For example, the amplitude of the electrical signal provided by the sensor may be indicative of the temperature(C) detected by thermistor, or an oxygen saturation value detected by the SpO2 sensor. The pressure value detected by a piezoelectric sensor, the resistance detected by piezo resistive sensor, the strain value detected by a strain sensor or other values detected may be indicative for respiration by aspirations relevant parameters (e.g. respiration depth) or pulse wave signals. Furthermore, the frequency of the electrical signal obtained from the sensor, may be dependent on the recurring or varying pattern in the value of physiological signal, e.g. heart beat and respiration rate, then the intensity of the optical signal varies. Hence the intensity of optical signal is modulated in dependence of the amplitude or frequency of the electrical signal, and in dependence of the type and the parameter of the physiological signal that is being. For example for respiration the respiration rate may be measured, which may be related to the frequency of the electrical signal that is obtained with the sensor, or the respiration depth (e.g. how deep is the individual breathing) which may be related to the amplitude of the electrical signal that is obtained with the sensor.

Further, the portable device in the system for converting an optical signal to a physiological signal of a subject, comprises an image sensor for acquiring an optical image sequence of the optical signal and a processor for deriving from the optical image sequence of the optical signal the physiological signal, where the value of the physiological signal is dependent on the detected modulation in the intensity of the optical signal in the acquired optical image sequence The portable device 30 may be arranged to receive a predetermined or default type of physiological signal (e.g. heart rate). The portable device may be programmable such that it can interpret a plurality of optical signals and determine for the programmed type of physiological signal the received amplitude or frequency.

The intensity of the optical signal in the acquired optical image can be measured by estimating the luminance of the image. For example, it may be implemented by determining the average of the gray scales of all pixels. Other alternatives such as determining the luminance directly from the full color image (RGB color) may also be used.

In an embodiment of the present invention, the portable device in the system further comprises a physiological signal identification means configured to enable the device to determine the corresponding physiological signal for the optical signal to be received out of several possible types of physiological signals. In this way, the device is able to serve as a universal device to determine a value for a plurality of types of physiological signals instead of being limited to determine a value for only one particular physiological signal by default or predetermination.

In this way, the present invention proposes a method, apparatus and system for physiological signal acquisition by utilizing portable device, with features of low-cost, ease-of-use and portability. These features increase patients' awareness of their own risks of diseases, such as arteriosclerosis, and help them improve their compliance. In addition, the present invention provides desired advantages of instant data assessment functionality, which is of high value for patients caring at home, instant consult service from medical professionals, and convenient data communication and data storing. The portable device based measurement could significantly increase the interactions of working people, who don't have time to do physical exam routinely.

The portable device utilized in the system of the present invention may be a conventional cell phone, a tablet computer, or a PDA, etc., as long as it has such an image sensor for acquiring the optical image sequence from the apparatus and a processor for processing the acquired optical image sequence.

In an embodiment of the present invention, the portable device may further comprise a memory for storing the derived physiological signal.

In an embodiment of the present invention, the portable device may comprise a communication unit for sending the derived physiological signal to a receiving unit or smart phone for review by medical professional.

By utilizing the computation ability of modern portable device with optical cameras, the physiological signal can be acquired equivalently like the professional medical instruments. By utilizing the powerful calculation ability of portable device, the calculation of some key parameters of the physiological signal can be computed quickly. By utilizing the storage capability of portable device, the historical data and results can be retrospect anytime anywhere. Finally, by utilizing the built-in communication ability of portable device, the acquired signal, computed data, patient's input, and concerns of measurements, can be transmitted to medical professional and obtain the instant feedback service.

Further, in an embodiment of the present invention, the apparatus in the system may further comprise an optical fiber for guiding the optical signal. The optical fiber may be a pigtail fiber having an optical connector pre-installed on one end. However, any other type of optical fiber suitable to guide the optical signal will be in scope of the invention.

In an embodiment of the present invention, the portable device may further comprise a camera comprising the image sensor, a camera adaptor mounted on the front of the camera, comprising: an optical band-pass filter for filtering out spray beam in the optical signal; and a collimation lens for coupling the filtered optical signal into the imaging sensor in the camera.

In this way, the optical signal may be better guided and collimated so that the quality of the optical signal received by the camera may be improved.

In an embodiment of the present invention, a system for deriving a physiological signal of a subject is proposed. The system comprises a first apparatus attachable to a first artery of the subject and a second apparatus attachable to a second artery of the subject, where the system is arranged to derive a pulse wave velocity, PWV, of the subject, and the device is arranged to receive a first optical signal of the first apparatus and a second optical signal of the second apparatus and derive a PWV in dependence of the received first and second optical signal.

Specifically, the device in the system is arranged to acquire a third optical image sequence. Each optical image of the third optical image sequence comprising respective portion of the first optical signal and the second optical signal. The processor is further configured for deriving from the third optical image sequence a first optical image sequence of the first optical signal and a second optical image sequence of the second optical signal, deriving from the first optical image sequence a first arterial pulse wave signal and deriving from the second optical image sequence a second arterial pulse wave signal and deriving a pulse wave velocity PWV of the subject from the first arterial pulse wave signal and the second arterial pulse wave signal.

In this way, the present invention proposes a PWV measurement method and apparatus, which is based on the optical amplitude modulation technology. The portable device is able to receive two optical signals in one optical image sequence and derive the PWV directly from the received optical image sequence, which results in a high efficiency. The artery pulse signals are picked up by using deformation-sensitive sensors or accelerometers, but the transmission and conversion functions are replaced by optical solution, in order to utilize the advantages of portable device.

In addition, by replacing the use of high resolution ADC device, which is commonly used in conventional PWV measurement modality, the implementation proposed in the present invention significantly reduces the system cost and system complexity. If embodied as a gadget affiliated to modern portable device, this system is then featured by low-cost, portability and ease-of-use.

In accordance with another aspect of the present invention, a method of generating an electrical signal in dependence of a measured physiological signal of the subject is proposed. The electrical signal has an amplitude or a frequency of the electrical signal being indicative of a value of the physiological signal measured by the physiological sensor (11,21), emitting the optical signal having an intensity and one or more wavelength within the visible range and modulating the intensity of the optical signal over time in accordance with the amplitude or frequency of the electrical signal.

In accordance with another aspect of the present invention, a method of acquiring an optical image sequence of an optical signal is proposed. It derives from the optical image sequence of the optical signal the amplitude or a frequency of the physiological signal where the value of the physiological signal is dependent on a modulated intensity of the optical signal in the acquired optical image sequence.

Further, in accordance with another aspect of the present invention, a computer program product is proposed comprising a set of instructions, which when downloaded into a portable device(e.g. a smart phone) and implemented, are capable of: driving a camera in the portable device to acquire an optical image sequence of the optical signal emitted from the above mentioned apparatus; and driving a processor in the portable device to derive the physiological signal from the optical image sequence of the optical signal.

Various aspects and features of the disclosure are described in further detail below. These and other aspects of the invention will be apparent from and elucidated with reference to the embodiment(s) described hereinafter.

DESCRIPTION OF THE DRAWINGS

The present invention will be described and explained hereinafter in more detail in combination with embodiments and with reference to the drawings, wherein:

Fig. 1 is a block diagram of an apparatus 10 for emitting an optical signal representing a physiological signal of a subject according to the present invention;

Fig. 2 is a block diagram of a system 200 for deriving a physiological signal of a subject according to one embodiment of the present invention;

Fig. 3 is a block diagram of a system 300 for deriving arterial pulse wave signal of a subject according to one embodiment of the present invention;

Fig. 4 is a block diagram of the system 400 for deriving arterial pulse wave signal of a subject according to another embodiment of the present invention; and

Fig. 5 schematically shows the internal functional modules of a portable device 30 according to the present invention.

The same reference signs in the figures indicate similar or corresponding feature and/or functionality.

DETAILED DESCRIPTION

The present invention will be described with respect to particular embodiments and with reference to certain drawings but the invention is not limited thereto but only by the claims. The drawings described are only schematic and are non-limiting. In the drawings, the size of some of the elements may be exaggerated and not drawn on scale for illustrative purposes.

Fig. 1 is a block diagram of an apparatus 10 for emitting an optical signal representing a physiological signal of a subject according to the present invention.

In the following, the details of the apparatus 10 will be described, especially, in conjunction with Fig. 2, which is a block diagram of a system 200 for deriving a physiological signal of a subject according to one embodiment of the present invention.

As can be seen from Fig. 2, the system 200 for deriving a physiological signal of a subject comprises an apparatus 10 for emitting an optical signal representing a physiological signal of a subject and a portable device 30 for receiving the optical signal and deriving a physiological signal of a subject from the optical signal.

As can be seen from Figs. 1 and 2, the apparatus 10 in the system 200 comprises a physiological sensor 11 placed on the subject, for acquiring an electrical signal representing the physiological signal of the subject and a light source 13 for emitting an optical signal. The apparatus 10 further comprises an modulator 12 for modulating the intensity of the optical signal in accordance with the amplitude of the electrical signal.

As shown in Fig. 2, the apparatus 10 further comprises a signal amplifier with reference sign “amp”, usually a low-noise instrument amplifier to amplify the electrical signal acquired by the sensor 11. It can be easily understood that the amplifier is optional. In some cases, the electrical signal acquired may be strong enough and the amplifier is not necessary in that case.

It can be also easily understood by the skilled in the art that the physiological sensor may be various sensors for measuring different physiological parameters of the subject. For example, in one embodiment of the present invention, the physiological sensor 11 in the apparatus 10 may be a thermistor for measuring body temperature. In another embodiment of the present invention, the physiological sensor 11 may be a lighting emitter and sensor for measuring Oxygen saturation (SpO2). Further, the physiological sensor 11 may also be a strain sensor surrounding abdomen of the subject for measuring aspirations relevant parameters.

The modulator 12 is powered by a linear DC power supply, and modulates the following light source 13 according to the amplitude of the electrical signal acquired. The modulation may be carried out in various ways, for example optical modulation or electrical modulation, as long as the intensity of LED optical signal can represent the amplitude of the electrical signal. For example, the intensity of the optical signal is of linear relationship to the amplitude of the output electrical signal of the sensor 11.

Further, the light source 13 may be a high resolution and sensitivity light source, preferably with the wavelength within visual range of 400-700 nm so that the common camera of the conventional portable device 30 may acquire the optical image sequence of the optical signal emitted from the light source 13.

It is easily understood by the skilled in the art that since the above mentioned physiological signals, such as the body temperature, the SpO2 and the aspirations relevant parameters, can be respectively measured by one sensor alone, the system 200 for deriving such physiological signal of a subject comprises only one apparatus 10. However, for some particular physiological signals or parameters, only one sensor may not be enough, and therefore, the system may comprise at least two apparatus. For example, as shown in Fig. 3, which will be explained in more detail hereinafter, the system 300 for deriving arterial pulse wave signal of a subject comprises two apparatus for emitting an optical signal, which represents the arterial pulse wave signal of a subject.

Further, the portable device 30 in the system 200 comprises an image sensor for acquiring an optical image sequence of the optical signal emitted from the apparatus 10 and a processor for deriving the physiological signal from the optical image sequence of the optical signal. The portable device 30 may be arranged to receive a specific type physiological signal, such as temperature, pressure or any other value mentioned above.

Please note that the portable device 30 utilized in the system 200 of the present invention may be a conventional cell phone, a tablet computer, a laptop, or a PDA, etc., as long as it has a camera for acquiring the optical image sequence from the apparatus 10 and a processor for signal processing but being further adapted for deriving the physiological signal from the optical image sequence.

In an embodiment of the present invention, the portable device 30 may further comprise a memory for storing the derived physiological signal.

In an embodiment of the present invention, the portable device in the system further comprises a physiological signal identification means configured to enable the device to determine the corresponding physiological signal for the optical signal to be received out of several possible types of physiological signals. In this way, the device is able to serve as a universal device to determine a value for a plurality of types of physiological signals instead of being limited to determine from a received optical value a value for a single predetermined physiological signal. The portable device may comprise a user interface for allowing the user to change the setting of the portable device and select a type from a predetermined set of physiological signals. This set may for example comprise heart rate, respiration rate, respiration depth, oxygen saturation (SpO2), body temperature). In a further embodiment the portable device comprises a read out unit and the apparatus comprises an RFID storing data that identifies the sensor and the type of physiological that may be measured with said sensor. When the device is brought is the proximity of the apparatus the readout unit may obtain the data from the RFID. The device may change its settings in correspondence with the identified the sensor and the type of physiological.

In another embodiment of the present invention, the portable device 30 may further comprise a communication unit for sending the derived physiological signal to a medical professional.

By utilizing the computation ability of modern portable device with optical cameras, the physiological signal can be acquired equivalently like the professional medical instruments. By utilizing the powerful calculation ability of portable device, the calculation of some key parameters of the physiological signal can be computed quickly. By utilizing the storage capability of portable device, the historical data and results can be retrospect anytime anywhere. Finally, by utilizing the built-in communication ability of portable device, the acquired signal, computed data, patient's input, and concerns of measurements, can be transmitted to medical professional and obtain the instant feedback service.

Fig. 3 is a block diagram of a system 300 for deriving arterial pulse wave signal of a subject according to one embodiment of the present invention.

As mentioned above, for the arterial pulse wave signal detection and the measurement of the PWV, the system 300 needs two apparatus 10 and 20 for emitting optical signals representing the arterial pulse wave signal of a subject and one portable device 30 for receiving the optical signals and deriving the arterial pulse wave signal from the optical signals.

Specifically, as shown in Fig. 3, the physiological sensor 11 in the first apparatus 10 is placed above a first artery of the subject, for outputting a first electrical signal representing the arterial pulse wave signal of the subject, and the physiological sensor 21 in the second apparatus 20 is placed above a second artery of the subject different from the first artery, for outputting a second electrical signal representing the arterial pulse wave signal of the subject.

Conventionally, for arterial pulse wave signal detection and the measurement of the PWV, carotid artery is selected as the first artery and femoral artery is selected as the second artery. Needless to say, other arteries may be also possible according to different requirements.

The light source 13 in the first apparatus 10 emits a first optical signal and the light source 23 in the second apparatus 20 emits a second optical signal. The camera of the portable device 30 acquires an optical image sequence of the first optical signal and an optical image sequence of the second optical signal, and the processor of the portable device 30 derives a first arterial pulse wave signal from the optical image sequence of the first optical signal and derives a second arterial pulse wave signal from the optical image sequence of the second optical signal.

In an embodiment of the present invention, the physiological sensors 11 and 21 in the system 300 for deriving arterial pulse wave signal of a subject are deformation-sensitive sensors for outputting electrical signals representing the arterial pulse wave signal of the subject. In another embodiment, the physiological sensors 11 and 21 in the system 300 may be accelerometers as well, as long as they can output electrical signals representing the arterial pulse wave signal of the subject.

By configuring the camera acquisition settings, such as image acquisition speed, image resolution, and frame rate, users can achieve the optimal performance for acquiring pulse wave modulated optical image sequence. For most of contemporary cell phones, the minimal image acquisition speed can reach 25-30 frames per second (fps) for an image resolution at least 800 by 480 pixels. This image resolution and image acquisition speed allow the signal integrity for most pulse wave signals, whose signal spectra normally range within 0.35Hz–5 Hz. Therefore the time-resolved image contains full information of pulse wave signal and the pulse wave signal can be completely restored without losing any featured information.

Fig. 4 is a block diagram of the system 400 for deriving arterial pulse wave signal of a subject according to another embodiment of the present invention.

In this embodiment, compared with the embodiment shown in Fig. 3, each of the apparatus 10 and 20 in the system 400 further comprises an optical fiber 14 and 24 for guiding the respective optical signal.

Further, in this embodiment, the portable device 30 may further comprise a camera adaptor 31 mounted on the front of the camera. The camera adaptor 31 comprises a front lens 310, which is divided into two parts by an opaque blocker 310a, for splitting the received optical input from two fibers. Further, the adaptor 31 comprises an optical band-pass filter 311 to filter out the spray beam and make the beam nearly monochromatic, and a collimation lens 312 to couple the optical images into the imaging sensor, for example CCD or CMOS sensors, of the camera properly.

Please note that although the camera adaptor 31 shown in Fig. 4 comprises a front lens 310 for splitting the receiving optical input from two fibers, it can be easily understood that it is an optional component. For the system 200 used for one signal source, the camera adaptor may also be utilized and in that case, the front lens with opaque blocker is not necessary.

With the optical fiber 14 and 24 and the camera adaptor 31, the optical signal may be better guided and collimated so that the quality of the optical signal received by the camera may be improved.

In a further embodiment of the present invention, the processor of the portable device 30 is further configured for deriving a pulse wave velocity PWV of the subject from the first arterial pulse wave signal and the second arterial pulse wave signal.

Once the optical intensity image sequences are coupled into the camera of the portable device 30, the camera can record, save, and process these sequences of images. Fig. 5 schematically shows the internal functional modules of the portable device 30 according to the present invention.

The portable device, for example a cell phone, firstly records a sequence of time-resolved optical intensity images. See 301, each image is then split into two parts for acquiring two channels of signals. For each channel, the integral of image intensity within the region of interest (ROI) is summed and regarded as a single temporal point of the whole pulse wave (302). Once the entire image sequences of two channels are recorded, two completed pulse waveforms of two channels are then reconstructed (303). Then the periodic cycle detection algorithm detects the period of the pulse cycle, by utilizing well established algorithm of foot-detection or maximal slope point detection. Once the periodic of two channels, in term of featured points, such as foot-of-wave are determined, the phase difference between two channels of waveforms, or in term of pulse transmission time (PTT) can be extracted (304), and then the pulse wave velocity can be calculated by PWV = Dist/PTT (305), where Dist is the surface distance between two measurement sites, and PTT is the pulse transmission time. The PWV results and the risk categorization can be done by built-in clinical support functions.

The results can be displayed on the phone (306), stored in the local database or remote database (307), or directly sent to associate medical professional via wireless (GPRS/3G/4G) communication (308). The medical professionals can provide instant feedback based on the measurement results. If medication or triage is necessary, patient can get further advices instantly, too.

Please note that the ECG (electrocardiograph) signal, which is commonly used as time-reference signal in most conventional PWV assessment modalities, is not used in this invention. This is because the ECG signal encloses frequency of 40 Hz and above, especially for the upstroke of the R-wave. For most cell phone camera, the image acquisition cannot respond as quickly as this change of ECG signal. If using this incomplete ECG signal as the time reference, in particularly using the method of maximal-slope middle point method for determining consecutive PTTs between periodic pulse signals, phase error will occur and resultantly reduce the PWV accuracy.

In this way, the present invention also proposes an innovative PWV measurement method and system, which is based on the optical amplitude modulation technology. The artery pulse signals are picked up by using deformation-sensitive sensors or accelerometers, but the transmission and conversion functions are replaced by optical solution, in order to utilize the advantages of portable device.

In addition, by replacing the use of high resolution ADC device, which is commonly used in conventional PWV measurement modality, the implementation proposed in the present invention significantly reduces the system cost and system complexity. If embodied as a gadget affiliated to modern portable device, this system is then featured by low-cost, portability and ease-of-use.

The portable device based platform and the multi-thread computation ability can empower the handy convenience for any signals process, which dynamically varies in amplitude and in a 'slow' frequency, for example, the body temperature, SpO2, aspirations relevant parameters obtained by strain sensor surrounding abdomen, and artery pulse wave signal, etc., as long as the signal frequency is within the Nyquist sampling frequency range.

In addition to the above mentioned apparatus and system, the skilled in the art would easily understand that the present invention has disclosed a method for modulating an optical signal emitted from a light source as well, which is embodied in the above described apparatus 10.

Specifically, the method for modulating an optical signal emitted from a light source is about the operation of the apparatus 10 side and comprises the step of acquiring an electrical signal representing a physiological signal of a subject with a physiological sensor placed on the subject; and the step of modulating the intensity of the optical signal in accordance with the amplitude of the electrical signal.

Further, the skilled in the art would easily understand that the present invention has also disclosed a method for deriving a physiological signal of a subject, which is about the operation of the whole system 200 and comprises the steps of acquiring an electrical signal representing the physiological signal of the subject with a physiological sensor placed on the subject; modulating intensity of an optical signal emitted from a light source in accordance with the amplitude of the electrical signal; acquiring an optical image sequence of the optical signal; and deriving the physiological signal from the optical image sequence of the optical signal.

Still further, it may be easily understood that the method performed in the portable device may be carried out by a computer program, i.e., gadget, which when downloaded into the portable device 30 and implemented, are capable of driving the camera in the portable device 30 to acquire an optical image sequence of the optical signal emitted from the apparatus 10, and driving a processor in the portable device 30 to derive the physiological signal from the optical image sequence of the optical signal.

Furthermore, as can be easily understood by the skilled in the art, in the apparatus claim enumerating several means, several of these means can be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention and that those skilled in the art would be able to design alternative embodiments without departing from the scope of the appended claims. In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. The word “comprising” does not exclude the presence of elements or steps not listed in a claim or in the description. The word “a” or “an” preceding an element does not exclude the presence of a plurality of such elements. In the system claims enumerating several units, several of these units can be embodied by one and the same item of software and/or hardware. The usage of the words first, second and third, et cetera, does not indicate any ordering. These words are to be interpreted as names.

CLAIMS:

1. An apparatus (10, 20) for converting a physiological signal of a subject to an optical signal, comprising:

a physiological sensor (11, 21) attachable to the subject, for generating an electrical signal in dependence of a measured physiological signal of the subject, an amplitude or a frequency of the electrical signal being indicative of a value of the physiological signal measured by the physiological sensor (11,21);

a light source (13, 23) for emitting the optical signal having an intensity and one or more wavelength within the visible range; and

a modulator (12, 22) for modulating the intensity of the optical signal in accordance with the amplitude or frequency of the electrical signal.

2. The apparatus (10, 20) according to claim 1, further comprising:

an optical fiber (14, 24) for guiding the optical signal.

3. The apparatus (10, 20) according to any one of claims 1-2, wherein the light source (13, 23) comprises a LED and the modulator(12,22) comprises a LED driver.

4. A device (30) for converting an optical signal to a physiological signal of a subject, comprising:

an image sensor for acquiring an optical image sequence of the optical signal, the optical signal having an intensity and one or more wavelength within the visible range; and

a processor for deriving from the optical image sequence of the optical signal a value of the physiological signal;

wherein the value of the physiological signal is dependent on a modulation of the intensity of the optical signal in the acquired optical image sequence.

5. The device (30) according to claim 4, further comprising:

a physiological signal identification for determining a type of the physiological signal.

6. The device according to claim 5 wherein the physiological identification means comprises a user interface for allowing a user to define the type of physiological signal, the type of physiological signal being chosen by the user from a predefined set comprising heart rate, breathing rate, SpO2 and body temperature.

7. The device (30) according to any one of claims 4-6, further comprising: a camera comprising the image sensor,

an adaptor (31) mounted on the front of the camera, the adaptor comprising:

an optical band-pass filter (311) for filtering out spray beam in the optical signal; and

a collimation lens (312) for coupling the filtered optical signal into the imaging sensor in the camera.

8. The device (30) according to any one of claims 4-7, further comprising:

a communication unit for sending the value or the type of physiological signal to a receiving unit for review by a medical professional.

9. A system (200) for deriving a physiological signal of a subject, comprising:

at least one apparatus (10, 20) according to claim 1-3; and

the device (30) according to one of claims 4-8.

10. The system (200) according to claim 9 or an apparatus (10, 20) according to any one of claims 1-3, wherein the physiological sensor (11, 21) in the apparatus (10, 20) is one of a thermistor, an SpO2 sensor, a deformation-sensitive sensor and an accelerometer.

11. The system (200) for deriving a physiological signal of a subject according to claim 9 or claim 10, the system comprising a first apparatus according to any of claim 1-3 attachable to a first artery of the subject and a second apparatus according to any of claim 1-3 attachable to a second artery of the subject, wherein the system is arranged to derive a pulse wave velocity, PWV, of the subject, wherein the device according to any of claim 4-7 is arranged to receive a first optical signal of the first apparatus, a second optical signal of the second apparatus and derive a PWV in dependence of the received first and second optical signal.

12. The system (300, 400) according to claim 11, comprising:

wherein the device is arranged to acquire a third optical image sequence;

wherein each optical image of the third optical image sequence comprises respective portion of the first optical signal and the second optical signal,

wherein the processor is further configured for

deriving from the third optical image sequence a first optical image sequence of the first optical signal and a second optical image sequence of the second optical signal;

deriving from the first optical image sequence a first arterial pulse wave signal and deriving from the second optical image sequence a second arterial pulse wave signal;

deriving a pulse wave velocity PWV of the subject from the first arterial pulse wave signal and the second arterial pulse wave signal.

13. A method of converting a physiological signal of a subject to an optical signal, comprising:

generating an electrical signal in dependence of a measured physiological signal of the subject, an amplitude or a frequency of the electrical signal being indicative of a value of the physiological signal measured by the physiological sensor (11,21);

emitting the optical signal having an intensity and one or more wavelength within the visible range; and modulating the intensity of the optical signal over time in accordance with the amplitude or frequency of the electrical signal.

14. A method of converting an optical signal to a physiological signal of a subject, comprising:

acquiring an optical image sequence of the optical signal; and

deriving from the optical image sequence of the optical signal a value of the physiological signal;

wherein the value of the physiological signal is dependent on a modulated intensity of the optical signal in the acquired optical image sequence.

15. A computer program product comprising a set of instructions, which, when downloaded into a device (30) of claim 4 results in:

acquiring with the image sensor an optical image sequence of the optical signal; and

deriving from the optical image sequence of the optical signal a value of the physiological signal;

wherein the value of the physiological signal is dependent on a modulation of intensity of the optical signal in the acquired optical image sequence.

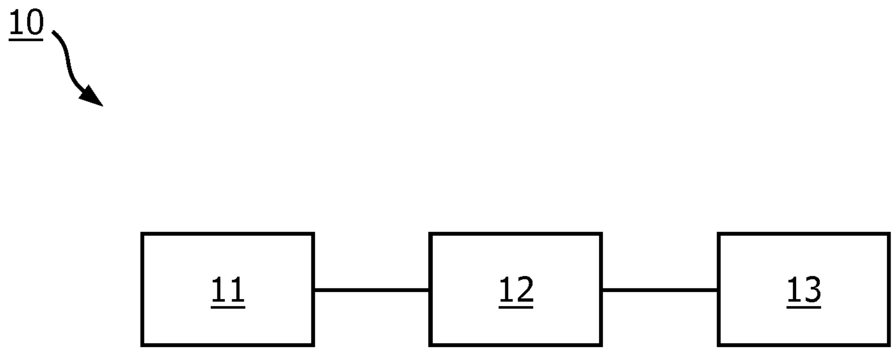

FIG. 1

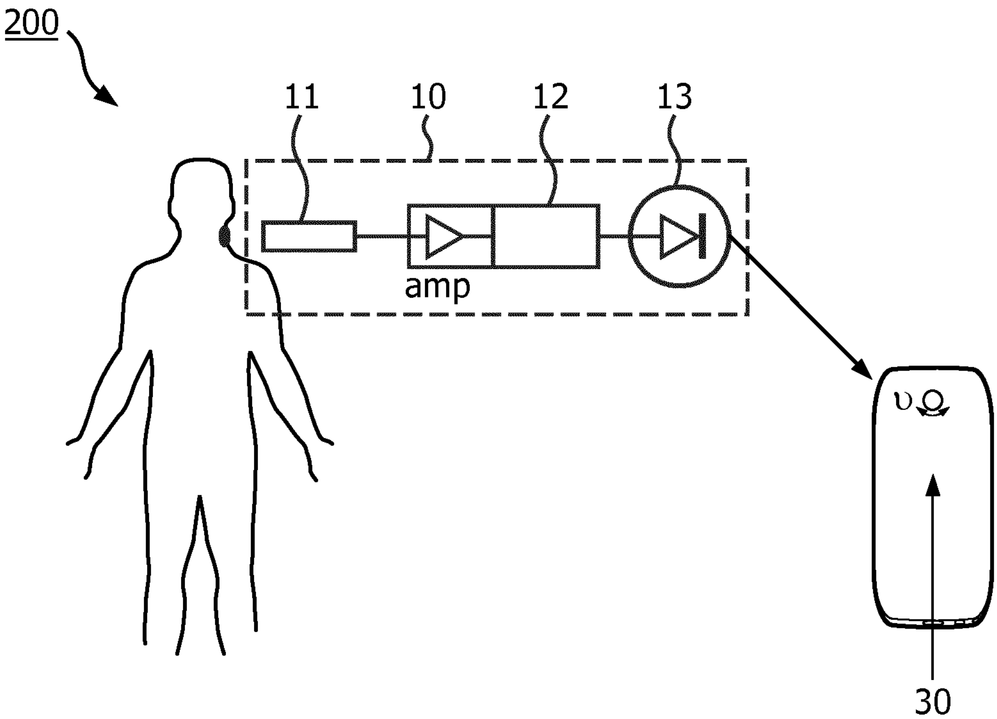

FIG. 2

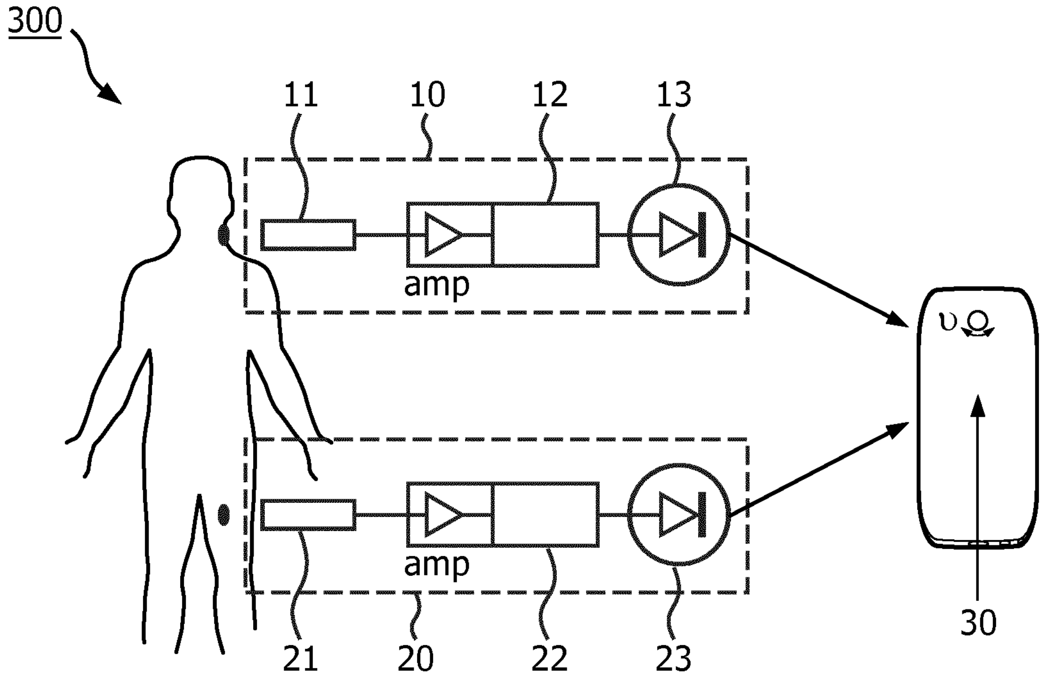
300
11
10
12
13
amp
amp
21
20
22
23
30

FIG. 3

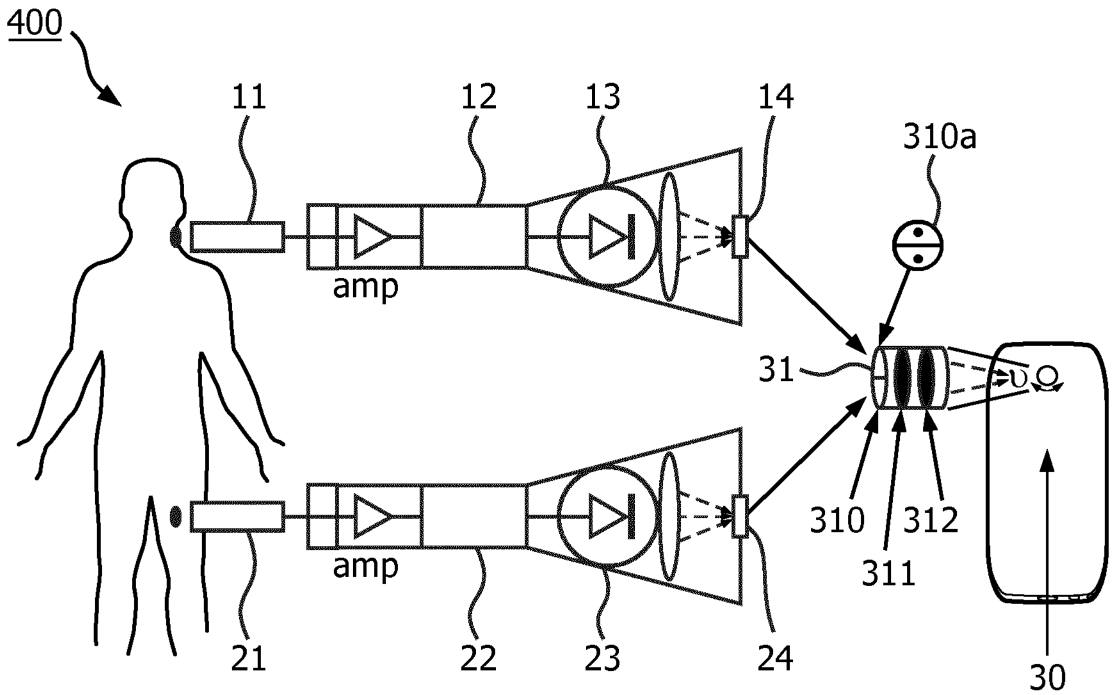
400
11
12
13
14
310a
amp
31
amp
310
311
312
21
22
23
24
30

FIG. 4

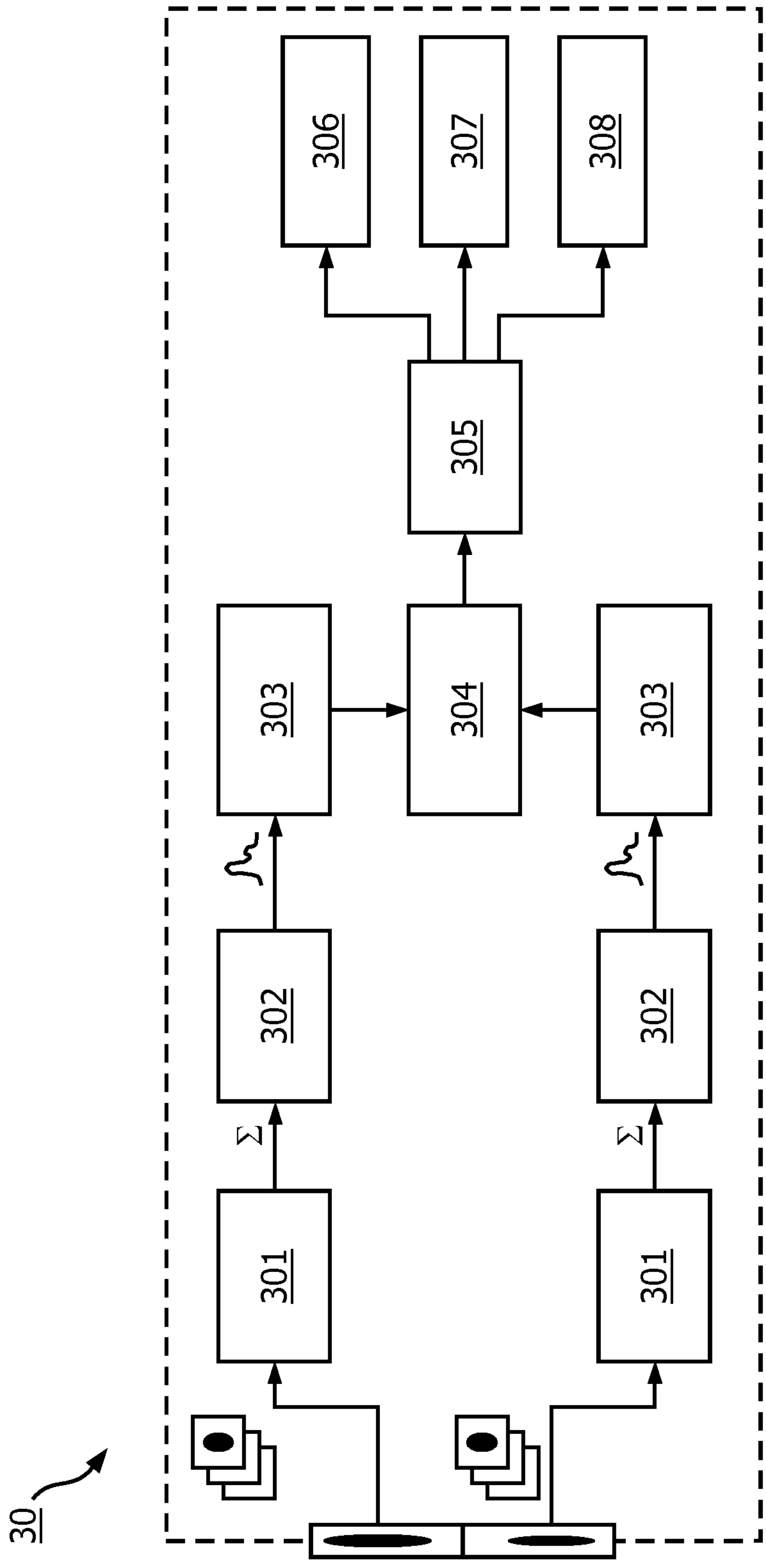

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/EP2014/076157

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.:
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:

see additional sheet

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 an 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.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2014/076157

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/00
ADD. A61B5/01 A61B5/113 A61B5/1455 A61B5/024

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	US 2012/018302 A1 (SHIRAKI YASUNORI [JP] ET AL) 26 January 2012 (2012-01-26) abstract; figures 1-14 paragraphs [0009] - [0044], [0055] - [0057], [0064] - [0069] -----	1-15
X	US 5 865 733 A (MALINOUSKAS DONALD [US] ET AL) 2 February 1999 (1999-02-02) abstract; figures 1-9 column 2, line 1 - column 3, line 4 column 4, lines 1-41 column 5, line 12 - column 6, line 65 column 7, lines 10-50 -----	1-15

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[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

"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	Date of mailing of the international search report
20 February 2015	04/03/2015

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	Carta, Riccardo

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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	FR 2 685 968 A1 (DISTR APP MEDICAUX OFF [FR]) 9 July 1993 (1993-07-09) abstract; figures 1,2 page 1, lines 1-17 page 2, line 1 - page 3, line 21 page 4, lines 1-8 page 5, lines 6-11 -----	1,2,4, 13,14
A	US 2005/083194 A1 (SHEN YUAN-YAO [TW]) 21 April 2005 (2005-04-21) abstract; figures 1-3 paragraphs [0008] - [0029] -----	1-15
A	US 2010/040203 A1 (AYRAUD MICHEL [FR]) 18 February 2010 (2010-02-18) abstract; figures 1-6 paragraphs [0011] - [0014], [0027] - [0030], [0037], [0044] -----	1-15
A	US 2004/111034 A1 (LIN KIN YUAN [TW] ET AL) 10 June 2004 (2004-06-10) abstract; figures 1,2a,10 paragraphs [0001] - [0009], [0015] - [0017], [0032] - [0036], [0063] -----	1-15
A	US 2007/073119 A1 (WOBERMIN JAMES [US] ET AL) 29 March 2007 (2007-03-29) abstract; figures 1-4 paragraphs [0002], [0005] - [0012], [0022] - [0028], [0030] - [0037] -----	1-15
A	US 2010/075712 A1 (SETHURAMAN ANAND [US] ET AL) 25 March 2010 (2010-03-25) figures 1-2 paragraphs [0021] - [0031], [0048], [0052] -----	1-15

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/EP2014/076157

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		US 2013178246 A1	11-07-2013

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. claims: 1-15

   Transfer physiological data thorough an optical link

1.1. claims: 1-3, 13(completely); 9(partially)

   Physiological signal acquisition and optical transmission

1.2. claims: 4-8, 14, 15(completely); 9-12(partially)

   Optical reception and signal processing
