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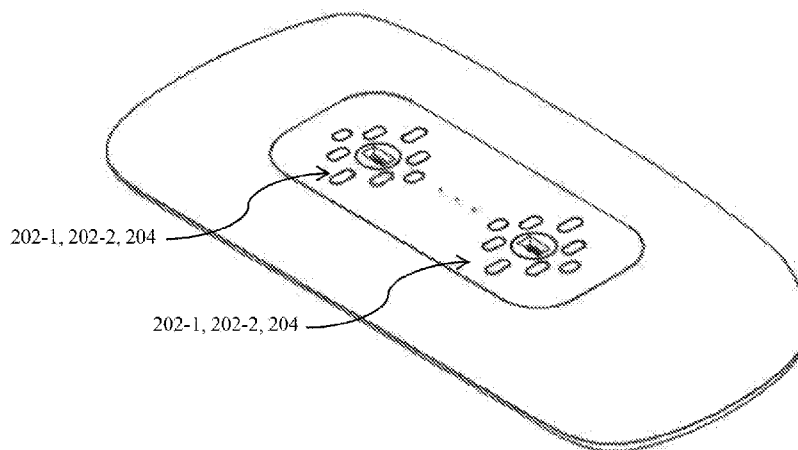
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(54) Title: NON-INVASIVE SENSOR FUSION AND AI TECHNOLOGY FOR HUMAN VITAL MEASUREMENT



Sensing Device 102

(57) Abstract: The present disclosure relates to a non-invasive sensing system (100) for measuring key body vitals. The system (100) includes a sensing device (102) to generate a pre-processed signal in response to the lights reflected by the fingertips of a user. The pre-processed signal is received by a client application (708) for extracting features using a pre-trained artificial intelligence (AI) based model to accurately measure at least six key body vitals including blood glucose, blood sugar (HBA1C), electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature. The system (100) also includes a user interface (706), of the client application (708), to receive a request for the measured key body vitals and to output the measured key body vitals.



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INVASIVE SENSOR FUSION AND AI TECHNOLOGY FOR HUMAN VITAL MEASUREMENT

TECHNICAL FIELD

- 5 **[0001]** The present disclosure relates generally to non-invasive sensor fusion and artificial intelligence (AI) technology. In particular, the present subject matter relates to a non-invasive sensing system for measuring key body vitals and a method for operating the same.

10 **BACKGROUND**

[0002] Background description includes information that may be useful in understanding the present disclosure. It is not an admission that any of the information provided herein is prior art or relevant to the presently claimed subject matter, or that any publication specifically or implicitly referenced is prior art.

- 15 **[0003]** Leading a healthy lifestyle is becoming a concern of great tribulation in recent times. A key to leading a healthy lifestyle is to know how your body has been performing and have an analysis of the very simple things that can have colossal effects on your vitals. Understanding basic vitals such as heart rate, oxygen saturation (Spo2), blood glucose, blood pressure, heart rate variability (HRV), etc,
20 can facilitate one to lead a healthy lifestyle.

- [0004]** However, current methods of measuring these key vitals, for example, blood sugar level are agonizing due to the invasive procedures they follow to measure the blood sugar level. No matter how small and thin the needle is, the pain is still there. While some people get used to it and hence bear it, it can be
25 problematic for others. Measuring blood glucose levels is an everyday thing for diabetics, so it becomes difficult to incorporate this pain into your routine.

[0005] In 2014, 8.5 percent of adults aged 18 years and older had diabetes. In 2019, diabetes was the direct cause of 1.5 million deaths and 48 of all deaths due to

diabetes occurred before the age of 70 years. Another 460000 kidney disease deaths were caused by diabetes, and raised blood glucose causes around 20 percent of cardiovascular deaths” - The World Health Organisation (WHO).

5 [0006] The above information from WHO interprets how significantly catastrophic diabetes can be. A small step towards avoiding this catastrophic effect on the user can be a regular measurement of the vitals and an understanding of blood glucose levels daily for lifestyle improvements.

[0007] A Product that can measure the key vitals above discussed in a way where there are no agonizing invasive procedures can bring compelling results and
10 help us to adapt to lead a healthy life.

[0008] Therefore, there is a need in the art for a system and method to provide non-invasive procedures to measure the key body vitals and help users to lead healthy life.

SUMMARY

15 [0009] This summary is provided to introduce concepts related to a non-invasive sensing system for measuring key body vitals and a method for operating the same. The concepts are further described below in a detailed description. This summary is not intended to identify key features or essential features of the claimed subject matter, nor is it intended to be used to limit the scope of the claimed subject
20 matter.

[0010] Various embodiments of the present disclosure relate to a non-invasive sensing system for measuring key body vitals and a method for operating the same. In an aspect, the proposed system includes a sensing device and a computing coupled to the sensing device.

25 [0011] In an implementation, the sensing device includes a light emitting unit, a photodetector, an elementary filter, a first in first out (FIFO) data registers, a pre-processing module, and a communication module.

[0012] The light-emitting unit is mounted underneath the top glass. The light-emitting unit comprises two sets of light-emitting diodes to emit two different wavelengths into the fingertip of the user when the user places the fingertip on the top glass. The two sets of light-emitting diodes include:

- 5 • Light Emitting Diodes (LED) with a wavelength of 660 nm; and
- Near Infra-Red LEDs (NIRs) with a wavelength of 880 nm.

[0013] The photodetector, mounted underneath the top glass, is configured to receive the light reflected from the fingertip and convert the light into a Photoplethysmography (PPG) signal. In an aspect, the photodetector is configured
10 with spectral range sensitivity of 600 to 5000 nm.

[0014] Further, the top glass allows wavelength frequencies of 600 nm to 900nm with about 85% - 95% transmission percentage.

[0015] Also, the system includes a black optical sensor shield that covers the boundaries of the light emitting unit and the photodetector for absorbing unwanted
15 light that might bounce back to the photodetector.

[0016] The elementary filter is configured to cooperate with the photodetector to receive the PPG signal, filter the PPG signal to remove noise frequencies that are not containing information about the key body vitals, and generate a denoised signal. In an aspect, the elementary filter is a Finite Impulse Response (FIR) band-
20 pass filter with band frequencies from 0.5Hz to 5.0Hz and a gain of 1100, wherein the FIR band-pass filter is configured to remove the noise frequencies lying beyond a frequency range of 0.5Hz to 5.0Hz

[0017] Further, the FIFO data registers are provided for linear processing of the denoised signal generated by the elementary filter.

25 [0018] Then, the pre-processing module is configured to receive the denoised signal from the elementary filter. The denoised signal is obtained as a matrix of signals ($n \times 7$), where said matrix of signals includes 3000 data samples with a sampling frequency of 100 samples per second and a sampling period of 30 seconds,

and where said pre-processing module is configured to pre-process the denoised signal to generate a pre-processed signal.

[0019] In an aspect, the pre-processing module is configured to receive the matrix of signal ($n \times 7$) to perform:

- 5 • concatenation of two parts consisting in the matrix of signals ($n \times 7$) including 3000 data samples to generate a concatenated signal, where the first part of the matrix of signals ($n \times 7$) lies in 3rd column of said matrix and a second part of the matrix of signals ($n \times 7$) lies 1st column of said matrix;
- 10 • trimming of the concatenated signal to discard a part from the beginning of capturing the PPG signal and a part from the ending of capturing the PPG signal to generate a trimmed signal, wherein the part from the beginning includes about 300 data samples and the part from the ending includes about 100 data samples from the array of 3000 data samples;
- 15 • Performing Ultra-low pass conditioning to the trimmed signal to generate a Ultra - low pass conditioned signal
- generating the pre-processed signal as a pre-processed difference signal computed based on a difference between the Ultra-low pass conditioned signal and the trimmed signal.
- 20 **[0020]** Further, the communication module is coupled to the pre-processing module to transmit the pre-processed signal.

[0021] The preprocessing signal is received by a client application, and executed by a processor on a computing device, for extracting features using a pre-trained artificial intelligence (AI) based model to accurately measure at least six
 25 key body vitals including blood glucose, blood sugar (HBA1C), electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature. In an aspect, the user interface of the client application is configured to request the measured key body vitals and to output the measured key body vitals.

[0022] Further, the client application may include a blood glucose module, a blood sugar module (HbA1C), an ECG module, a heart rate module, a blood pressure module, and a body temperature module.

[0023] For blood glucose measurement, the blood glucose module is configured to receive the ultra lowpass conditioned signal signal from the pre-processing module of the sensing device. The blood glucose module comprises:

- a glucose conditioning module to receive the Ultra-low pass conditioned signal from the pre-processing module of the sensing device and compute Normal value of the key two dimensional components analyzed by AI a conditioning interference module to receive the computed Normal as a parameter, wherein the conditioning module is configured to compute a user's blood glucose value based on a range in which the computed normal value falls, wherein for computing the user's blood glucose value, the conditioning interference module uses a polynomial equation where one of the key inputs is the computed Normal value and coefficients for each range are determined by pre-training a regression classifier of the AI-based model with badging.

[0024] For blood sugar measurement (HbA1C), the blood sugar module is configured to receive the pre-processed difference signal from the pre-processing module of the sensing device. The blood sugar module is configured to perform:

- batching the pre-processed difference signal into an M number of batches of an N number of samples, where $N = 50$;
- for each batch, simultaneously computing a peak-to-peak value and an average peak-to-valley for each peak in the batch,
- computing median reference values of the peak-to-peak and the peak-to-valley values of entire batches of the key components of overall length of the difference signal analyzed by the AI categorization.

- implementing the pre-trained AI-based model to receive the median reference values as the extracted features for predicting blood sugar (HBA1C).

[0025] For ECG measurement, the ECG module is configured to perform:

- 5 • receiving the denoised signal as the matrix of signal ($n \times 7$);
- perform motion artifact removal from the denoised signal;
- processing the motion artifact removed signal to identify the heart rate with multiple frequency filters, wherein the heart rate is present only in the frequency range of 0.663 to 3.66 Hz; and
- 10 • passing the filtered signal through a series of thresholding functions, wherein each peak that is observed after the set threshold functions is considered as a heart beat, and a number of peaks which are detected in the signal for a defined time frame with respective their timestamp are utilized to generate an ECG report to understand sinus rhythm of the heart.
- 15 • The hardware unit also comprises of a set of Dry electrodes which acts as one of the sensors for ECG module

[0026] For heart rate measurement, the client application further comprises a heart rate module to perform:

- 20 • receiving the denoised signal as the matrix of signal ($n \times 7$);
- perform motion artifact removal from the denoised signal;
- processing the motion artifact removed signal to identify the heart rate with multiple frequency filters, wherein the heart rate is present only in the frequency range of 0.663 to 3.66 Hz;
- 25 • passing the filtered signal through a series of thresholding functions, wherein each peak that is observed after the set threshold functions is

considered as a heart beat, and a number of peaks detected in the signal for a defined time frame with respect to their timestamp are utilized to measure the heart rate of the user.

[0027] For blood oxygen level (SPo2) measurement, the blood oxygen level
5 (SPo2) module is configured to perform:

- receiving the PPG signal at the photodetector;
- measuring saturation of blood by oxygen from PPG signal received at two wavelengths including red signals received from LED and IR signals received from NIR;
- 10 • calculating the blood oxygen (SpO2) level is calculated from a calibration R curve plotting SpO2 versus ratio red and IR signals, wherein the R is calculated as:

$$R = (R_{ac}/R_{dc}) / (I_{Rac}/I_{Rdc})$$

15 where R_{ac} is the pulsating AC component of the fingertip by red signal and R_{dc} is the non-pulsating DC component of the fingertip by a red signal of wavelength 660 nm, and I_{Rac} and I_{Rdc} are also pulsating AA and DC components of the fingertip by the IR signal of wavelength 880nm.

[0028] For blood pressure measurement, the blood pressure module is
20 configured to perform:

- separating the denoised signal obtained as a matrix of signals ($n \times 7$) into two component signals: red component and irr component, wherein the red component is formed by concatenating zero-indexed columns 3 and 1, which denotes the signal that is obtained from the reflected light
25 of red signal of wavelength 660 nm, and wherein the irr component is formed by concatenating the zero-indexed columns 2, 4 which denotes the signal that is obtained from the reflected IR light of wavelength 880 nm;

- Ultra Lowpass conditioning and trimming the signal.
- The Ultra Lowpass conditioned signal and trimmed components (r_curr , i_curr) by the normal of the respective component signals,
- for the red component (r_curr), normalising it and computing its inverse representation (r_curr_inv) by multiplying 1.01 by a maximum value in this normalised signal and then subtracting each element of the normalised signal from this value;
- for the irr component (i_curr), multiply 1.01 by a maximum value in the irr component and then subtract each element of the signal from this value to obtain i_curr_inv .
- finding indices of peaks in the signals i_curr_inv and i_curr as $maxIndices$ and $minIndices$;
- implementing the $maxIndices$ to index into r_curr_inv to get an array of values ($r_curr_inv_maxima$);
- implementing $minIndices$ to index into r_curr_inv to get another array of values ($r_curr_inv_minima$);
- converting both of these arrays to the same length by only considering values up until the length of the smaller of the two arrays; and
- once both of these arrays are obtained as two arrays of equal length, computing their respective normals, add both their normals up and divide this sum by 2 to obtain the input to the equations for computing the systolic and diastolic blood pressure values, wherein the equations for both systolic and diastolic blood pressure are Polynomial equations, whose coefficients are determined by a pre-training a regression classifier of the AI-based model.

[0029] For measurement of the body temperature, the temperature sensor is configured to measure the temperature of the user based on the IR signal of wavelength 880 nm obtained from the NIRs.

[0030] The present disclosure further relates to a method for operating a non-invasive sensing system for measuring key body vitals. The method includes:

- receiving, by a top glass of a sensing device, a touch of a fingertip of a user;
- emitting, by a light emitting unit mounted underneath the top glass with two sets of light emitting diodes, two different wavelengths into the fingertip of the user when the user places the fingertip on the top glass;
- receiving, by a photodetector mounted underneath the top glass, the light reflected from the fingertip to convert the reflected light into a Photoplethysmography (PPG) signal;
- receiving the PPG signal by an elementary filter configured to cooperate with the photodetector
- filtering, by the elementary filter, the PPG signal to remove noise frequencies that are not containing information about the key body vitals for generating a denoised signal;
- receiving, by a pre-processing module, the denoised signal from the elementary filter, wherein the denoised signal is obtained as a matrix of signals ($n \times 7$), wherein said matrix of signals includes 3000 data samples with a sampling frequency of 100 samples per second and a sampling period of 30 seconds;
- pre-processing, by the pre-processing module, the denoised signal to generate a pre-processed signal;
- transmitting the pre-processed signal by a communication module coupled to the pre-processing module;

- receiving, by a client application executed by a processor on a computing device, the pre-processed signal for extracting features using a pre-trained artificial intelligence (AI) based model to accurately measure at least six key body vitals including blood glucose, blood sugar (HBA1C), electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature; and
- outputting, by a user interface of the client application, the measured key body vitals in response to a request received from the user.

10 **[0031]** Further, as per another embodiment of the present invention, Differential Analysis of blood can be done by using more than one finger of the user, at a time, at the time of data collection. The analysis of blood by more than one finger of the user, at the time of data collection, forms a closed loop around the body and understands differential vital parameters more accurately.

15 **[0032]** The Entire computation modules described above for the accurately measurement of key body vitals including blood glucose, blood sugar (HBA1C), electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature are computed from the signals collected from, for example, both the left and right fingers of the user, at a time, at the time of data collection. The vital results have shown better correlation if the system can understand the minor variations in both the fingers there by producing unified results.

25 **[0033]** Various objects, features, aspects, and advantages of the inventive subject matter will become more apparent from the following detailed description of preferred embodiments, along with the accompanying drawing figures in which numerals represent like components.

[0034] It is to be understood that the aspects and embodiments of the disclosure described above may be used in any combination with each other. Several of the

aspects and embodiments may be combined to form a further embodiment of the disclosure.

[0035] The foregoing summary is illustrative only and is not intended to be in any way limiting. In addition to the illustrative aspects, embodiments, and features
5 described above, further aspects, embodiments, and features will become apparent by reference to the drawing and the following detailed description.

BRIEF DESCRIPTION OF THE DRAWING

[0036] The illustrated embodiments of the subject matter will be best understood by reference to the drawings, wherein like parts are designated by like
10 numerals throughout. The following description is intended only by way of example, and simply illustrates certain selected embodiments of devices, systems, and processes that are consistent with the subject matter as claimed herein, wherein:

[0037] FIG. 1 illustrates a high-level network architecture of a non-invasive sensing system for measuring key body vitals in accordance with an embodiment
15 of the present disclosure;

[0038] FIG. 2 illustrates an exemplary block diagram of the sensing device in accordance with an embodiment of the present disclosure;

[0039] FIG. 3 illustrates exemplary sensing device in accordance with an embodiment of the present disclosure;

20 [0040] FIGs. 4A, 4B, and 4B illustrate different exemplary views of the sensing device in accordance with an embodiment of the present disclosure;

[0041] FIG. 5 illustrates an experimental outcome of the implementation of the lights with different wavelength of the sensing device in accordance with an embodiment of the present disclosure;

25 [0042] FIG. 6 illustrates a functional flowchart of a pre-processing module of the sensing device in accordance with an embodiment of the present disclosure;

[0043] FIG. 7 illustrates an exemplary functional block diagram of a computing device coupled to the sensing device in accordance with an embodiment of the present disclosure;

5 [0044] FIG. 8 illustrates an exemplary functional block diagram of a blood glucose module coupled to the sensing device in accordance with an embodiment of the present disclosure;

[0045] FIG. 9 illustrates an exemplary functional block diagram of a blood sugar module coupled to the sensing device in accordance with an embodiment of the present disclosure;

10 [0046] FIG. 10 illustrates an exemplary functional block diagram of a heart rate module coupled to the sensing device in accordance with an embodiment of the present disclosure;

[0047] FIG. 11 illustrates an exemplary functional block diagram of a blood pressure module coupled to the sensing device in accordance with an embodiment of the present disclosure; and

[0048] FIG. 12A-12B illustrate an exemplary flow diagram illustrating a method of operating a non-invasive sensing system for measuring key body vitals in accordance with an embodiment of the present disclosure.

DETAILED DESCRIPTION

20 [0049] A few inventive aspects of the disclosed embodiments are explained in detail below with reference to the various figures. Embodiments are described to illustrate the disclosed subject matter, not to limit its scope, which is defined by the claims. Those of ordinary skill in the art will recognize a number of equivalent variations of the various features provided in the description that follows.

25 [0050] The following is a detailed description of embodiments of the disclosure depicted in the accompanying drawings. The embodiments are in such detail as to clearly communicate the disclosure. However, the amount of detail offered is not intended to limit the anticipated variations of embodiments; on the contrary, the

intention is to cover all modifications, equivalents, and alternatives falling within the spirit and scope of the present disclosure as defined by the appended claims.

[0051] As used in the description herein and throughout the claims that follow, the meaning of “a,” “an,” and “the” includes plural reference unless the context
5 clearly dictates otherwise. Also, as used in the description herein, the meaning of “in” includes “in” and “on” unless the context clearly dictates otherwise.

[0052] Each of the appended claims defines a separate invention, which for infringement purposes is recognized as including equivalents to the various elements or limitations specified in the claims. Depending on the context, all
10 references below to the "invention" may in some cases refer to certain specific embodiments only. In other cases, it will be recognized that references to the "invention" will refer to subject matter recited in one or more, but not necessarily all, of the claims.

[0053] Groupings of alternative elements or embodiments of the invention
15 disclosed herein are not to be construed as limitations. Each group member can be referred to and claimed individually or in any combination with other members of the group or other elements found herein. One or more members of a group can be included in, or deleted from, a group for reasons of convenience and/or patentability. When any such inclusion or deletion occurs, the specification is
20 herein deemed to contain the group as modified thus fulfilling the written description of all groups used in the appended claims.

[0054] Various embodiments are further described herein with reference to the accompanying figures. It should be noted that the description and figures relate to exemplary embodiments and should not be construed as a limitation to the subject
25 matter of the present disclosure. It is also to be understood that various arrangements may be devised that, although not explicitly described or shown herein, embody the principles of the subject matter of the present disclosure. Moreover, all statements herein reciting principles, aspects, and embodiments of the subject matter of the present disclosure, as well as specific examples, are

intended to encompass equivalents thereof. Yet further, for the sake of brevity, operation or working principles pertaining to the technical material that is known in the technical field of the present disclosure have not been described in detail so as not to unnecessarily obscure the present disclosure.

5 Overview

[0055] A key tool to understand human key body vitals in a way where there are no agonizing invasive procedures can be spectroscopy. Spectroscopy allows the user to understand human key body vitals with great detail and minimum user discomfort.

- 10 [0056] Spectroscopy allows us to measure Photoplethysmography also known as PPG which has been playing a significant role in the measurement of heart rate, oxygen saturation (Spo2), etc.

- [0057] Having this backdrop, the present disclosure proposes an in-depth multi-level analysis of a PPG signal with combinations of various components of the
15 signal combined with different wavelengths at which the signal is captured giving a greater understanding of human key body vitals and measurement of key body vitals, such as blood glucose, non-invasively.

- [0058] As per the inventive implementation of the present disclosure, the measurement of the key body vitals is initiated with a user placing the tips of his/her
20 thumb on a sensing device (hardware device). Then, sensors embedded in the device, consisting of Light Emitting Diodes (LEDs) with a wavelength of 660 nm and a Near Infra-Red LED (NIR) with a wavelength of 880 nm, emit light on the tip of the thumb of the user, and a photodetector with spectral range sensitivity of 600 nm to 5000 nm receives reflected light from the tip of the thumb of the user. In
25 the present disclosure, a particular fusion of LEDs with 2 different wavelengths has been chosen for an optimal understanding of blood to accurately measure the key body vitals.

Exemplary Environment

[0059] FIG. 1 illustrates an exemplary architecture for implementing a non-invasive sensing system 100 for measuring key body vitals in accordance with an exemplary embodiment of the present disclosure. In an aspect, the system 100 of the present disclosure can include a plurality of sensing devices 102-1, 102-2, ... , 102-N, hereinafter collectively referred to as sensing devices 102 and individually as sensing device 102. In an aspect, the sensing device 102 is a hardware unit consisting of mainly five different blocks as shown in FIG. 2. The sensing device 102 comprises a top glass configured to receive a touch of a fingertip of a user and generate a pre-processed signal.

10 [0060] The sensing device 102 may communicate with other sensing devices 102 over a communication network 104. In an aspect, the communication network 104 can be 3G, 4G, 5G, 6G, or any suitable wireless communication network.

[0061] The sensing device 102 may be in communication with a computing device 104-1, 104-2 over the communication network 104. Once the physical sensing of body parameters is performed, the pre-processed signal from the sensing device 102 is transmitted to a client application executed by a processor on the computing device 106, to receive the pre-processed signal for extracting features using a pre-trained artificial intelligence (AI) based model to accurately measure at least six key body vitals including blood glucose, blood sugar (HBA1C), electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature. Further, the client application includes a user interface to receive a request for the measured key body vitals, output the measured key body vitals, and store them in a database 108 coupled to the computing device 106-1, 106-2 for future analysis.

25 Exemplary Embodiments/Implementations

[0062] FIG. 2 illustrates a block diagram of the sensing device 102 in accordance with an embodiment of the present disclosure. In an aspect, the sensing device 102 is a hardware unit consisting of mainly five different blocks as shown in FIG. 2. The sensing device 102 comprises a top glass configured to receive a

touch of a fingertip of a user. The top glass allows wavelength frequencies of 600 nm to 900nm with about 85% - 95% transmission percentage. Further, the sensing device 102 includes:

- 5 i. a light emitting unit mounted underneath the top glass, said light emitting unit comprising two sets of light emitting diodes 202-1, 202-2 to emit two different wavelengths into the fingertip of the user when the user places the fingertip on the top glass;
- 10 ii. a photodetector 204, mounted underneath the top glass, to receive the light reflected from the fingertip and convert the light into a Photoplethysmography (PPG) signal;
- 15 iii. an elementary filter 206 configured to cooperate with the photodetector 204 to receive the PPG signal, filter the PPG signal to remove noise frequencies that are not containing information about the key body vitals, and generate a denoised signal;
- 20 iv. a pre-processing module 208 to receive the denoised signal from the elementary filter 206, where the denoised signal is obtained as a matrix of signals ($n \times 7$), where said matrix of signals includes 3000 data samples with a sampling frequency of 100 samples per second and a sampling period of 30 seconds, and where said pre-processing module 208 is configured to pre-process the denoised signal to generate a pre-processed signal; and
- v. a communication module 210 coupled to the pre-processing module 208 to transmit the pre-processed signal.

[0063] In an aspect, said two sets of light-emitting diodes include:

- 25
 - Light Emitting Diodes (LEDs) 202-1 with a wavelength of 660 nm; and
 - Near Infra-Red LEDs (NIRs) 202-2 with a wavelength of 880 nm.

[0064] In an aspect, the sensing device 100 includes a black optical sensor shield that covers the boundaries of the light emitting unit and the photodetector for absorbing unwanted light that might bounce back to the photodetector.

[0065] Also, the photodetector 204 is configured with spectral range sensitivity
5 of 600 nm to 5000 nm.

[0066] Further, as can be seen from FIG. 2, the sensing device 102 may include LED drivers 212-1, and 212-2 for controlling the illumination of the LEDs 202-1 and NIRs 202-2.

[0067] In an aspect, the elementary filter 206 is a Finite Impulse Response
10 (FIR) band-pass filter with band frequencies from 0.5Hz to 5Hz and a gain of 1100. The FIR band pass filter is configured to remove the noise frequencies lying beyond a frequency range of 0.5Hz to 5Hz .

[0068] In an alternative aspect, instead of the elementary filter 206 or in addition to the elementary filter 206, the sensing device 102 may include a first in
15 first out (FIFO) data registers for linear processing of the denoised signal generated by the elementary filter.

[0069] FIG. 3 illustrates a perspective view of the sensing device 102 in accordance with an embodiment of the present disclosure.

[0070] FIGs. 4A, 4B, 4C illustrate different views (front view, top view, and
20 bottom view) of the sensing device 102 in accordance with an embodiment of the present disclosure. The dimensions shown in these figures are for the sake of understanding the exemplary size of the sensing device 102, and are in no way restrictive to the sensing device 102. The shape and size of the sensing device 102 can be varied depending on the required component configuration inside the sensing
25 device 102.

[0071] As per the inventive implementation of the present disclosure, the measurement of the key body vitals is initiated with a user placing the tips of his/her thumb on a sensing device (hardware device). Then, sensors embedded in the

device, consisting of Light Emitting Diodes (LEDs) with a wavelength of 660 nm and a Near Infra-Red LEDs (NIRs) with a wavelength of 880 nm, emit light on the tip of the finger of the user, and a photodetector with spectral range sensitivity of 600 up to 5000 nm receives reflected light from the tip of the thumb of the user. In the present disclosure, a particular fusion of LEDs with 2 different wavelengths has been chosen for an optimal understanding of blood to accurately measure the key body vitals.

[0072] In the present disclosure, a particular fusion of LEDs 202-1 and NIRs 202-2 with two different wavelengths has been chosen for the optimal understanding of blood.

[0073] An exemplary experimental outcome of the implementation of the lights with different wavelengths is shown in FIG. 5. As shown in FIG. 5:

- Absorption of light at these wavelengths differs significantly between blood loaded with oxygen and blood lacking oxygen.
- Oxygenated hemoglobin absorbs more infrared light and allows more red light to pass through.
- Deoxygenated hemoglobin allows more infrared light to pass through and absorbs more red light.

[0074] With the understanding of these intrinsic characteristics of blood, further wavelength fusions are under the scope of the present disclosure and can be explored more.

[0075] With the sensor (light emitting unit 202-1, 202-2) fusion and photodetector 204 with the right spectral range sensitivity acting as the roots for measuring the PPG signal from the fingertips of the user, here the sensor (light emitting unit 202-1, 202-2) is covered with a hydrolytic resistance class glass (not shown in figures) which acts as a basic cover for the photodetector 204 which compensates for basic motion artifacts and provides a robust base for the measurement of the PPG signal.

[0076] Once the user places their fingertip on the sensors (light emitting unit 202-1, 202-2), the LEDs and NIRs 202-2 emit the light into the fingertip and the photodetector 204 senses the reflected light, and the photodetector 204 sends the entire data it read to the processing module 208 for further processing which is
5 discussed in detail in the description provided herein below in the present disclosure.

[0077] A raw PPG signal consists of a very diverse set of noise contributors to the PPG signal, hence it is very important to understand these noise contributors first, and design/choose filters and methods to remove these noises without
10 compromising the main signal as it sometimes is very easy to eliminate a particular component assuming it to be noise to the signal where it can be a key feature for a vital like glucose.

[0078] Previous studies show that few particular frequency removal is suggested where components like AC noise/ Powerline Interference around the user
15 and minor motion artifacts, etc. are to be understood as noise contributors and needs to be carefully eliminated from the main signal (PPG signal).

[0079] The FIR band-pass filter is chosen as the elementary filter 206 with band frequencies from 0.5Hz to 5Hz and a gain of 1100, the band frequencies have been chosen where, Components like heart rate, Respiration rate which typically lie
20 in frequencies ranging from 0.75Hz to 2.0 Hz, etc. are preserved in the main signal for an accurate analysis of vitals like Heart Rate, Blood Pressure, HRV, etc. and only noise from above-mentioned sources like powerline are removed which typically range in 50Hz. This artifact introduces a sinusoidal component into the recording, at not only its fundamental frequency of 50 Hz, but also as spikes at 100
25 Hz and its higher harmonics.

[0080] After processing the raw PPG signal from the band-pass filter, a signal is left in which noise contributors are present in the same frequency where key body vital information is present. Hence, the further filtering of the filtered PPG signal becomes critically important, and ways in which the noise contributors are found

and the delta differences are adjusted for the key body vitals in the PPG signal instead of removing them completely, which may cause feature loss of signal.

[0081] The denoised signal that is an output of the elementary bandpass filter 206 is transmitted. Different methods such as Single level Discrete Wavelet Transform (DWT) analysis & Multi-level Discrete Wavelet Transform (DWT) were also used to understand the features of the signal in a way where the noise contributors are identified and are compensated in the form of delta correction in the end.

[0082] The denoised signal is obtained as a matrix of shape $(n \times 7)$. With a sampling frequency of 100 samples per second and a sampling period of 30 seconds, we will have 3000 samples. This matrix is fed as an input to the algorithms that compute the vital values, which have been described hereinbelow.

[0083] The denoised signal is then fed through the pre-processing module 208. The objective of the pre-processing module 208 is to render the denoised signal in a form that is conducive to the analyses and computations for calculating the vitals, especially sensitive key body vitals like glucose needs legitimate signal processing modules like this. The pre-processing module 206 is composed of three steps:

First Step: Concatenation of raw signal columns indexed 3 and 1 (zero-indexed convention) : -

A matrix of signal that is $(n \times 7)$ consists of the raw signal in two parts, where the first part of the signal lies in the 3rd column of our matrix and the second part of the signal lies in 1st column of only combining both of this in this particular order reveals the original signal, The matrix is designed this way for Data transmission security and signal Protection

Second Step: Trimming of concatenated signal: -

Trimming the signal is also a key operation, It is observed that when a user places their fingers on the device a minor movement is observed at the start and end of the sample collection, hence a part of the signal from the beginning (300

values) and a part from the end (100) values are trimmed. A 10 second window allowing users to hold the unit at the beginning of starting the sample collection is also observed as an important operation as this 10 second window allows users to have a firm placement of their fingers on the sensors avoiding any physical movements at the time of sample collection.

Third Step: Ultra Lowpass conditioning

An Ultra Lowpass filtering is performed on the trimmed signal and is matched with the length of the original trimmed signal for prevention of data loss.

10

[0084] In particular, as shown in FIG. 6, the pre-processing module 208 is configured to receive the matrix of signal ($n \times 7$) to perform:

- Step 1: concatenation of two parts consisting in the matrix of signals ($n \times 7$) including 3000 data samples to generate a concatenated signal, where a first part of the matrix of signals ($n \times 7$) lies in 3rd column of said matrix and a second part of the matrix of signals ($n \times 7$) lies 1st column of said matrix;
- Step 2: trimming the concatenated signal to discard a part from the beginning of capturing the PPG signal and a part from ending of capturing the PPG signal so as to generate a trimmed signal, wherein the part from the beginning includes about 300 data samples and the part from the ending includes about 100 data samples from the array of 3000 data samples;
- Step 3: Performing Ultra Lowpass conditioning on the trimmed signal
- Step 4: generating the pre-processed signal as a pre-processed difference signal computed based on a difference between the Ultra Lowpass conditioned Signal and the trimmed signal.

[0085] The preprocessing signal from the pre-processing module 208 is received by a client application 708, executed by a processor 702 on a computing device 106, for extracting features using a pre-trained artificial intelligence (AI) based model to accurately measure at least six key body vitals including blood glucose, blood sugar (HBA1C), electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature. In an aspect, the user interface 706 of the client application is configured to request the measured key body vitals and to output the measured key body vitals.

[0086] FIG. 7 illustrates an exemplary system diagram indicating different functional components of computing device 106, which is coupled to the sensing device 102) in accordance with an exemplary embodiment of the present disclosure. The disclosed computing device 106 for measuring key body vitals can include one or more processor(s) 702. The one or more processor(s) 702 may be implemented as one or more microprocessors, microcomputers, microcontrollers, digital signal processors, central processing units, logic circuitries, and/or any devices that manipulate data based on operational instructions. Among other capabilities, one or more processor(s) 702 are configured to fetch and execute computer-readable instructions stored in memory 704 of the computing device 106. The memory 704 may store one or more computer-readable instructions or routines, which may be fetched and executed to establish end-to-end service between multiple domains. The memory 704 may include any non-transitory storage device including, for example, volatile memory such as RAM, or non-volatile memory such as EPROM, flash memory, and the like.

[0087] The computing device 106 may also include an interface(s) 706 (or say, a user interface). The interface(s) 706 may include a variety of interfaces, for example, interfaces for data input and output devices, referred to as I/O devices, storage devices, user interfaces, and the like. The interface(s) 706 may facilitate communication of the computing device 106 with various devices coupled to the computing device 106. The interface(s) 706 may also provide a communication

pathway for one or more components of the computing device 106. Examples of such components include, but are not limited to, client application 708 and data 710.

[0088] The client application 708 may be implemented as a combination of hardware and programming (for example, programmable instructions) to implement one or more functionalities of the client application 208. In the examples described herein, such combinations of hardware and programming may be implemented in several different ways. For example, the programming for the client application 708 may be processor-executable instructions stored on a non-transitory machine-readable storage medium and the hardware for the client application 708 may include a processing resource (for example, one or more processors), to execute such instructions. In the present examples, the machine-readable storage medium may store instructions that, when executed by the processing resource, implement the client application 708. In such examples, the computing device 106 may include the machine-readable storage medium storing the instructions and the processing resource to execute the instructions, or the machine-readable storage medium may be separate but accessible to computing device 106 and the processing resource. In other examples, the client application 708 may be implemented by electronic circuitry.

[0089] The data 710 may include data that is either stored or generated as a result of functionalities implemented by any of the components of the client application 708.

[0090] In an aspect, the client application 708 may include a blood glucose module 712, a blood sugar module 714, an electrocardiogram (ECG) module 716, a heart rate module 718, a blood pressure module 720, a body temperature module 722 and other module(s) 724. The other module(s) 724 may implement functionalities that supplement applications or functions performed by the computing device 106 or the client application 708. The working and operation principles of these modules are described with reference to the following figures.

Blood glucose module 712

[0091] In operation, as shown in FIG. 8, for the blood glucose measurement, the blood glucose module 712 is configured to receive the Ultra Lowpass conditioned Signal from the pre-processing module 208 of the sensing device 102. The blood glucose module 712 comprises:

- 5 • a glucose conditioning module to receive the Ultra Lowpass conditioned Signal from the pre-processing module of the sensing device and compute a normal value of the key two dimensional components analyzed by AI, a conditioning interference module 802 to receive the computed Normal value as a parameter, wherein the
10 conditioning module is configured to compute user's blood glucose value based on a range in which the computed normal value falls, wherein for computing the user's blood glucose value, the conditioning interference module 802 uses a polynomial equation where one of the
15 key inputs is the computed Normal value and coefficients for each range are determined by pre-training a regression classifier 804 of the AI-based model.

[0092] In other words, after processing the PPG signal through the pre-processing module 208 consisting of 3 key operations, a normal is computed on the key two dimensional components analyzed by AI, and this value of the normal is
20 passed as a parameter to the conditional inferencing module 802. In the conditional inferencing module 802, the value of the user's blood glucose is computed based on the range that this normal value falls within. The equation for computing the
| glucose value is a Polynomial equation where the key input is the normal_value described above and the coefficients for each range are determined by pre-training
25 a regression classifier or a regression module 804.

[0093] The reason behind choosing to compute the normal on key two dimensional components analyzed by AI rather than the entire signal is because it is observed to give maximum stability and consistent results by restricting the

interference of the motion artifacts by the users while adjusting their fingers that might cause variations in the input signals.

Blood Sugar Module (HbA1c) 714

[0094] In operation, as shown in FIG. 9, for blood sugar measurement, the blood sugar module (HbA1c) 714 is configured to receive the pre-processed difference signal from the pre-processing module 208 of the sensing device 102. The blood sugar module is configured to perform:

- batching, by a signal batching module, the pre-processed difference signal into an M number of batches of an N number of samples, where N = 50;
- Computing median reference values of P2P and P2V of the intermediate signal that was generated by the 2 dimensional AI categorization from the preprocessed difference signal.
- computing median reference values of the peak-to-peak and the peak-to-valley values of entire batches of the key components of overall length of the difference signal analyzed by the AI categorization. implementing the pre-trained AI-based model to receive the median reference values as the extracted features for predicting the blood sugar (HBA1C).

[0095] In other words, for HBA1C measurement, the preprocessing steps consist of: the concatenation of raw signal columns indexed 3 and 1 (zero-indexed convention), Ultra lowpass conditioning of the concatenated signal, and computing the difference signal by subtracting the Ultra lowpass conditioned signal signal from the concatenated raw signal.

[0096] This preprocessed difference signal is then batched into M no.of batches of N samples (where N = 50) each. For each batch, we compute the peak-to-peak value and the average peak-to-valley for each peak in the batch. The peak-to-peak value for the batch is calculated by multiplying 2 sqrt(2) with the RMS for the

signal. On the other hand, for the peak-to-valley computation, the minimum valley that is adjacent to each peak is first found. For most peaks, there will occur a valley before and after the peak value. Then, the minimum valley is determined which will then provide a peak-valley pair. Once this pair is received, the difference is
 5 computed between the values of the peak and valley, and then an average difference is computed for each peak-valley pair in the batch. This average value gives the normal peak-to-valley reference. Once the peak-to-peak and normal peak-to-valley values for each batch are computed, the median reference values are computed of the peak-to-peak & -to-valley values of entire batches, batches of the key
 10 components of overall length of the difference signal analyzed by the AI categorization. After splitting the signal into M number of batches with N samples in each batch, the median is chosen as a key operation for determining which value to pick from the entire array of computed peak-to-peak & peak-to-valley values. The median eliminates picking any potential motion artifacts in the signal. Motion
 15 artifacts usually have higher peak-to-peak & peak-to-valley values hence after arranging the entire array of computed peak-to-peak & peak-to-valley values in ascending order all the motion artifacts tend to settle in the end. This allows the user to pick the middle value that is not influenced by motion artifacts.

[0097] These computed median reference values of peak-to-peak & peak-to-valley are then used as features for the HbA1c algorithm to predict a real-time HbA1c range of the user.
 20

ECG module 716

[0098] In operation, For ECG measurement, the ECG module 716 is configured to perform:

- 25
- receiving the denoised signal as the matrix of signal ($n \times 7$);
 - receiving input from set of Dry electrodes which acts as one of the sensors for ECG module
 - perform motion artifact removal from the denoised signal;

- processing the motion artifact removed signal to identify the heart rate with multiple frequency filters, wherein the heart rate is present only in the frequency range of 0.663 to 3.66 Hz; and
- passing the filtered signals through a series of thresholding functions, wherein each peak that is observed after the set threshold functions is considered as a heart beat, and a number of peaks detected in the signal in a defined time frame with respect to their timestamp are utilized to generate an ECG report to understand sinus rhythm and other parameters of the heart.

10 [0099] Hence, motion artifact removed signals are fed into the ECG computation algorithm where the algorithm identifies the heart rate with multiple frequency filters, heart rate is present only in the frequency range of 0.663 to 3.66 Hz this particular frequency is filtered & later passes through series of thresholding functions and each peak that is observed after the set threshold functions can be
 15 considered as a heart beat. Number of peaks noted in signal that is captured in a known time frame helps along with the timestamp at which the peak is noted, here a series of timestamps are noted at each respective peak in the array and the normal is computed to know the Average time interval for each peak which can help us understand the *Sinus Rhythm* and other parameters of the heart.

20 Heart Rate Module 718

[00100] In operation, for heart rate measurement, the heart rate module 718 is configured to perform:

- receiving the denoised signal as the matrix of signal (n x 7);
- perform motion artifact removal from the denoised signal;
- processing the motion artifact removed signal to identify the heart rate with multiple frequency filters, wherein the heart rate is present only in the frequency range of 0.663 to 3.66 Hz;

- passing the filtered signal through a series of thresholding functions, wherein each peak that is observed after the set threshold functions is considered as a heart beat, and a number of peaks detected in the signal in a defined time frame with respect to their timestamp are utilized to measure the heart rate of the user.

[00101] In brief, a motion artifact removed signal is fed into the heart rate algorithm where the algorithm identifies the heart rate with multiple frequency filters, heart rate is present only in the frequency range of 0.663 to 3.66 Hz. This particular frequency is filtered & later passes through a series of thresholding functions and each peak that is observed after the set threshold functions can be considered a heartbeat. A number of peaks noted in a signal that is captured in a known time frame help to calculate beats per minute, i.e., heart rate, challenges in heart rate measurement can be detecting the motion artifact as a heart beat and using them in the computation of heart rate calculation.

Blood Pressure Module 720

[00102] In operation, as shown in FIG. 11, for blood pressure measurement, the blood pressure module 720 is configured to perform:

- separating the denoised signal obtained as a matrix of signals ($n \times 7$) into two component signals: red component and irr component, wherein the red component is formed by concatenating zero-indexed columns 3 and 1, which denotes the signal that is obtained from the reflected light of red signal of wavelength 660 nm, and wherein the irr component is formed by concatenating the zero-indexed columns 4 and 2, which denotes the signal that is obtained from the reflected IR light of wavelength 880 nm;
- ultra lowpass conditioning and trimming both the components;

- subtracting both the ultra lowpass conditioned signal and trimmed components (r_curr , i_curr) by a normal of the respective component signals,
- for the red component (r_curr), normalizing it and computing its inverse representation (r_curr_inv) by multiplying 1.01 by a maximum value in this normalized signal and then subtracting each element of the normalized signal from this value;
- for the irr component (i_curr), multiply 1.01 by a maximum value in the irr component and then subtract each element of the signal from this value to obtain i_curr_inv .
- finding indices of peaks in the signals i_curr_inv and i_curr as $maxIndices$ and $minIndices$;
- implementing the $maxIndices$ to index into r_curr_inv to get an array of values ($r_curr_inv_maxima$);
- implementing $minIndices$ to index into r_curr_inv to get another array of values ($r_curr_inv_minima$);
- converting both of these arrays to the same length by only considering values up until the length of the smaller of the two arrays; and
- once both of these arrays are obtained as two arrays of equal length, computing their respective normals, add both their normals up and divide this sum by 2 to obtain the input to the equations for computing the systolic and diastolic blood pressure values, wherein the equations for both systolic and diastolic blood pressure are Polynomial equations, whose coefficients are determined by a pre-training a regression classifier of the AI-based model.

[00103] In brief, in order to calculate blood pressure, first, the raw signal is to be separated into two component signals: red component and irr component. The red

component is formed by concatenating zero-indexed columns 3 and 1, which denotes the signal that we get from the reflected light of Red led of 660 nm & the irr component is formed by concatenating the zero-indexed columns 2 and 4 which denotes the signal that we get from the reflected light of NIR led of wavelength
 5 880 nm Then, both components are ultra lowpass conditioned , trimmed and each element is subtracted by the normal of the respective component signals. A call is made for each component obtained thus far, r_curr and i_curr. After this step, for the red component (r_curr), normalize it and compute its inverse representation (r_curr_inv) by multiplying 1.01 by the maximum value in this normalized signal
 10 and then subtracting each element of the normalized signal from this value. On the other hand, for the irr component (i_curr), multiply 1.01 by the maximum value in the irr component and then subtract each element of the signal from this value to obtain i_curr_inv.

Blood oxygen level (SPo2) Module 722

15 **[00104]** For blood oxygen level (SPo2) measurement, the blood oxygen level (SPo2) module 722 is configured to perform:

- receiving the PPG signal at the photodetector;
- measuring saturation of blood by oxygen from PPG signal received at two wavelengths including red signals received from LED and IR
 20 signals received from NIR;
- calculating the blood oxygen (SpO2) level is calculated from a calibration R curve plotting SpO2 versus ratio red and IR signals, wherein the R is calculated as:

25
$$R = (R_{ac}/R_{dc}) / (I_{Rac}/I_{Rdc})$$
 where Rac is the pulsating AC component of the fingertip by red signal and Rdc is the non-pulsating DC component of the fingertip by a red signal of wavelength 660 nm, and IRac and IRdc are also pulsating AA and DC components of the fingertip by the IR signal of wavelength 880nm.

Body temperature Module

[00105] For measurement of the body temperature, the temperature sensor is configured to measure the temperature of the user based on the IR signal of wavelength 880 nm obtained from the NIRs.

5 Motion Artefact Removal: -

[00106] Motion Artifacts can be a major noise contributor to the PPG signal and it becomes excruciatingly difficult to predict vitals like Glucose without a legitimate process to remove motion artifacts.

[00107] Motion Artefact apperception and filtering is an adamantine process due
 10 to the nature of motion artifact lying in the same frequency where other key features of vitals are observed, It's easy to identify motion artefacts through a visual inspection and trail to run it through a band-pass or low pass filters which can show a compelling result of removing the artefacts but a reduction of quality features for measurement of key vitals is observed, a heterogeneous level of DWT and different
 15 levels of thresholding can give a decent result of removal of motion artifact while maintaining the integrity of the features in the signal

Finger Pressure Analysis: -

[00108] Removing the motion artifact components from the signal directly may not yield accurate results as filtering them out, sometimes, can cause feature loss.
 20 For better accuracy of the measurements, the present invention includes a finger pressure analysis method wherein, the present described computation models compute the vitals first and later adjust the measurements based on the pressure exerted by the user

[00109] Finger Pressure Analysis is done during the computation of vitals, where
 25 the pressure is identified and removed. This can be done by using various modules like ultra low pass filter regression models and AI. The computation modules compute the vitals first, later based on the pressure exerted by the user the delta difference is adjusted from the vitals. The delta differences are calculated by a

regression model which understands pressure components and can provide the necessary delta correction. This approach showed compelling results than removing the noise components directly from the signal

Ultra low pass Filter: -

- 5 **[00110]** A key process that helps to obtain a fair signal out of the raw signal that we get from the hardware unit is removing a baseline drift from the raw signal the baseline drift is observed by factors like user respiration rate and sometimes motion artefacts effect the baseline drift that the signal consists of, this baseline drift can be identified by calculating the Ultra low pass filter for the entire signal.
- 10 Ultra Lowpass Conditioned Signal

[00111] The Ultra lowpass conditioned Signal is subtracted from the raw signal resulting in a signal where baseline drift is removed. A Signal that has baseline drift removed is helpful for calculations like heart rate and ECG where the peaks are better identified than a Signal that has a baseline drift.
- 15 **[00112]** Ultra lowpass conditioned Signal can be helpful in many ways and we can take the advantage of the custom conditioning to efficiently eliminate artefacts like a baseline drift and information about respiration rate based on the signal conditioning. Similarly, the other advantages of the ultra Lowpass conditioned signal are discussed in the segment of the key features.
- 20 **[00113]** FIG. 12 illustrates example method 1200 for operating a non-invasive sensing system for measuring key body vitals. The order in which method 1200 is described is not intended to be construed as a limitation, and any number of the described method blocks may be combined in any order to implement method 1200, or an alternative method. Furthermore, method 1200 may be implemented by

25 processing resource or computing device(s) through any suitable hardware, non-transitory machine-readable medium/instructions, or combination thereof.

[00114] At block 1202, method 1200 includes receiving, by a top glass of a sensing device 102, a touch of a fingertip of a user.

[00115] At block 1204, method 1200 includes emitting, by a light emitting unit mounted underneath the top glass with two sets of light emitting diodes 202-1, 202-2, two different wavelengths into the fingertip of the user when the user places the fingertip on the top glass.

- 5 [00116] At block 1206, method 1200 includes receiving, by a photodetector 204 mounted underneath the top glass, the light reflected from the fingertip so as to convert the reflected light into a Photoplethysmography (PPG) signal.

[00117] At block 1208, the method 1200 includes receiving the PPG signal by an elementary filter 206 configured to cooperate with the photodetector 204.

- 10 [00118] At block 1210, the method 1200 includes filtering, by the elementary filter 204, the PPG signal to remove noise frequencies that are not containing information about the key body vitals for generating a denoised signal.

- [00119] At block 1212, the method 1200 includes receiving, by a pre-processing module 208, the denoised signal from the elementary filter 206, wherein the
15 denoised signal is obtained as a matrix of signals ($n \times 7$), and wherein said matrix of signals includes 3000 data samples with a sampling frequency of 100 samples per second and a sampling period of 30 seconds.

[00120] At block 1214, the method 1200 includes pre-processing, by the pre-processing module 208, the denoised signal to generate a pre-processed signal.

- 20 [00121] At block 1216, the method 1200 includes transmitting the pre-processed signal by a communication module 210 coupled to the pre-processing module 208.

- [00122] At block 1218, the method 1200 includes receiving, by a client application 708 executed by a processor 702 on a computing device 106, the pre-processed signal for extracting features using a pre-trained artificial intelligence
25 (AI) based model to accurately measure at least six key body vitals including blood glucose, blood sugar (HBA1C), electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature.

[00123] At block 1220, the method 1200 outputs, by a user interface 706 of the client application 708, the measured key body vitals in response to a request received from the user.

[00124] As per another embodiment of the present invention, badging features of the user for example, demographic information can be analysed. Based on the nx7 matrix received from the device, a badging analysis is performed on the signal by studying multiple components of the signal to understand various badging features of the user including demographic information. This badged signal can help with an in-depth analysis of various vital computations. A pre-trained AI model is used for the segmentation analysis.

TECHNICAL ADVANCEMENT

[00125] Ultralow pass conditioned signal contains fair information that is not just baseline drift, it is observed that Ultralow pass conditioned signal shows a downward trend when the sample collection of the user happened while he/she was fasting or when their glucose trend was also going down like a postprandial state of 2 hours and observed that the Ultralow pass conditioned signal shows a fairly stable trend when even the glucose levels are stable

[00126] The Ultralow pass conditioned signal contains information about respiration which helps us to calculate the respiration rate

[00127] Multi-level DWT can yield de-noised signals which contain key features for the classification of vitals like Glucose, but heavy processing is required for consistent & accurate results

[00128] Classification of Diabetic and Non-Diabetic using real-time PPG signals is possible by Multi-level DWT and Pre-processing filters like Chebyshev type 2 order 4 filters

[00129] The 1st and 2nd order Derivative of raw signal with respect to time does contain features for the classification of BGL levels

Equivalents

[00130] The above description does not provide specific details of the manufacture or design of the various components. Those of skill in the art are familiar with such details, and unless departures from those techniques are set out, techniques, known, related art, or later developed designs and materials should be employed. Those in the art can choose suitable manufacturing and design details.

[00131] Note that throughout the following discussion, numerous references may be made regarding servers, services, engines, modules, interfaces, portals, platforms, or other systems formed from computing devices. It should be appreciated that the use of such terms is deemed to represent one or more computing devices having at least one processor configured to or programmed to execute software instructions stored on a computer-readable tangible, non-transitory medium or also referred to as a processor-readable medium. For example, a server can include one or more computers operating as a web server, database server, or other type of computer server in a manner to fulfill described roles, responsibilities, or functions. Within the context of this document, the disclosed devices or systems are also deemed to comprise computing devices having a processor and a non-transitory memory storing instructions executable by the processor that cause the device to control, manage, or otherwise manipulate the features of the devices or systems.

[00132] Some portions of the detailed description herein are presented in terms of algorithms and symbolic representations of operations on data bits performed by conventional computer components, including a central processing unit (CPU), memory storage devices for the CPU, and connected display devices. These algorithmic 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. An algorithm is generally perceived as a self-consistent sequence of steps leading to the desired result. The steps are those requiring physical manipulations of physical quantities. Usually, though not necessarily, these quantities take the form of electrical or magnetic signals capable of being stored, transferred, combined, compared, and otherwise manipulated. It has proven

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.

[00133] It should be understood, however, that all of these and similar terms are to be associated with the appropriate physical quantities and are merely convenient
5 labels applied to these quantities. Unless specifically stated otherwise, as apparent from the discussion herein, it is appreciated that throughout the description, discussions utilizing terms such as “processing,” “receiving,” “generating,” “transmitting,” or “outputting,” or the like, refer to the action and processes of a computer system, or similar electronic computing device, that manipulates and
10 transforms data represented as physical (electronic) quantities within the computer system's registers and memories into other data similarly represented as physical quantities within the computer system memories or registers or other such information storage, transmission or computing devices.

[00134] The exemplary embodiment also relates to an apparatus for performing
15 the operations discussed 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-
20 ROMs, magnetic-optical disks, read-only memories (ROMs), random access memories (RAMs), EPROMs, EEPROMs, magnetic or optical cards, or any type of media suitable for storing electronic instructions, and each coupled to a computer system bus.

[00135] The algorithms and displays presented herein are not inherently related
25 to any particular computer or other apparatus. Various general-purpose systems may be used with programs in accordance with the teachings herein, or it may prove convenient to construct a more specialized apparatus to perform the methods described herein. The structure for a variety of these systems is apparent from the description above. In addition, the exemplary embodiment 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 exemplary embodiment as described herein.

5 [00136] The methods illustrated throughout the specification may be implemented in a computer program product that may be executed on a computer. The computer program product may comprise a non-transitory computer-readable recording medium on which a control program is recorded, such as a disk, hard drive, or the like. Common forms of non-transitory computer-readable media include, for example, floppy disks, flexible disks, hard disks, magnetic tape, or any
10 other magnetic storage medium, CD-ROM, DVD, or any other optical medium, a RAM, a PROM, an EPROM, a FLASH-EPROM, or other memory chip or cartridge, or any other tangible medium from which a computer can read and use.

[00137] Alternatively, the method may be implemented in transitory media, such as a transmittable carrier wave in which the control program is embodied as a data
15 signal using transmission media, such as acoustic or light waves, such as those generated during radio wave and infrared data communications, and the like.

[00138] The terminology used herein is for the purpose of describing embodiments only and is not intended to be limiting of the disclosure. It will be appreciated that several of the above-disclosed and other features and functions, or
20 alternatives thereof, may be combined into other systems or applications. Various presently unforeseen alternatives, modifications, variations, or improvements therein may subsequently be made by those skilled in the art without departing from the scope of the present disclosure as encompassed by the following claims.

[00139] The claims, as originally presented and as they may be amended,
25 encompass variations, alternatives, modifications, improvements, equivalents, and substantial equivalents of the embodiments and teachings disclosed herein, including those that are presently unforeseen or unappreciated, and that, for example, may arise from applicants/patentees and others.

[00140] It will be appreciated that variants of the above-disclosed and other features and functions, or alternatives thereof, may be combined into many other different systems or applications. Various presently unforeseen alternatives, modifications, variations, or improvements therein may be subsequently made by those skilled in the art which are also intended to be encompassed by the following claims.

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WE CLAIM

1. A non-invasive sensing system (100) for measuring key body vitals, said system (100) comprising:

5 i. a sensing device (102) comprising a top glass configured to receive a touch of a fingertip of a user, wherein the sensing device (102) includes:

10 a light emitting unit mounted underneath the top glass, said light emitting unit comprising two sets of light emitting diodes (202-1, 202-2) to emit two different wavelengths into the fingertip of the user when the user places the fingertip on the top glass;

a photodetector (204), mounted underneath the top glass, to receive the light reflected from the fingertip and convert the light into a Photoplethysmography (PPG) signal;

15 an elementary filter (206) configured to cooperate with the photodetector to receive the PPG signal, filter the PPG signal to remove noise frequencies that are not containing information about the key body vitals, and generate a denoised signal;

20 a pre-processing module (208) to receive the denoised signal from the elementary filter (206), wherein the denoised signal is obtained as a matrix of signals ($n \times 7$), wherein said matrix of signals includes 3000 data samples with a sampling frequency of 100 samples per second and a sampling period of 30 seconds, and wherein said pre-processing module is configured to pre-process the denoised signal to generate a pre-processed signal; and

25 a communication module (210) coupled to the pre-processing module (208) to transmit the pre-processed signal;

ii. a client application (708), executed by a processor (702) on a computing device (106), to receive the pre-processed signal for

5 extracting features using a pre-trained artificial intelligence (AI) based model to accurately measure at least six key body vitals including blood glucose, blood sugar (HBA1C), electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature; and

iii. a user interface (706), of the client application (708), to receive a request for the measured key body vitals and to output the measured key body vitals.

10 2. The non-invasive sensing system (100) as claimed in claim 1, wherein the pre-processing module (208) receives the matrix of signal ($n \times 7$) to perform:

15 concatenation of two parts consisting in the matrix of signals ($n \times 7$) including 3000 data samples to generate a concatenated signal, where a first part of the matrix of signals ($n \times 7$) lies in 3rd column of said matrix and a second part of the matrix of signals ($n \times 7$) lies 1st column of said matrix;

20 trimming of the concatenated signal to discard a part from the beginning of capturing the PPG signal and a part from the ending of capturing the PPG signal so as to generate a trimmed signal, wherein the part from the beginning includes about 300 data samples and the part from the ending includes about 100 data samples from the array of 3000 data samples;

Performing Ultra Low pass conditioning on the trimmed signal for extracting the key component of the trimmed signal to generate a smooth signal; and

25 generating the pre-processed signal as a pre-processed difference signal computed based on a difference between the Ultralow pass conditioned signal and the trimmed signal.

3. The non-invasive sensing system (100) as claimed in claim 2, wherein for blood glucose measurement, the client application (708) further comprises a blood glucose module (712) to receive the Ultralow pass conditioned signal from the pre-processing module of the sensing device (102), wherein
5 the blood glucose module (712) comprises:

a glucose conditioning module to receive the Ultralow pass conditioned signal from the pre-processing module of the sensing device and compute a normal value of the key two dimensional components analyzed by AI and

- 10 a conditioning interference module (802) to receive the computed Normal Value as a parameter, wherein the conditioning module is configured to compute a user's blood glucose value based on a range in which the computed Normal value falls, wherein for computing the user's blood glucose value, the conditioning
15 interference module (802) uses a polynomial equation where an input is the computed normal value and coefficients for each range are determined by pre-training a regression classifier (804) of the AI-based model.

4. The non-invasive sensing system (100) as claimed in claim 2, wherein for
20 blood sugar measurement, the client application (708) further comprises a blood sugar module (HbA1c) (714) to receive the pre-processed difference signal from the pre-processing module (208) of the sensing device (102), wherein the blood sugar module (HbA1c) (714) is configured to perform:

25 batching the pre-processed difference signal into an M number of batches of an N number of samples, where $N = 50$;

for each batch, simultaneously computing a peak-to-peak value and an average peak-to-valley for each peak in the batch,

computing median reference values of the peak-to-peak and the peak-to-valley values of entire batches of the key components of

overall length of the difference signal analyzed by the AI categorization, implementing the pre-trained AI-based model to receive the median reference values as the extracted features for predicting the blood sugar (HbA1C).

- 5 **5.** The non-invasive sensing system (100) as claimed in claim 1, wherein for ECG measurement, the client application (708) further comprises an ECG module (716) to perform:

receiving the denoised signal as the matrix of signal ($n \times 7$);

perform motion artefact removal from the denoised signal;

- 10 processing the motion artefact removed signal to identify the heart rate with multiple frequency filters, wherein the heart rate is present only in the frequency range of 0.663 to 3.66 Hz; and

- 15 passing the filtered signal through a series of thresholding functions, wherein each peak that is observed after the set threshold functions is considered as a heart beat, and a number of peaks detected in the signal in a defined time frame with respect to their timestamp are utilized to generate an ECG report to understand sinus rhythm of the heart and other components of the heart

- 20 **6.** The non-invasive sensing system (100) as claimed in claim 1, wherein for heart rate measurement, the client application further comprises a heart rate module to perform:

receiving the denoised signal as the matrix of signal ($n \times 7$);

perform motion artefact removal from the denoised signal;

- 25 processing the motion artefact removed signal to identify the heart rate with multiple frequency filters, wherein the heart rate is present only in the frequency range of 0.663 to 3.66 Hz;

passing the filtered signal through a series of thresholding functions, wherein each peak that is observed after the set threshold functions is considered as a heart beat, and a number of peaks detected in the signal in a defined time with respect to their timestamp are utilized to measure the heart rate of the user.

7. The non-invasive sensing system as claimed in claim 1, wherein said two sets of light emitting diodes includes:

- Light Emitting Diodes (LED) with a wavelength of 660 nm; and
- Near Infra-Red LED (NIR) with a wavelength of 880 nm.

8. The non-invasive sensing system as claimed in claim 1, wherein the photodetector is configured with spectral range sensitivity of 600 to 5000 nm.

9. The non-invasive sensing system as claimed in claim 7, wherein for blood oxygen level (SpO2) measurement, the client application further comprises a blood oxygen level (SpO2) module to perform:

receiving the PPG signal at the photodetector;

measuring saturation of blood by oxygen from PPG signal received at two wavelengths including red signals received from LED and IR signals received from NIR;

calculating the blood oxygen (SpO2) level is calculated from a calibration R curve plotting SpO2 versus ratio red and IR signals, wherein the R is calculated as:

$$R = (R_{ac}/R_{dc}) / (I_{Rac}/I_{Rdc})$$

where R_{ac} is the pulsating AC component of the fingertip by red signal and R_{dc} is the non-pulsating DC component of the fingertip by a red signal of wavelength 660 nm, and I_{Rac} and I_{Rdc} are also pulsating AA and DC components of the fingertip by the IR signal of wavelength 880nm.

10. The non-invasive sensing system as claimed in claim 7, wherein for blood pressure measurement, the client application further comprises a blood pressure module to perform:

5 separating the denoised signal obtained as a matrix of signals ($n \times 7$) into two component signals: red component and irr component, wherein the red component is formed by concatenating zero-indexed columns 3 and 1, which denotes the signal that is obtained from the reflected light of red signal of wavelength 660 nm, and wherein the irr component is formed by concatenating the zero-indexed columns
10 4 and 2, which denotes the signal that is obtained from the reflected IR light of wavelength 880 nm;

Ultra lowpass conditioning and trimming both the components;
subtracting both the Ultra lowpass conditioned signal and trimmed components (r_curr , i_curr) by the normal of the respective
15 component signals,

for the red component (r_curr), normalising it and computing its inverse representation (r_curr_inv) by multiplying 1.01 by a maximum value in this normalised signal and then subtracting each element of the normalised signal from this value;

20 for the irr component (i_curr), multiply 1.01 by a maximum value in the irr component and then subtract each element of the signal from this value to obtain i_curr_inv .

finding indices of peaks in the signals i_curr_inv and i_curr as $maxIndices$ and $minIndices$;

25 implementing the $maxIndices$ to index into r_curr_inv to get an array of values ($r_curr_inv_maxima$);

implementing $minIndices$ to index into r_curr_inv to get another array of values ($r_curr_inv_minima$);

converting both of these arrays to the same length by only considering values up until the length of the smaller of the two arrays; and

once both of these arrays are obtained as two arrays of equal length, computing their respective normals, add both their normals up and divide this sum by 2 to obtain the input to the equations for computing the systolic and diastolic blood pressure values, wherein the equations for both systolic and diastolic blood pressure are Polynomial equations, whose coefficients are determined by a pre-training a regression classifier of the AI-based model.

11. The non-invasive sensing system as claimed in claim 1, wherein the elementary filter is a Finite Impulse Response (FIR) band-pass filter with band frequencies from 0.5Hz to 5.0Hz and gain of 1100, and wherein the FIR band-pass filter is configured to remove the noise frequencies lying beyond a frequency range of 0.5Hz to 5Hz

12. The non-invasive sensing system as claimed in claim 1, wherein the top glass allows wavelength frequencies of 660 nm to 880 nm with about 85% - 95% transmission percentage.

13. The non-invasive sensing system as claimed in claim 1, wherein the sensing device comprises a black optical sensor shield that covers the boundaries of the light emitting unit and the photodetector for absorbing unwanted light that might bounce back to the photodetector.

14. The non-invasive sensing system (100) as claimed in claim 1, wherein the sensing system further measures the differential analysis of blood by utilizing more than one finger of the user, at a time, at the time of data collection.

15. The non-invasive sensing system (100) as claimed in claim 1, wherein the sensing system implements finger pressure analysis wherein, the

computation models compute the vitals first and later adjust the key vital measurements based on the pressure exerted by the user

16. A method for operating a non-invasive sensing system for measuring key body vitals, said method comprising:

5 receiving, by the top glass of a sensing device, a touch of a fingertip of a user;

 emitting, by a light emitting unit mounted underneath the top glass with two sets of light emitting diodes, two different wavelengths into the fingertip of the user when the user places the fingertip on the top glass;

10 receiving, by a photodetector mounted underneath the top glass, the light reflected from the fingertip so as to convert the reflected light into a Photoplethysmography (PPG) signal;

 receiving the PPG signal by an elementary filter configured to cooperate with the photodetector;

15 filtering, by the elementary filter, the PPG signal to remove noise frequencies that are not containing information about the key body vitals for generating a denoised signal;

 receiving, by a pre-processing module, the denoised signal from the elementary filter, wherein the denoised signal is obtained as a matrix of signals ($n \times 7$), wherein said matrix of signals includes 3000 data samples with a sampling frequency of 100 samples per second and a sampling period of 30 seconds;

20 pre-processing, by the pre-processing module, the denoised signal to generate a pre-processed signal;

25 transmitting the pre-processed signal by a communication module coupled to the pre-processing module;

receiving, by a client application executed by a processor on a computing device, the pre-processed signal for extracting features using a pre-trained artificial intelligence (AI) based model to accurately measure at least six key body vitals including blood glucose, blood sugar (HBA1C),
5 electrocardiogram (ECG), heart rate, blood oxygen level (SPo2), blood pressure, and body temperature; and

outputting, by a user interface of the client application, the measured key body vitals in response to a request received from the user.

10 Dated this 24th day of November 2022



Santharam Konduru
Applicant's Patent Agent
15 (IN/PA 1588)

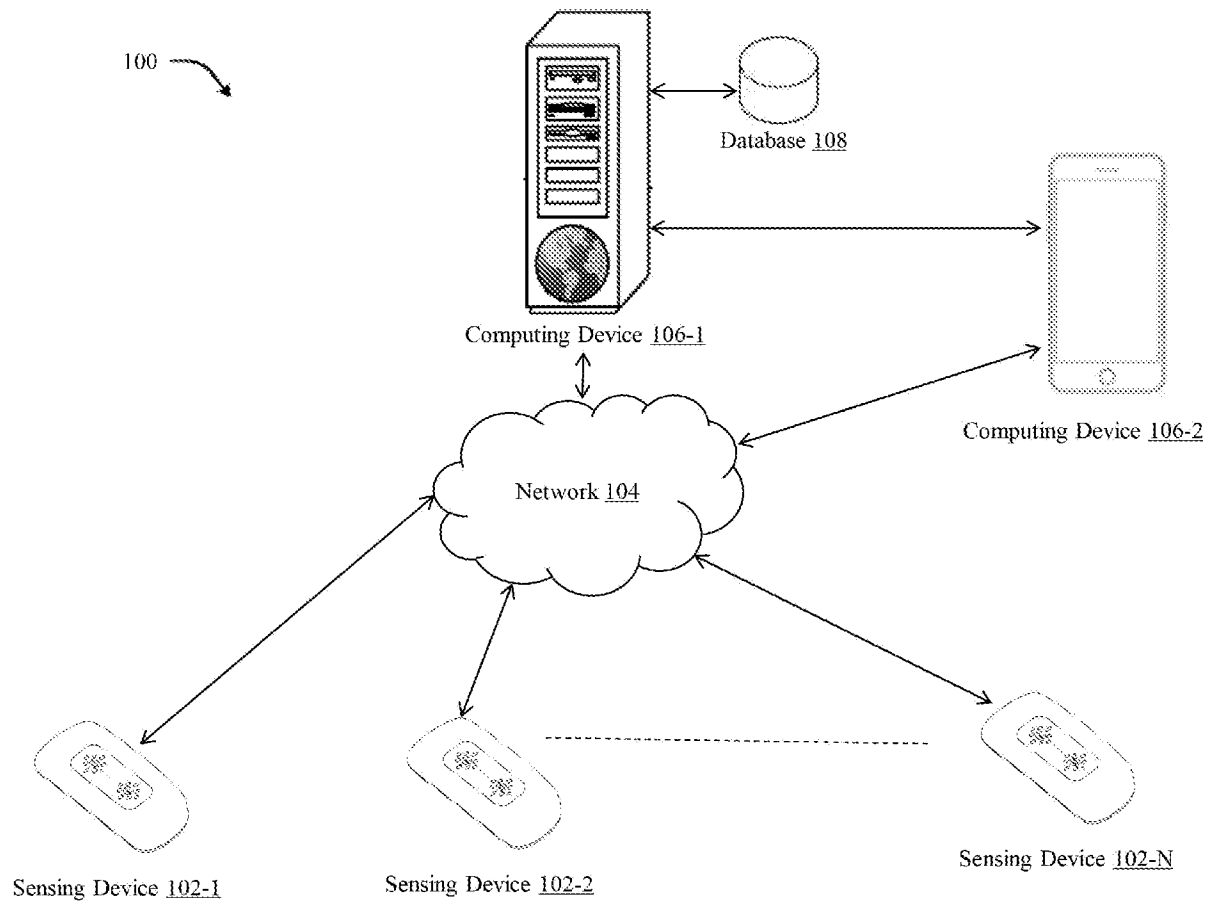


FIG. 1

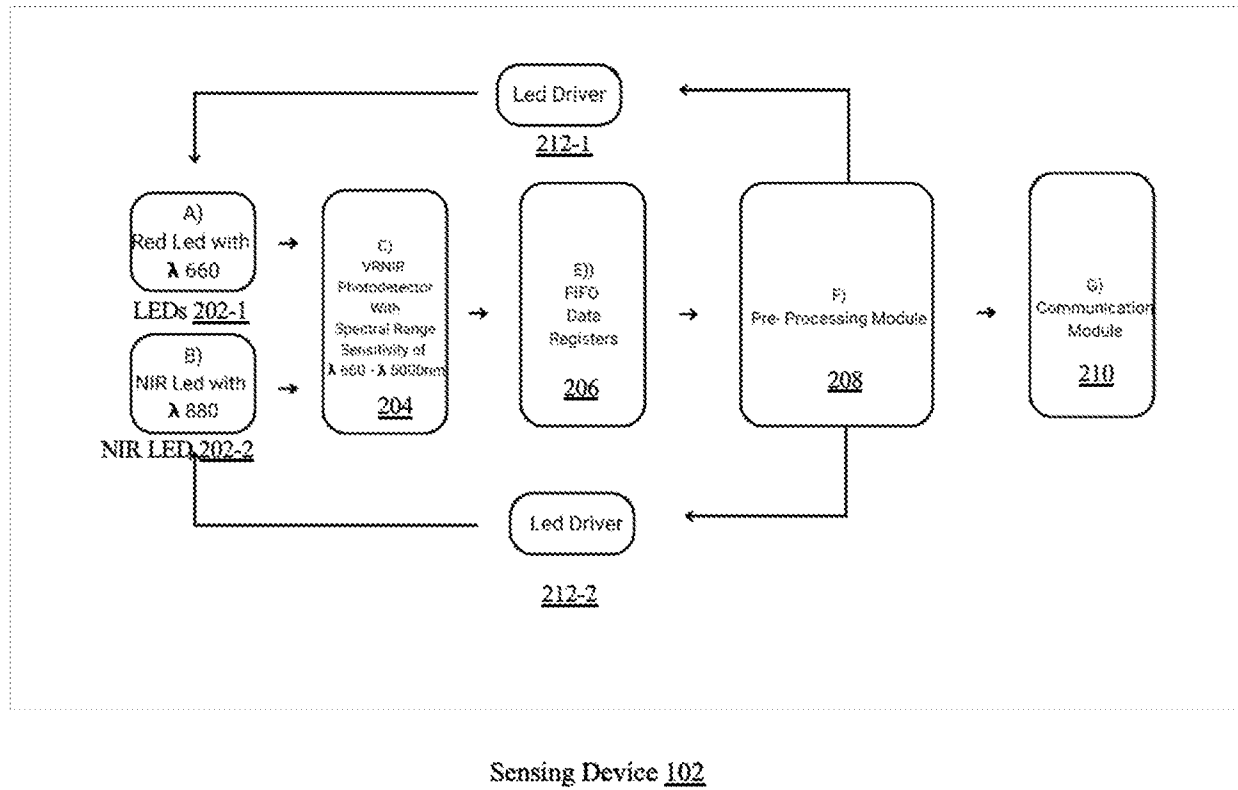
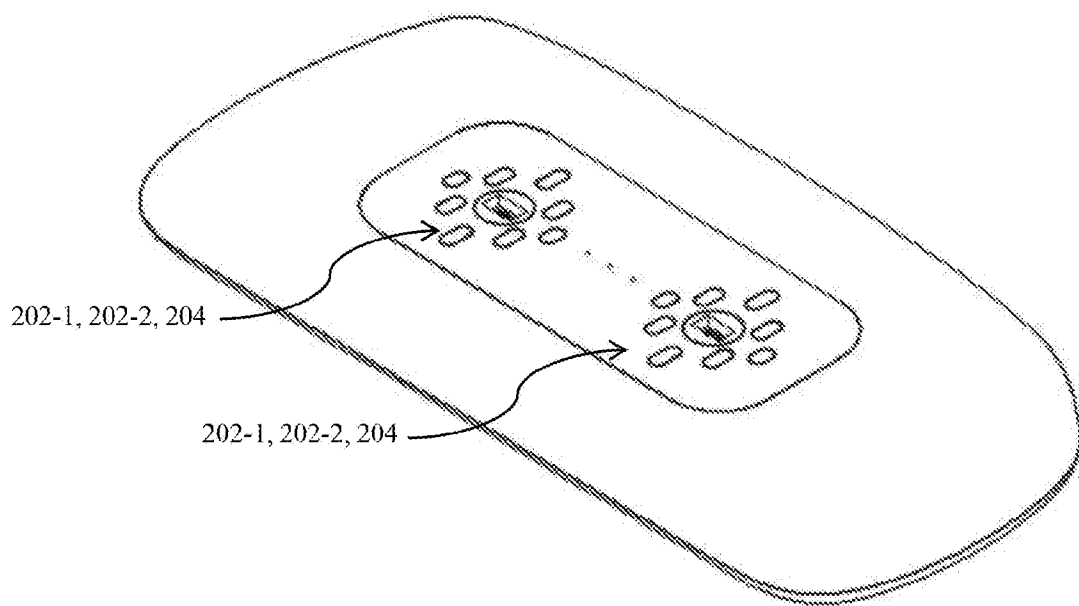


FIG. 2



Sensing Device 102

FIG. 3

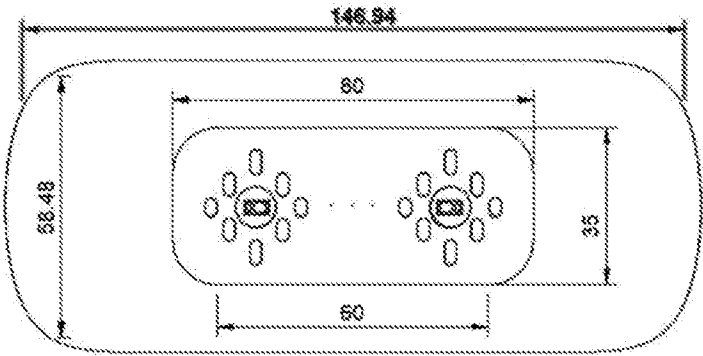


FIG. 4A

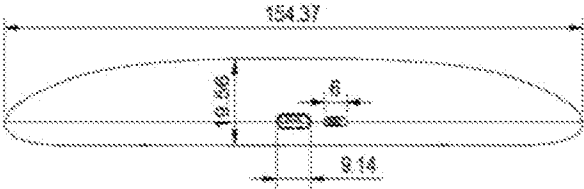


FIG. 4B

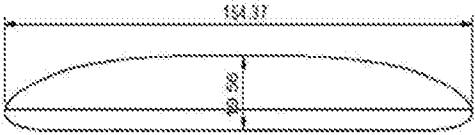


FIG. 4C

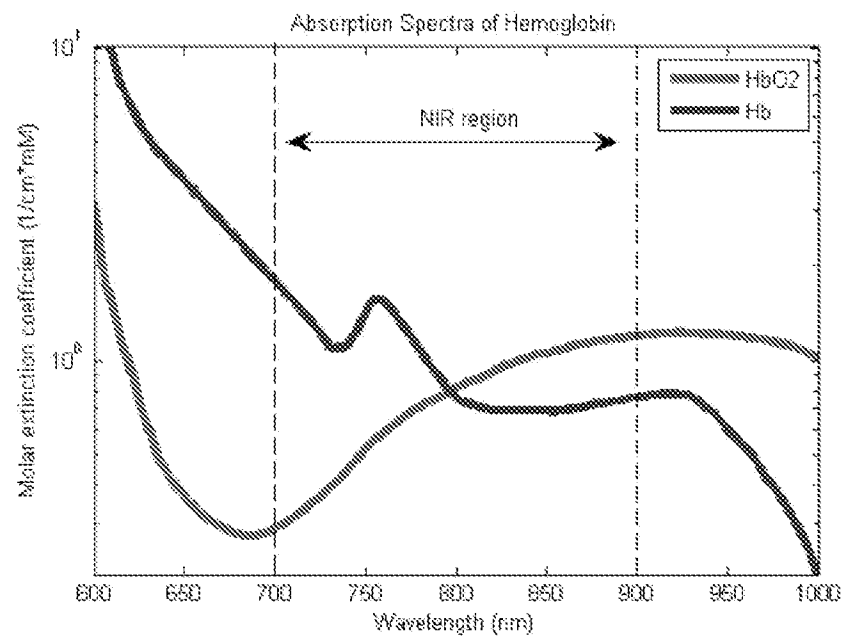


FIG. 5

Signal Preprocessing Module 208

Raw signal: col[0],col[1],col[2],col[3],col[4],col[5],col[6]

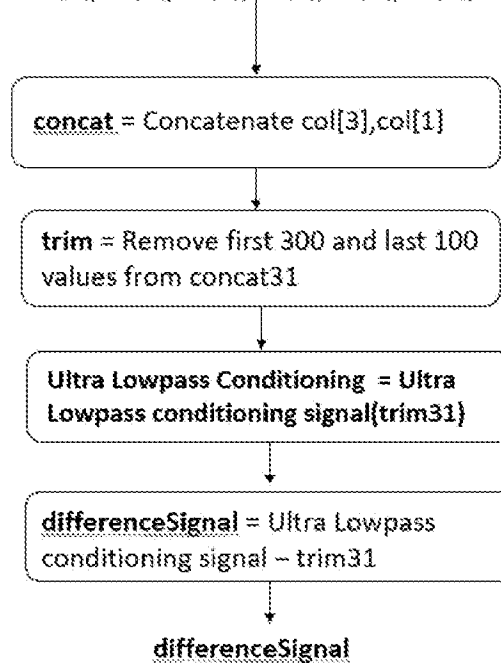


FIG. 6

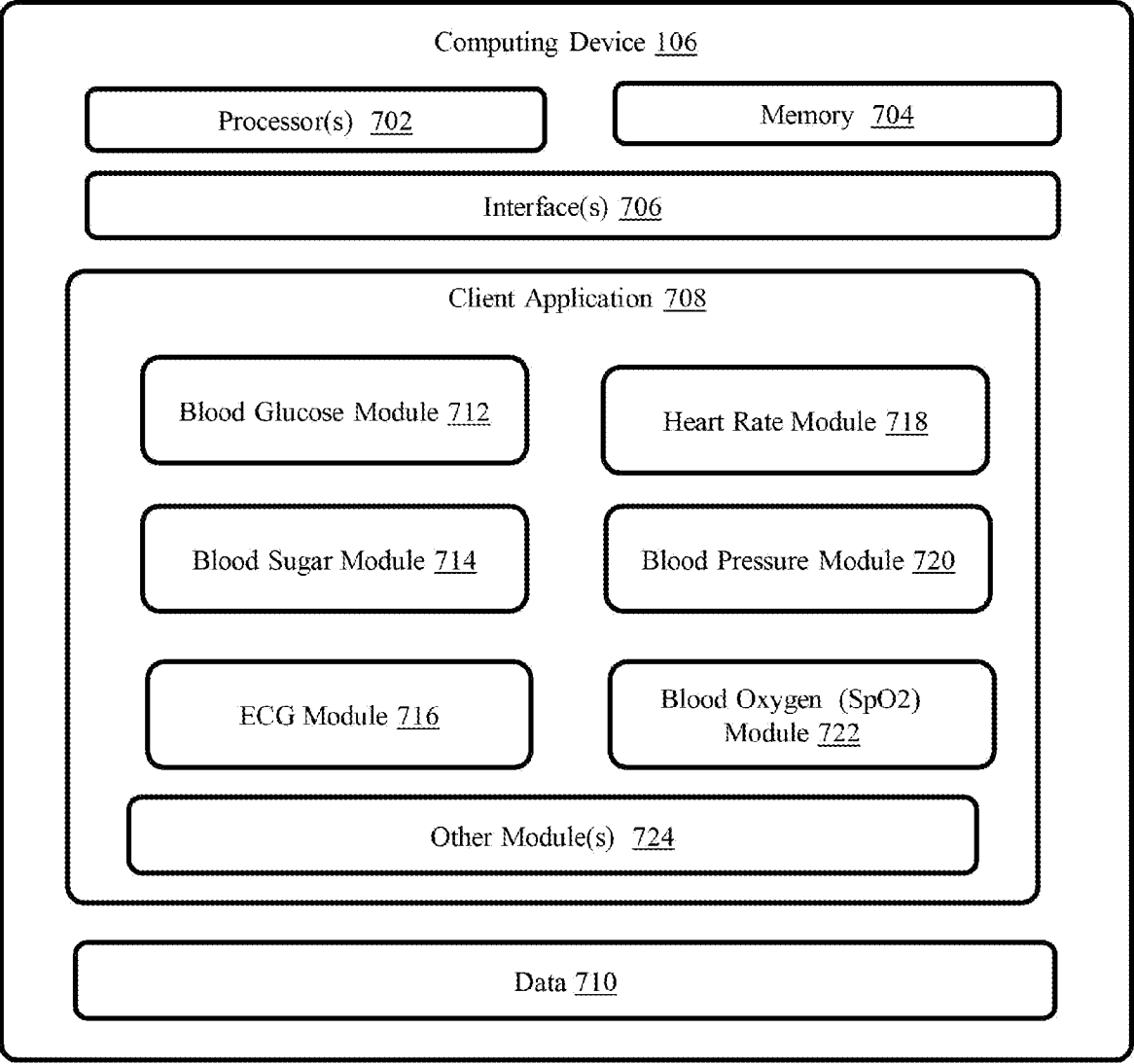


FIG. 7

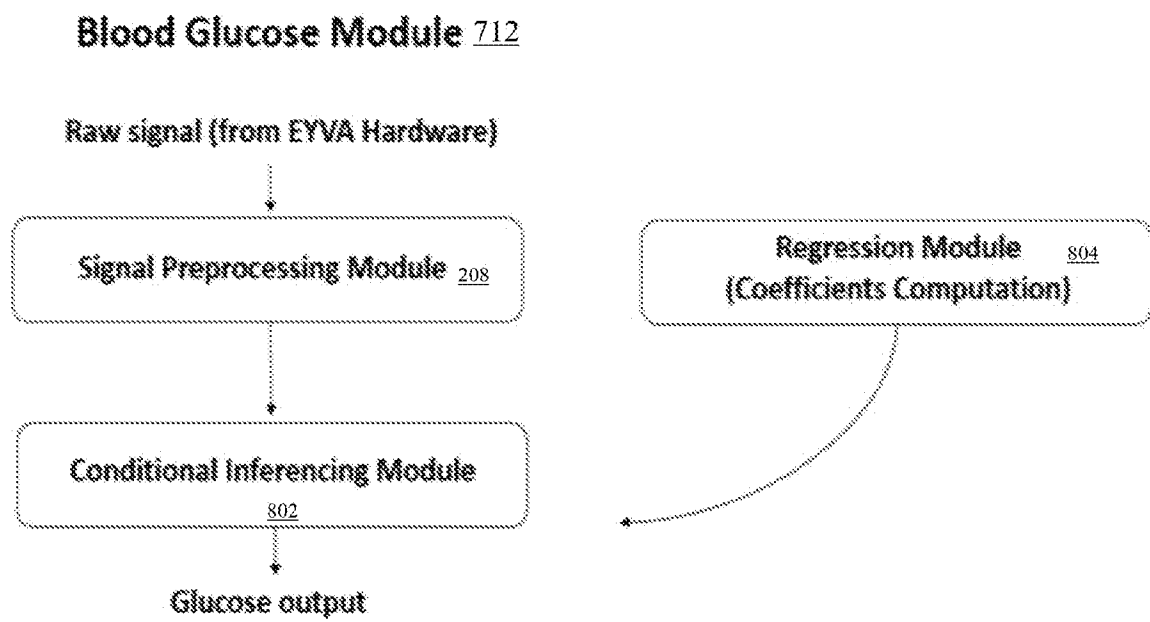


FIG. 8

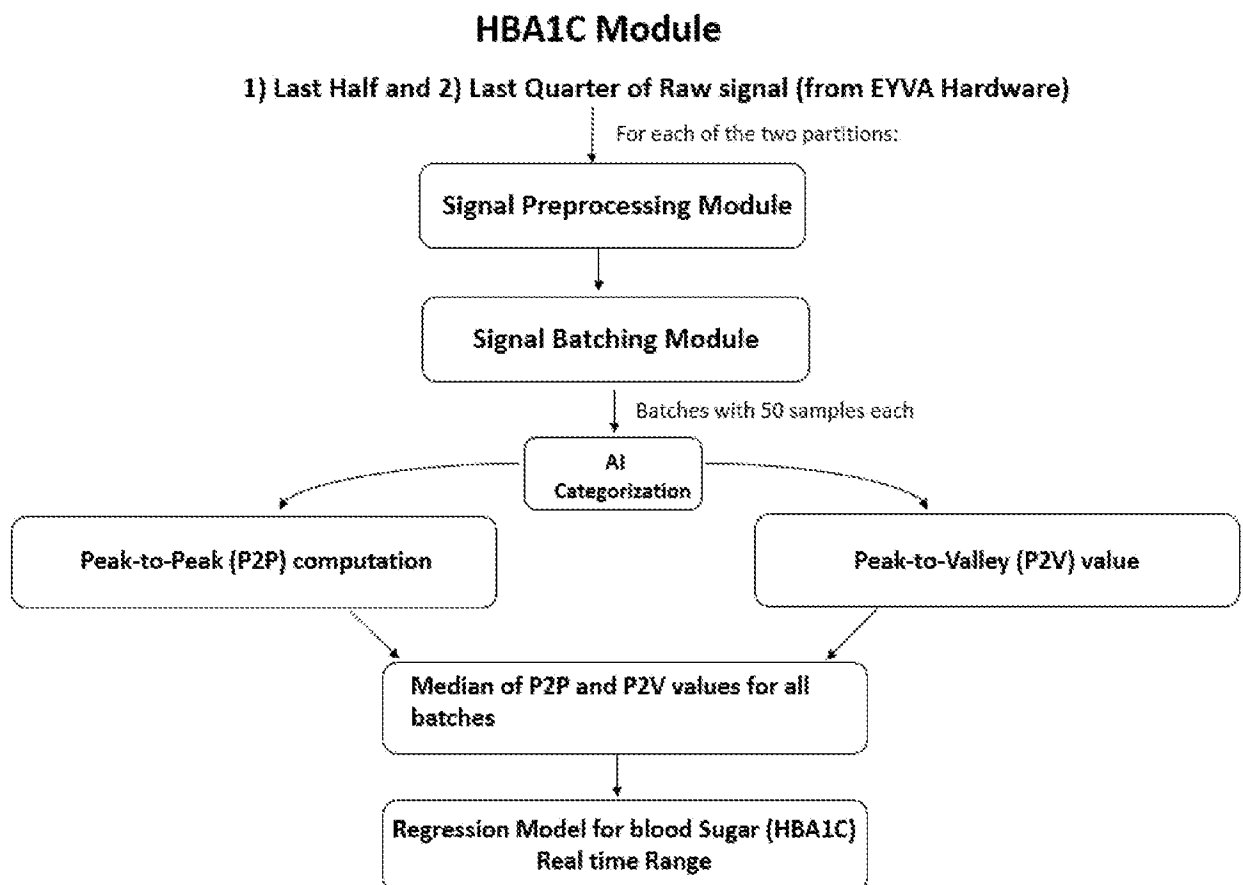


FIG. 9

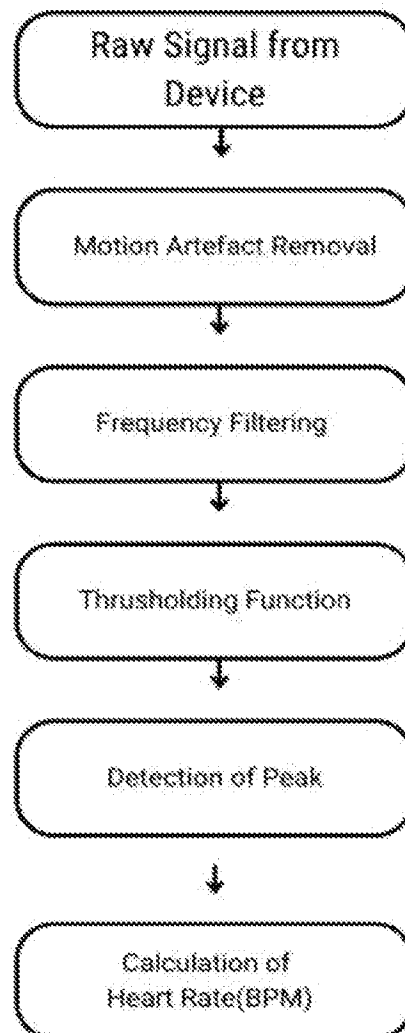


FIG. 10

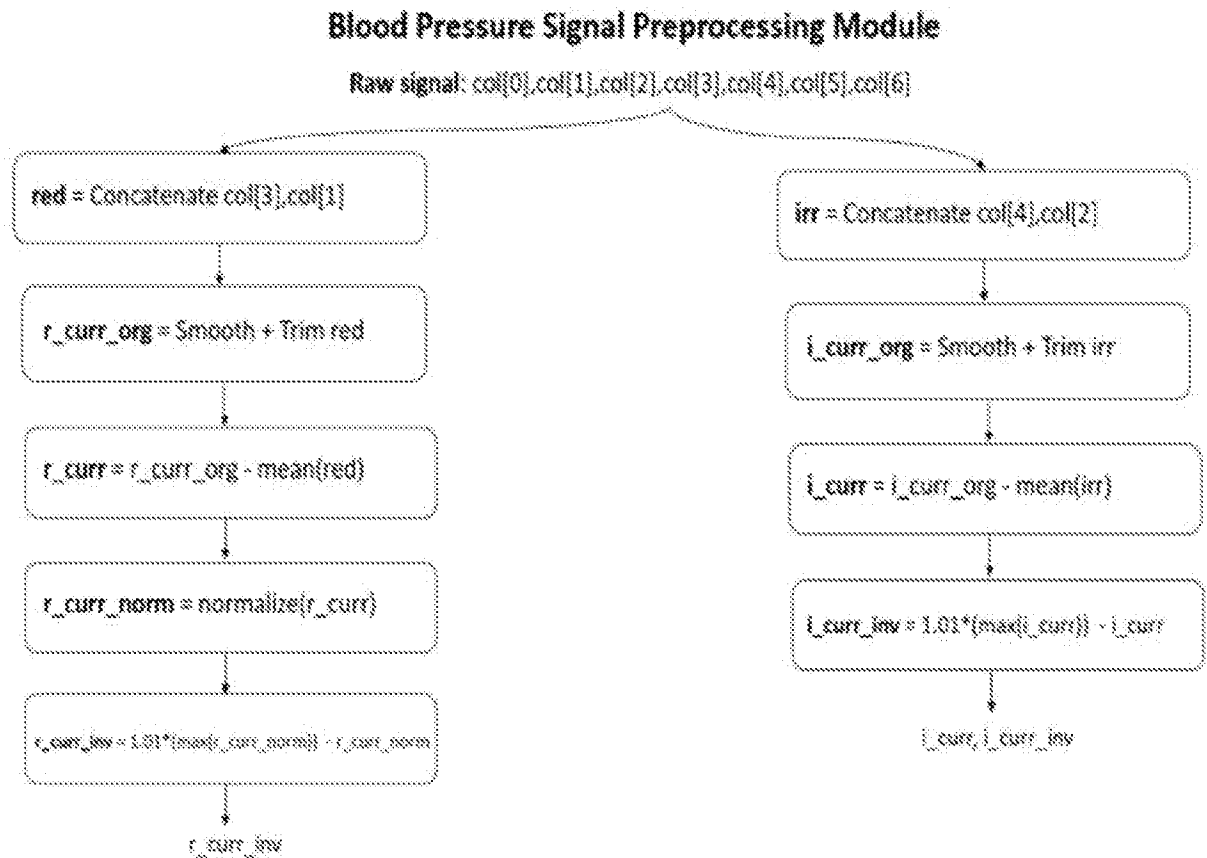


FIG. 11

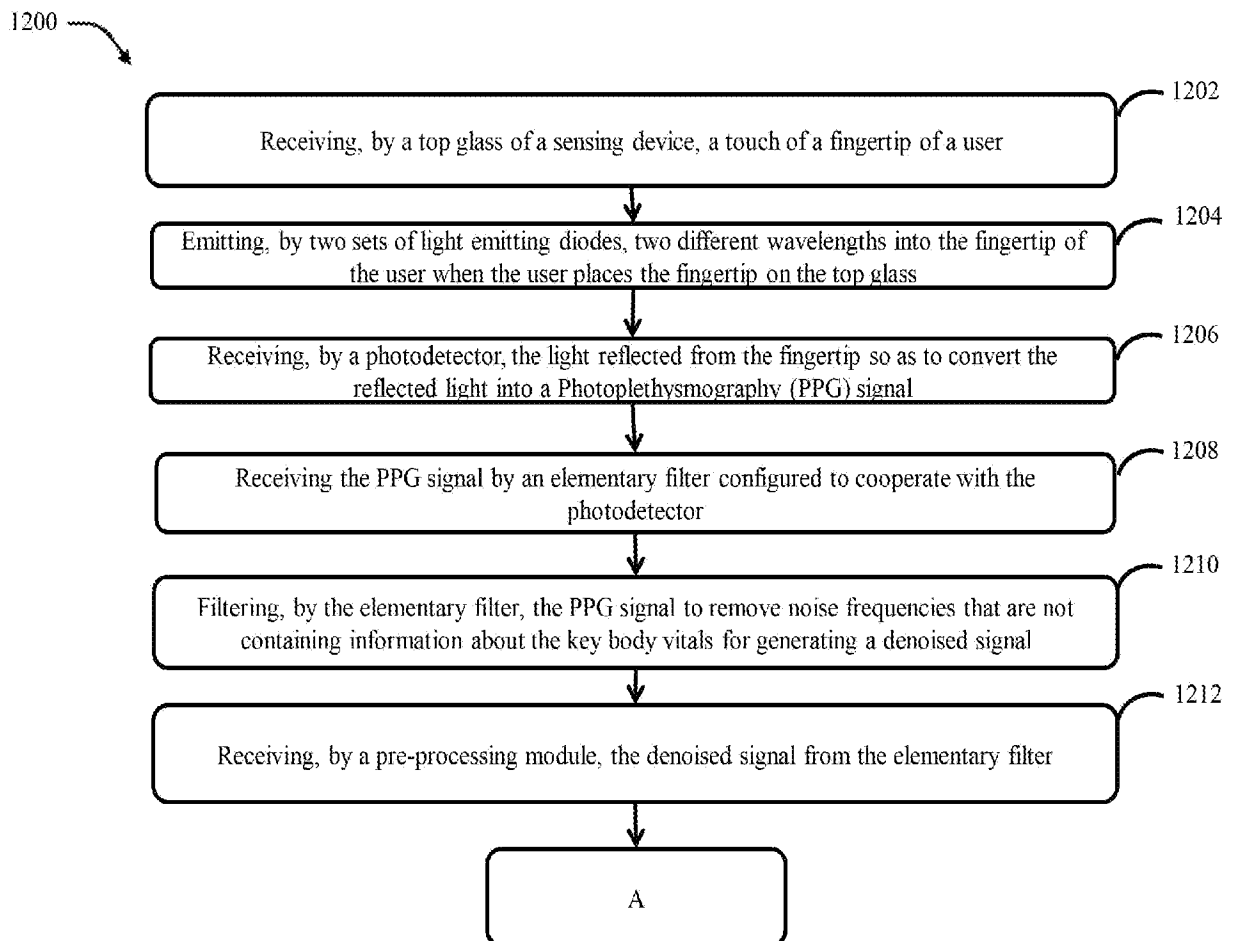


FIG. 12A

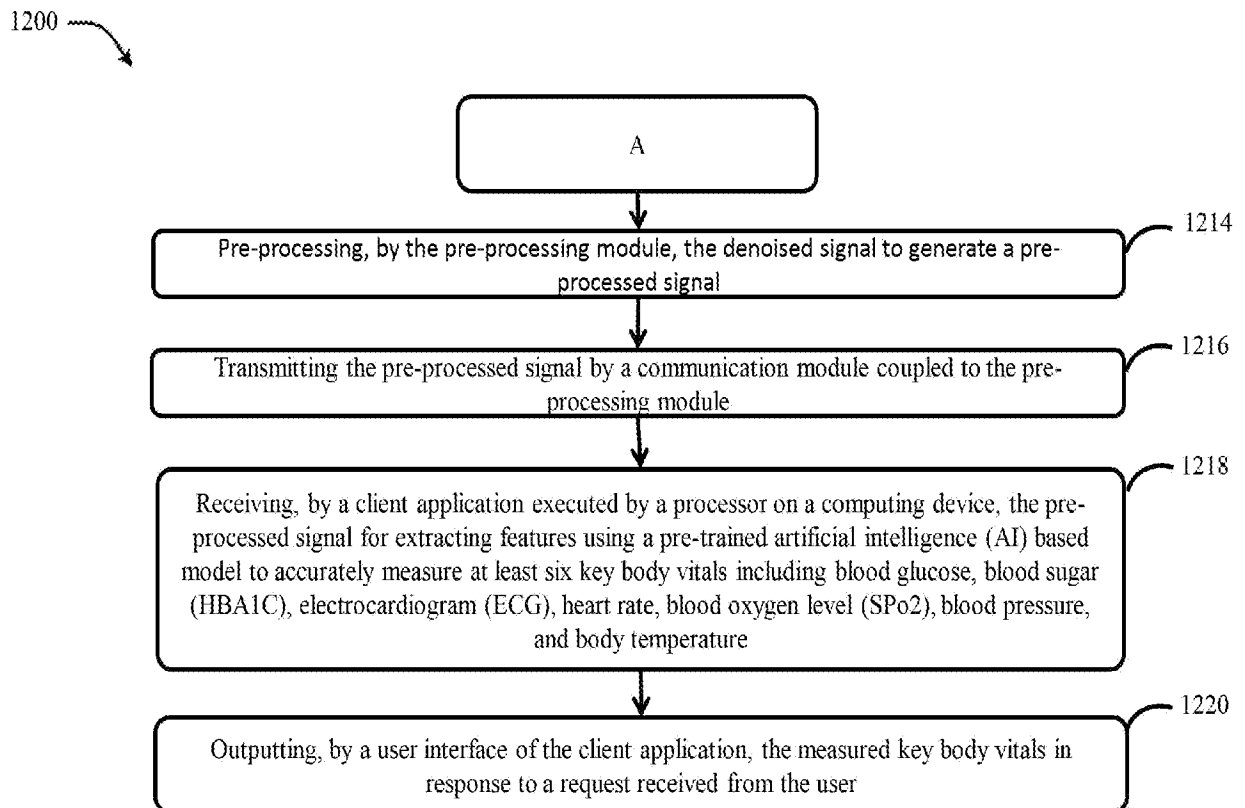


FIG. 12B

INTERNATIONAL SEARCH REPORT

International application No.
PCT/IN2022/051031

A. CLASSIFICATION OF SUBJECT MATTER

A61B5/01, A61B5/02, G06F17/16, G06N20/00 Version=2023.01

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, G06F, G06N

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

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

Databases: PatSeer, IPO Internal Database

Keywords: wearable, noninvasive, parameters, infrared

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US2020000441A1 (FITBIT INC) 02 January 2020 (02-01-2020) Whole document	1-16
Y	US9459202B2 (ZYOMED HOLDING INC) 04 October 2016 (04-10-2016) Whole document	1-16
Y	CN106104408A (PROXEI CO LTD, MECHIO INC) 09 November 2016 (09-11-2016) Whole document	1-16



Further documents are listed in the continuation of Box C.



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

"D" document cited by the applicant in the international application

"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

02-02-2023

Date of mailing of the international search report

02-02-2023

Name and mailing address of the ISA/

Indian Patent Office
Plot No.32, Sector 14, Dwarka, New Delhi-110075
Facsimile No.

Authorized officer

Devendra Kumar Deshmukh

Telephone No. +91-1125300200

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/IN2022/051031

Citation	Pub.Date	Family	Pub.Date
US 2020000441 A1	02-01-2020	EP 3813645 A1	05-05-2021
		WO 2020006072 A1	02-01-2020
US 9459202 B2	04-10-2016	WO 2016054079 A1	07-04-2016
CN 106104408 A	09-11-2016	EP 4071581 A1	12-10-2022
		US 2022057832 A1	24-02-2022