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(54) TRANSCUTANEOUS PHOTOPLETHYSMOGRAPHY

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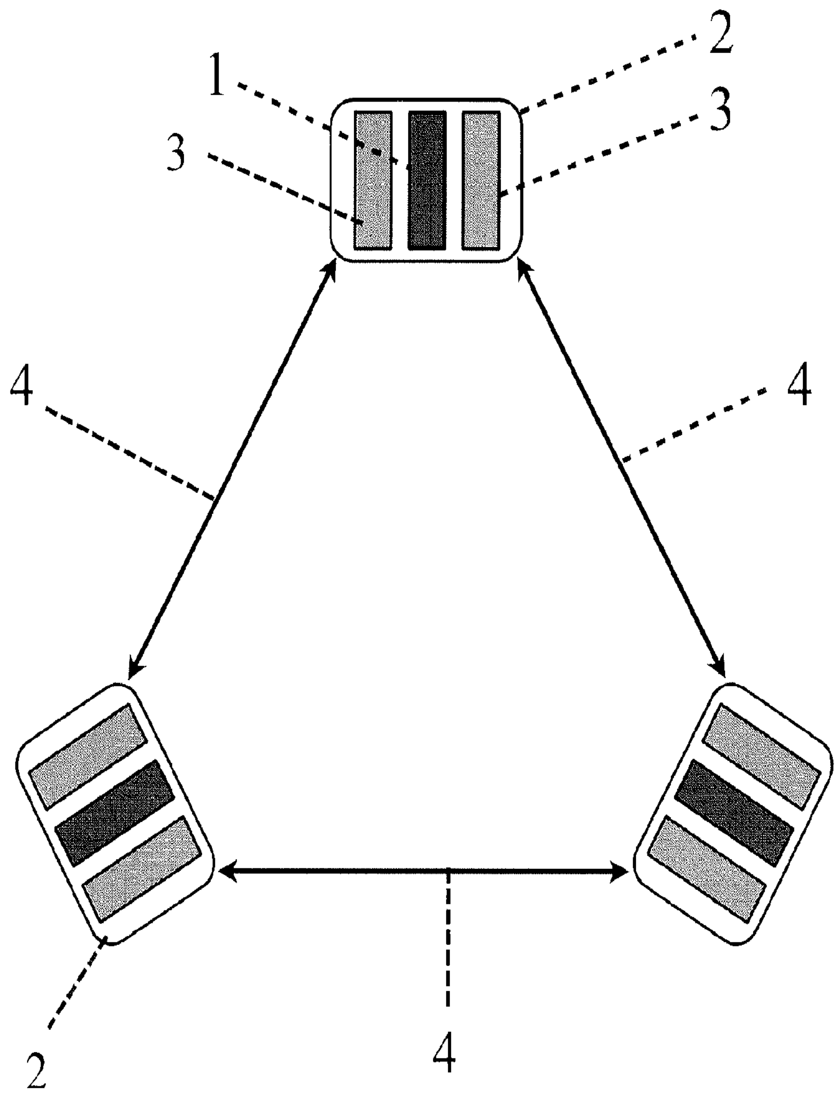
CPC ***A61B 5/02416*** (2013.01); ***A61B 5/0002*** (2013.01); ***A61B 5/02125*** (2013.01); ***A61B 5/02*** (2013.01)

(57) **ABSTRACT**

The present invention discloses a reflectance type PPG-based physiological sensing system with a close proximity triangulation approach toward robustly measuring several physiological parameters including, but is not limited to, heart rate, breathing rate, blood oxygen saturation and pulse wave velocity.



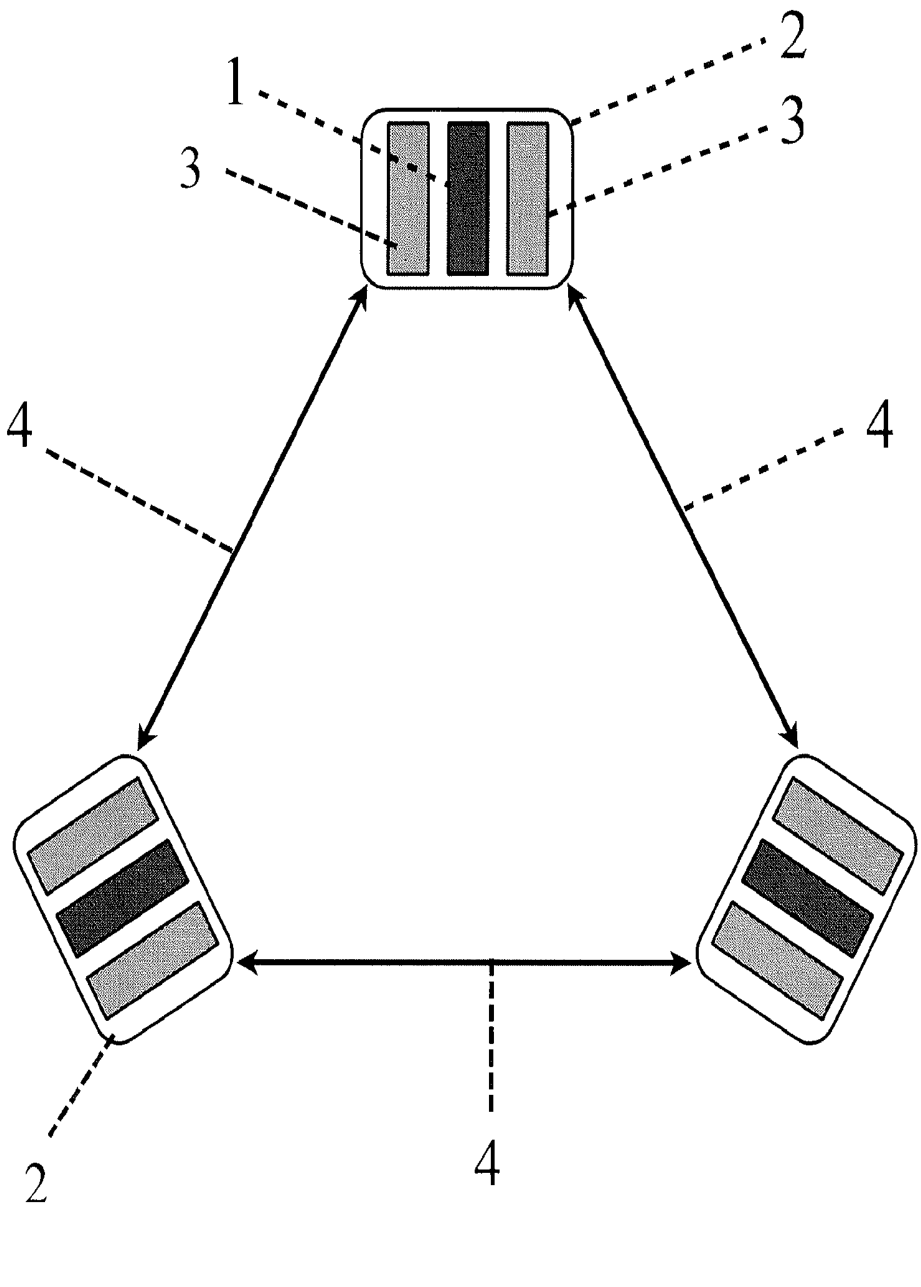


Figure 1

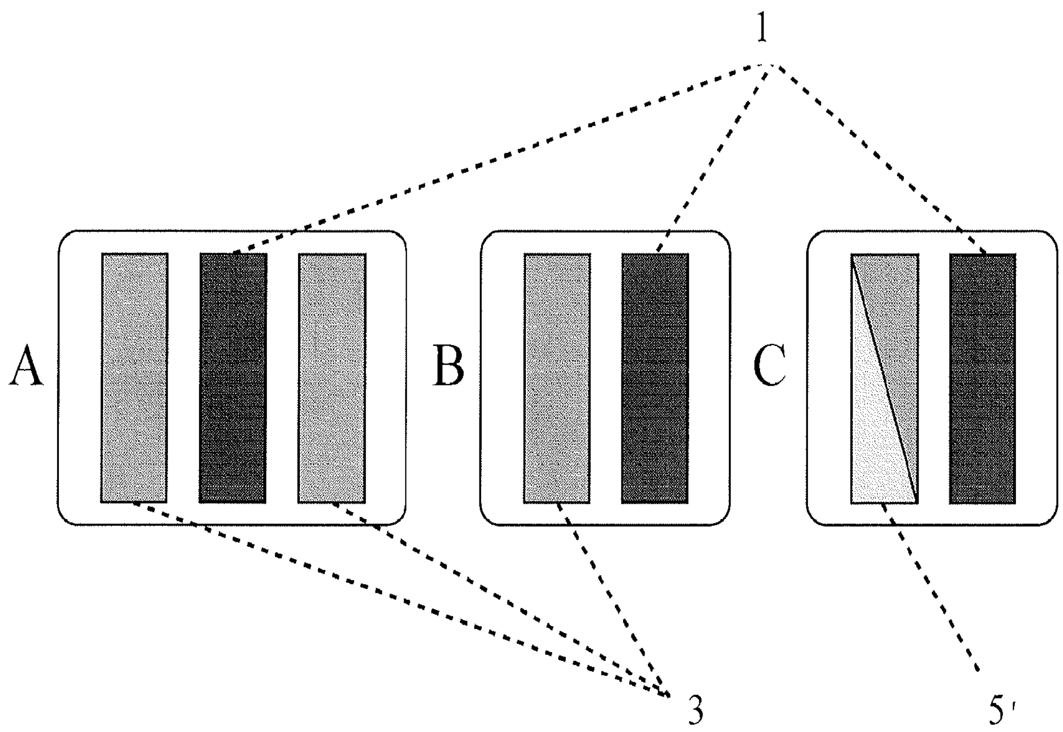
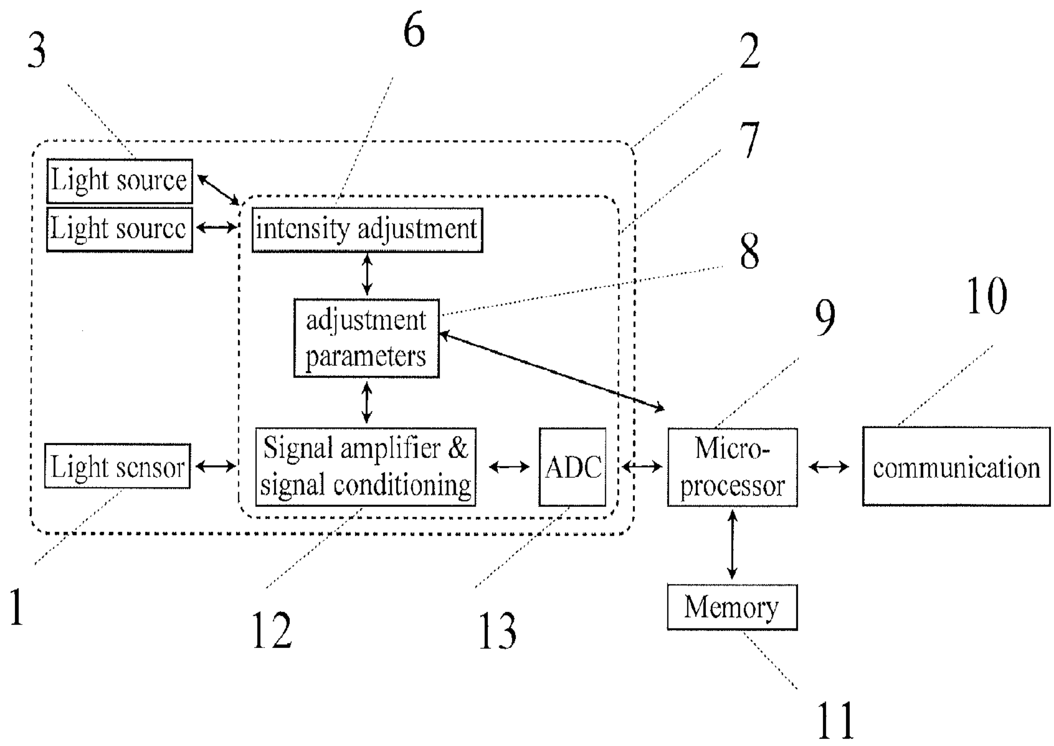


Figure 2


3
6
2
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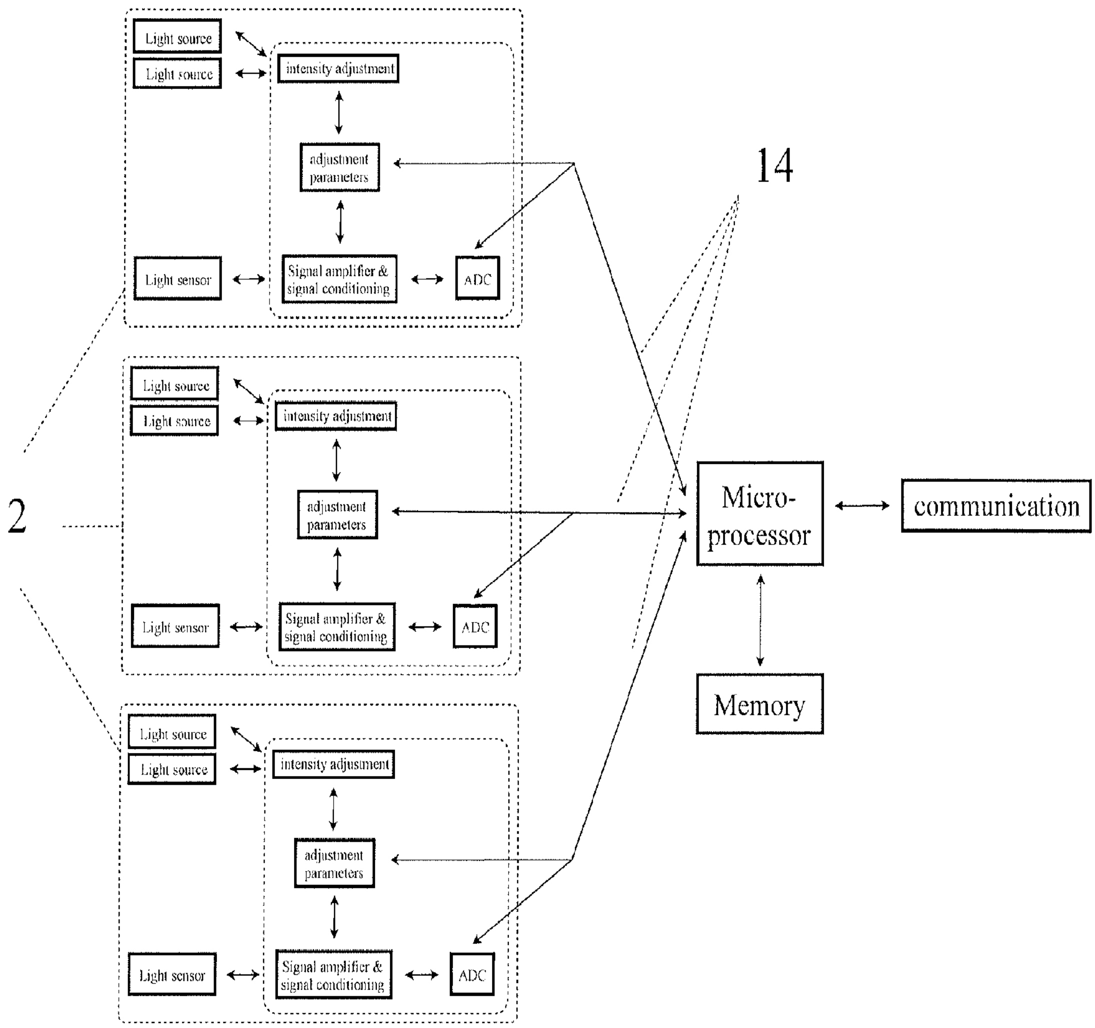
8
9
10
Light source
Light source
intensity adjustment
adjustment parameters
Signal amplifier & signal conditioning
ADC
Micro-processor
communication
Light sensor
Memory
1
12
13
11

Figure 3


Light source
Light source
intensity adjustment
adjustment parameters
Light sensor
Signal amplifier & signal conditioning
ADC
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Light source
Light source
intensity adjustment
adjustment parameters
Light sensor
Signal amplifier & signal conditioning
ADC
Light source
Light source
intensity adjustment
adjustment parameters
Light sensor
Signal amplifier & signal conditioning
ADC
Micro-processor
communication
Memory

Figure 4

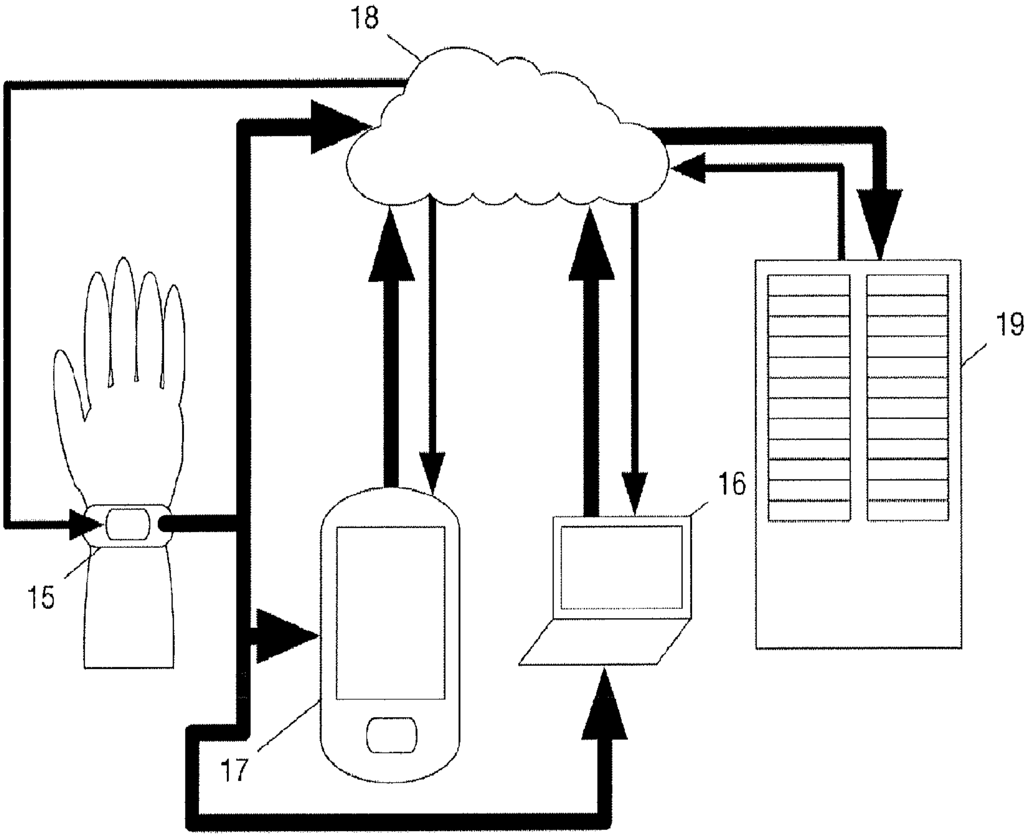

Figure 5

TRANSCUTANEOUS PHOTOPLETHYSMOGRAPHY

FIELD OF THE INVENTION

[0001] The present invention pertains mainly to physiological/vital sign monitoring by making use of close-proximity triangulation photoplethysmography—in particular by enabling robust and accurate determination of physiological parameters, including but not limited to heart rate, breathing rate and pulse wave velocity.

BACKGROUND OF THE INVENTION

[0002] Traditionally, health monitor devices were only applicable in fixed hospital/medical settings, using expensive, high tech machinery relying on trained medical personal. Recently however, portable health monitoring devices have become a growing trend in modern healthcare to provide continuous physiological information to the wearer and/or to guide healthcare practitioners in their medical decisions. Continuous access to physiological parameters can be widely beneficial in a scientific and clinical research setting, as well as in the sport and fitness sector to motivate and guide users to achieve and maintain personal health, wellness and fitness goals.

[0003] Photoplethysmography (PPG) is a well-known optical sensing technique used to measure the hemodynamic properties in organisms. Transcutaneous PPG technology essentially entails the illumination of the skin of an organism and the subsequent photo-detection of reflected or transmitted light through a sample in order to measure small changes in light intensity. These small changes in light intensity are due to shifts in the concentration of several subcutaneous chromophores (molecules that absorb light). These concentration changes occur due to changes in subcutaneous blood volume due to the level of tissue perfusion as a result of (i) expansion and contraction of capillary vessels during the cardiac cycle and (ii) subcutaneous fluid movement due to motion of the organism. Several transformations of the PPG signal have been proposed and implemented to obtain physiological parameters from the PPG signal, and several algorithms and embodiments have been proposed to yield accurate, motion resistant physiological parameters, such as heart rate and oxygen saturation, from wearable PPG sensors.

[0004] Progress has been made to reduce the cost of wearable PPG-based sensors that are resistant to motion artifacts, but most of the PPG solutions currently employed use a combination of optical and accelerometer based solutions to accurately determine heart rate. US Patent Application Publication 20140213863 to Texas Instruments Inc. describes a PPG-based heart rate monitor is that uses an optical motion sensor to remove artifacts. A reference signal for motion compensation is generated either by a incorporating a second light emitting diode (LED) of a different wavelength, alternatively, by either lowering the driving current of the primary LED or by changing the wavelength of the primary LED, which is subtracted from the desired heart rate signal to correct for motion artifacts. In U.S. Pat. No. 8,483,788 to Covidien Lp. a motion compensated pulse oximeter is described that includes an accelerometer to measure the changes induced by motion between the LED and the photodetector. Furthermore, US 20140058217 described a pulse PPG device including motion artifact mitigation methods. Here, a first circuit comprises a PPG-based sensor, while a second circuit comprised of an impedance-based sensor for surface motion artifacts. Currently, PPG technologies are still inherently susceptible to motion artifacts, therefore, they are limited to measure heart rate and oxygen saturation as there is no PPG based device that resolves this problem satisfactory during severe bouts of physical activity.

[0005] Furthermore, currently no device, applied to a single point (defined as a surface not larger than a circle with 1.5 inch radius) on the body, can accurately gauge the velocity of a heart beat pulse propagated through the arterial circulation. Tins phenomenon is known as pulse wave velocity and there exist several optical based solutions where optical sensing modules are placed on different sites of the organism. For example, U.S. Pat. No. 7,674,231 B2 describes a wearable pulse wave velocity blood pressure sensor to perform circulatory measurements on an extremity of a subject. Here, a first PPG signal is obtained from a first position on the subject (such as the wrist) and a second PPG signal at a second position on the extremity (such as a digit). Alternatively, combination approaches exist where an optical sensing module and ECG are employed. For example, in U.S. Pat. No. 6,331,162 B2 claims to analyze blood flow by recording PPG-based waveforms at two locations along the descending thoracic aorta, while simultaneously recording the ECG waveform of the subject in order to determine pulse wave velocity.

[0006] In one embodiment, the current invention overcomes many problems and disadvantages associated with reflectance type PPG-based physiological sensing by introducing close-proximity triangulation PPG.

[0007] Close-proximity triangulation PPG entails the simultaneous PPG measurement at three, or more, independent sites that are in close proximity. In a preferred embodiment the measurement sites are spaced apart to form an equilateral triangle within a single point (as defined previously as a surface not larger than a circle with 1.5 inch radius). The respective PPG measurements are subsequently digitized and used to accurately determine physiological metrics by feeding the respective PPG measurements to an on-board processor and/or for processing on a secondary device/server, where said processing includes DSP algorithms such as dynamic time warping.

[0008] Close-proximity triangulation PPG is used towards identifying and removing motion artifacts from optical signals obtained from a wearable optical sensor device that acquired optical signals during extreme bouts of physical activity and movement. In addition, the current invention makes use of close-proximity optical sensing triangulation which enables one to determine the direction and velocity of the blood pulse wave, thus enabling one to gauge arterial stiffness and estimate blood pressure. Pulse wave velocity is a reliable prognostic parameter for cardiovascular morbidity and mortality that can be used in a variety of adult populations including patients with diabetes, hypertension and end-stage renal disease.

[0009] Furthermore, the pulse wave velocity data can be used to aid in the separation of motion artifacts and physiological features such as heart rate. The different wave propagation characteristics for physiological features and motion artifacts, as determined by triangulation PPG is used to decompose motion and physiological features.

[0010] While the present invention is described in detail with reference to various embodiments in subsequent pages, it will be appreciated that the present invention is not limited to the embodiments described herein, and that modifications may be made without departing from the scope of the invention defined in the accompanying description.

SUMMARY OF THE INVENTION

[0011] In one embodiment the present invention discloses a reflectance type PPG-based physiological sensing system with a close-proximity triangulation sampling approach (from here on called close-proximity triangulation PPG or tPPG) towards robustly measuring several physiological parameters and compensating for motion artifacts. The measured physiological parameters include, but not limited to, heart rate, breathing rate, oxygen saturation and pulse wave velocity.

[0012] The tPPG-based physiological sensing system comprises a wearable optical sensing module (contained in a wearable device). The optical sensing module contains three or more light-emitting diodes and three or more light-sensitive components (such as a phototransistor or photodiode) arranged, in a preferred embodiment, in a triangular fashion. The optical sensing module measures blood volume changes caused by the expansion and contraction of the blood capillaries in the skin and underlying tissue during the cardiac cycle (and other processes such as Mayer waves).

[0013] The design of the optical sensing module enables rapid simultaneous or rapid sequential sampling at the respective measuring sites. The measurements at the respective spatial points allows for the mathematical determination of physiological parameters such as the pulse wave vector. These measurements, apart from having clinical value, can also be used to effectively compensate for motion artifacts that occurs during measurement of physiological metrics such as, but not limited to, heart rate, breathing rate & oxygen saturation.

BRIEF DESCRIPTION OF DRAWINGS

[0014] The accompanying figures, where alike reference numerals refer to identical or functionally similar elements throughout the separate views, and which together with the detailed description below are incorporated in and form part of the specification, serve to further illustrate various embodiments of, and to explain principles in accordance with, the present invention.

[0015] The present invention is described by way of an exemplary embodiment with reference to the accompanying representations, not drawn to any scale, in which:

[0016] FIG. **0.1** is a conceptual illustration of the exemplary embodiment of the tPPG-based physiological sensing system comprising three measurement islands (**2**) (with each island consisting of a light detector (**1**) and two light sources (**3**) on either side of the light detector (**1**)) arranged to form the nodes of an equilateral triangle of a given size (**4**).

[0017] FIG. **0.2** is a conceptual illustration of some of the types of measurement islands (**2**).

[0018] FIG. **0.2**A illustrates a measurement island (**2**) consisting of a light detector (**1**) and two light sources (**3**) (able to transmit similar or different wavelengths) on either side of the light detector.

[0019] FIG. **0.2**B illustrates a measurement island (**2**) consisting of a light detector (**1**) and one light source (**3**) next to the light detector (**1**).

[0020] FIG. **0.2**C illustrates a measurement island (**2**) consisting of a light detector (**1**) and one monolithic light source (**5**) next to the light detector (**1**).

[0021] FIG. **0.3** is a conceptual illustration of the interaction of the electronic components of a single optical measurement island (**2**) and peripheral electronics.

[0022] FIG. **0.4** is a conceptual illustration of the electronic components comprising the preferred embodiment of the complete optical sensing module.

[0023] FIG. **0.5** illustrates a basic embodiment of the invention in the context of mobile and internet technologies.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0024] The following detailed description and appended drawings describe and illustrate various aspects of the present invention. The descriptions, embodiments and figures are not intended to limit the scope of the invention in any way.

[0025] FIG. **0.1** is a conceptual illustration of the exemplary embodiment of the tPPG-based physiological sensing system comprising three measurement islands (**2**) (with each island consisting of a light detector (**1**) and two light sources (**3**) on either side of the light detector) arranged to form the nodes of an equilateral triangle. The distance (**4**) between measurement islands (**2**) is as such that the light sources (**3**) of the respective measurement islands does not interfere with the light detectors (**1**) of the respective measurement islands (**2**). There might however still exist minor light contaminations between the respective sensing islands that can be compensated for analytically/mathematically. The respective measurement islands (**2**) is used to measure the blood pulse wave characteristics such as velocity and direction of the wave by analyzing the timing of the PPG peaks and PPG characteristics between the respective measurement islands. The PPG peak time at the three measurement islands can, for instance, be used to calculate the speed of wave propagation, as the distance (**4**) between the measurement islands (**2**) is known.

[0026] FIG. **0.2** is a conceptual illustration of some of the types of measurement islands (**2**). While many different measurement island configurations are possible, three of the types of measurement islands are briefly discussed.

[0027] FIG. **0.2**A illustrates a measurement island (**2**) consisting of a light detector (**1**) and two light sources (**3**) (able to transmit similar or different wavelengths) on either side of the light detector. In the case where the two light sources (**3**) are of the same wavelength, the two light sources are programmed to simultaneously emit light, and the light detector (**1**) such as a photodiode or phototransistor then subsequently detects the reflected light coming back from the skin. However, in the case where the two light sources (**3**) are of different wavelengths, the two light sources are programmed to sequentially emit light, and the light detector (**1**) then subsequently detects the reflected light.

[0028] FIG. **0.2**B is the simplest measurement island configuration where a single light source (**3**) transmits a specific wavelength into the skin and the light detector (**1**) measures the reflected light.

[0029] FIG. **0.2**C illustrates a similar methodology and configuration as in FIG. **2**A, but in this case two different wavelengths are encapsulated into a single monolithic light source (**5**).

[0030] FIG. 0.3 conceptually illustrates the electronic components involved for a single measurement island (2) with peripheral electronics included. A microprocessor (9) instructs a signal module (7) by adjusting several adjustment parameters (8) (containing parameters for intensity adjustment (6) and signal amplification & signal conditioning (12)) that affects the light source (3) intensity as well as the signal amplification and conditioning measured by the light sensor/detector (1). The amplified and conditioned signal is then digitized by an analog to digital converter (ADC) (13). Subsequently the digitized values are pushed to a microprocessor (9) to store the digitized signals on memory (11) and/or communicate it to peripheral electronics by a communication module (10). The communication module can either be wired or wireless. In addition, digitized signal values obtained by the microprocessor can be used to readjust the adjustment parameters (8) in order to obtain a signal with maximum resolution and the least amount of noise.

[0031] FIG. 0.4 depicts the same configuration as in FIG. 3, but shows that multiple measurement islands (2) can be coupled (14) to a single microprocessor, storage and communication module. In this case the preferred embodiment is displayed with three islands present.

[0032] FIG. 0.5 is a schematic illustration of a wearable device (15) for obtaining physiological parameters of a subject, which in this embodiment may be a human, but could also be an animal or other organism or process. The physiological sensors are incorporated into a band, which contacts the skin and may be worn on parts of the body including, but not limited to, the wrist, forearm and upper arm. The device optionally contains a display unit and is capable of transmitting data to a mobile device, such as a personal computer (16), mobile phone (17) and/or the Internet. The data may be stored (18) and further processed on a server (19) for future use and can be viewed on a computer platform such as a personal computer, mobile phone and/or a wearable device.

What is claimed:

1. A wearable device to determine at least one physiological parameter by way of close-proximity triangulation photoplethysmography to be worn against the user's skin, comprising a plurality of measurement islands including, but not limited to;

optical sensing module(s),

electronic embodiment(s) for measuring a signal,

a given the spatial arrangement of said measurement islands.

2. The wearable device of claim 1 where said optical sensing module(s) comprises one or more light-emitting diode(s) and one or more light-sensitive component.

3. The process of claims 1 and 2 to determine at least one physiological parameter by way of close-proximity triangulation photoplethysmography comprising;

where said optical sensing module comprises one or more light-emitting diode(s) and one or more light-sensitive component(s),

where the measurement islands measure pulse wave characteristics including, but not limited to, velocity, direction and magnification of the wave phenomena (such as pulse wave, Mayer waves and motion artifacts),

including electronic embodiments for measuring a signal,

where the amplified and conditioned signal(s) is digitized by an analog to digital converter (ADC),

where a microprocessor is employed to algorithmically distinguish between the biological waveforms and is used to store to digital signal.

4. The process of claims 1 to 3 where a microprocessor is used in conjunction with at least three signal modules to algorithmically separate and determine the speed, direction and magnitude of different biological waves, given the spatial arrangement of said measurement island(s);

including an electronic component to analyze the timing of the PPG peaks and PPG characteristics between the respective measurement islands,

including an algorithm to identify common features and/or align the raw features of the signals from different measurement islands to analyze the speed of the biological waves, as the distances between the measurement islands is known,

where the motion compensated, decomposition of the waveforms including, but not limited to, the pulse wave, motion artifacts and Mayer waves, allows for robust measurement of the physiological parameters,

where close-proximity triangulation PPG involves simultaneous and/or sequential PPG measurements at the individual sensor islands.

5. Where said measurement islands of claims 1 to 4 are spatially arranged in a configuration including, but not limited to, a triangular formation.

6. The process of claims 1 to 4 for determining a number of physiological parameters including, but not limited to, heart rate, heart rate variability, respiration rate, blood oxygen saturation and pulse wave velocity.

7. The process of claims 1 to 4 whereby the distance and illumination level of the respective measurement islands prevents interference with the light detectors on a separate measurement island.

8. Including embodiments of claims 1 to 4 where the plurality of the light source(s) of a single measurement island are of different wavelengths from the two light sources and are programmed to sequentially emit light, and then the light detector subsequently detects the reflected light.

9. Including embodiments of claims 1 to 4 where the adjustment parameters are adjusted/controlled, including, but not limited to;

embodiments where the light source intensity is adjusted,

embodiments where signal amplification and/or signal conditioning parameters are adjusted,

embodiments where digitized signal values obtained by the microprocessor can be used to readjust said signal amplitude and signal conditioning parameters.

10. A process of claims 1 to 4 where the amplified and/or conditioned digital signal is stored on memory and/or communicated to peripheral electronics by a communication module.

11. A wearable device of claims 1 to 4 that transmits the motion compensated physiological signal to a mobile electronic device, such as a mobile phone or personal computer.

12. The wearable device of claims 1 to 4 with the means to transmit the physiological data wirelessly to a platform where said data can be stored or processed on a server, analyzed and viewed on client computing platforms, including but not limited to mobile computing devices, home computers or a wearable electronic device.

* * * * *

patsnap

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公开(公告)日	2017-06-22
申请号	US15/118183
申请日	2015-02-10
[标]申请(专利权)人(译)	Q生活全球有限公司
申请(专利权)人(译)	LIFEQ GLOBAL LIMITED
当前申请(专利权)人(译)	LIFEQ GLOBAL LIMITED
[标]发明人	OLIVIER LAURENCE RICHARD
发明人	OLIVIER, LAURENCE RICHARD
IPC分类号	A61B5/024 A61B5/021 A61B5/00
CPC分类号	A61B5/02416 A61B5/0002 A61B5/02125 A61B5/02 A61B5/7235 A61B5/02427 A61B5/0295 A61B5/6813 A61B5/14552 A61B5/02116 A61B5/0285 A61B5/0816
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其他公开文献	US10314500
外部链接	Espacenet USPTO

摘要(译)

本发明公开了一种基于反射型PPG的生理传感系统，其具有紧密接近的三角测量方法，以稳健地测量若干生理参数，包括但不限于心率，呼吸速率，血氧饱和度和脉搏波速度。