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(54) **Title**: MULTIPLE SENSORS FOR BIOMETRIC ANALYSIS

(57) **Abstract**: Systems and methods are described that relate to a plurality of sensors configured to measure a physiological parameter. Each sensor of the plurality of sensors may be removably attached to an exterior surface of a living body. A controller may be configured to receive sensor data from the plurality of sensors. The sensor data may be indicative of the physiological parameter. The controller may correlate the sensor data to provide correlated data that is indicative of the physiological parameter. Based at least on the correlated data, the controller may determine a health state. The controller may further provide an indication based on the determined health state.

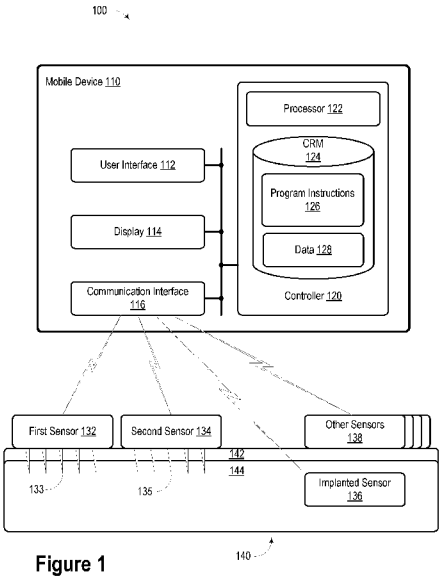

Figure 1

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Multiple Sensors for Biometric Analysis

CROSS-REFERENCE TO RELATED APPLICATIONS

[0001] The present application claims priority to United States Provisional Patent Application No. 62/187,712, filed July 1, 2015, the contents of which are hereby incorporated by reference.

BACKGROUND

[0002] Unless otherwise indicated herein, the materials described in this section are not prior art to the claims in this application and are not admitted to be prior art by inclusion in this section.

[0003] Biometric sensors may measure one or more physiological indicators of an individual. For example, a transdermal sensor may be configured to provide continuous or periodic information indicative of a concentration of an analyte, such as glucose.

[0004] However, application of some biometric sensors may be painful and/or time-consuming. Furthermore, if the sensor is not applied to a proper location on the body, an individual may replace the sensor with another sensor until the proper location is found. Also, biometric sensors may have an internal offset or error unique to each sensor. Additionally, such sensors may not always report accurate and/or comparable measurements.

SUMMARY

[0005] In a first aspect, a system is provided. The system includes a plurality of sensors for measuring a physiological parameter. Each sensor of the plurality of sensors is configured for removable attachment to a respective location on an exterior surface of a living body. The system also includes a controller that includes a memory and a processor. The memory stores instructions that are executable by the processor to cause the controller to perform operations. The operations include receiving, from a first sensor of the plurality of sensors, first sensor data indicative of the physiological parameter. The operations also include receiving, from a second sensor of the plurality of sensors, second sensor data indicative of the physiological parameter. The operations include correlating the first sensor data and the second sensor data to provide correlated data. The correlated data is indicative of the physiological parameter. The operations additionally include determining a health state based on the correlated data and providing an indication based on the determined health state.

[0006] In a second aspect, a system is provided. The system includes a plurality of sensors. A first sensor of the plurality of sensors is configured for implantation into a living

body. The first sensor is configured to detect a first physiological parameter. A second sensor of the plurality of sensors is configured for removable attachment to a respective location on an exterior surface of the living body. The second sensor is configured to detect a second physiological parameter. The system additionally includes a controller that includes a memory and a processor. The memory stores instructions that are executable by the processor to cause the controller to perform operations. The operations include receiving, from the first sensor, first sensor data indicative of the first physiological parameter. The operations also include receiving, from the second sensor, second sensor data indicative of the second physiological parameter. The operations further include adjusting the second sensor data based on the first sensor data to provide adjusted data. The adjusted data is indicative of the second physiological parameter. The operations yet further include determining a health state based on the adjusted data and providing an indication based on the health state.

[0007] In a third aspect, a method is provided. The method includes receiving, from a first sensor of a plurality of sensors, first sensor data indicative of a physiological parameter. The method further includes receiving, from a second sensor of the plurality of sensors, second sensor data indicative of the physiological parameter. Each sensor of the plurality of sensors is removably attached to a respective location on an exterior surface of a living body. The method additionally includes correlating the first sensor data and the second sensor data to provide correlated data. The correlated data is indicative of the physiological parameter. The method yet further includes determining a health state based on the correlated data and providing an indication based on the determined health state.

[0008] Other aspects, embodiments, and implementations will become apparent to those of ordinary skill in the art by reading the following detailed description, with reference where appropriate to the accompanying drawings.

BRIEF DESCRIPTION OF THE FIGURES

[0009] Figure 1 is a block diagram of a system according to an example embodiment.

[0010] Figure 2A illustrates sensors and respective mounting locations on a living body according to an example embodiment.

[0011] Figure 2B illustrates graphs of sensor data according to example embodiments.

[0012] Figure 3A illustrates a mobile device according to an example embodiment.

[0013] Figure 3B illustrates a mobile device according to an example embodiment.

[0014] Figure 4A illustrates a body-mountable device according to an example embodiment.

[0015] Figure 4B illustrates a cross-sectional view of a body-mountable device according to an example embodiment.

[0016] Figure 5 illustrates a system according to an example embodiment.

[0017] Figure 6 illustrates a method according to an example embodiment.

[0018] Figure 7 illustrates a method according to an example embodiment.

DETAILED DESCRIPTION

[0019] In the following detailed description, reference is made to the accompanying figures, which form a part hereof. In the figures, similar symbols typically identify similar components, unless context dictates otherwise. The illustrative embodiments described in the detailed description, figures, and claims are not meant to be limiting. Other embodiments may be utilized, and other changes may be made, without departing from the scope of the subject matter presented herein. It will be readily understood that the aspects of the present disclosure, as generally described herein, and illustrated in the figures, can be arranged, substituted, combined, separated, and designed in a wide variety of different configurations, all of which are contemplated herein.

[0020] Further, while embodiments disclosed herein make reference to use on or in conjunction with a living human body, it is contemplated that the disclosed methods, systems and devices may be used in any environment where measuring a physiological parameter with a plurality of sensors is desirable. The environment may be any living or non-living body or a portion thereof, etc. For example, one of skill in the art will recognize that the embodiments disclosed herein may be used to sense many different physiological parameters. Moreover, while the present disclosure describes embodiments for use *in vivo*, one of skill in the art will also recognize that *in vitro* applications are possible as well.

[0021] The terms "body-mountable device" or "wearable device," as used in this disclosure, refer to any device that is capable of being worn at, on or in proximity to a body surface, such as a wrist, ankle, waist, chest, or other body part.

Overview

[0022] In an example embodiment, a system may include multiple sensors positioned at one or more locations on a living body. For instance, two transdermal glucose sensors may be placed on two different locations on the living body. The multiple sensors may be placed in various locations on the body, e.g. forearm, bicep, tricep, shoulder, chest,

abdomen, buttocks, leg, back, etc. In some example embodiments, at least two of the multiple sensors may be located within the same transdermal patch.

[0023] Alternatively or additional, at least one sensor of the multiple sensors may include a sensor implanted in the living body. For example, an individual may have a temporary or permanent sensor implant configured to provide temperature data.

[0024] The system may include a controller configured to receive sensor data from each of the multiple sensors. The controller may include a memory and a processor. In an example embodiment, the controller may include a mobile device, such as a smartphone, smartwatch, wearable computing device, or another type of computer. The controller and the multiple sensors may communicate via a near-field communication (NFC), WiFi, or a Bluetooth Low Energy (BLE) wireless link. In an example embodiment, the controller may receive information indicative of a concentration of glucose from each of the transdermal glucose sensors.

[0025] Each of the multiple sensors may provide sensor data to the controller on a continuous and/or as-requested basis. For example, in the scenario in which the multiple sensors are configured to communicate with the controller using an NFC link, when the controller is in physical proximity to a biometric sensor, that sensor may upload stored sensor data to the controller. In an example embodiment, a mobile device may come into physical proximity with a glucose sensor incorporated into a transdermal patch. In response to the mobile device being in proximity to the sensor, the sensor may upload sensor data to the controller. The sensor data uploaded may include, for example, data stored since the last data upload to the controller or another set of sensor data.

[0026] In an alternative embodiment, where the sensors are operable to communicate with the controller via BLE or WiFi, the multiple sensors may provide sensor data to the controller on a periodic and/or continual basis. Alternatively, the multiple sensors may provide sensor data upon receipt of a request from the controller.

[0027] The controller may correlate the sensor data from the multiple sensors to provide correlated data. As an example, the controller may provide correlated data based on an average of the sensor data, e.g. to determine a mean concentration of glucose. Additionally or alternatively, the controller may provide correlated data based on a time-weighted average of the data based on the respective sensor age, e.g. sensor data from older sensors is discounted to a greater degree than sensor data from newer sensors. Yet further, the controller may be configured to determine an aging or unreliable sensor and discount or disregard the sensor data from that sensor when determining correlated data. For example,

a biometric sensor may become bio-fouled over time and/or run out of power, e.g. due to battery life. In an example embodiment, the controller may determine correlated data based on time-weighted information indicative of an individual's glucose concentration.

[0028] While some examples herein relate to sensor data relating to a glucose concentration, it will be understood that other types of data and/or other physiological parameters are possible. For example, the sensor data may provide information indicative of a concentration of glycated hemoglobin (HbA_{1c}).

[0029] In an example embodiment, the controller may determine correlated data based on sensor data that is within a predetermined number of standard deviations from an average. In other words, outlying data points may be dismissed or discounted. Alternatively or additionally, the controller may determine correlated data based on historical data and/or historical deviations from an average. Yet further, the controller may determine correlated data based on environmental factors, such as temperature, humidity, etc.

[0030] In some embodiments, the controller may cause one or more of the multiple sensors to turn off in response to determining that the sensors have become bio-fouled, are providing unreliable data, or are older than a predetermined age threshold. In such a scenario, the system may conserve power and/or battery life by powering down unreliable sensors.

[0031] In scenarios where at least one sensor includes a temperature sensor, the controller may be configured to provide correlated data based on a temperature offset and/or a temperature-dependent accuracy of the biometric sensors.

[0032] In scenarios where the multiple sensors are positioned at different physical locations on the living body, the controller may be configured to provide correlated data based on the respective physical locations of each of the multiple sensors. For example, the multiple sensors may provide information regarding local or global metabolism rates of an analyte based on the respective location of the sensors. Alternatively or additionally, the time-response of sensors at may indicate how fast a concentration of an analyte may change based on their respective locations on the body, e.g. in response to the introduction of insulin.

[0033] The controller may determine a health state based on the correlated data being within a predetermined range. For example, the controller may determine a high glucose health state (e.g. a hyperglycemic state) based on the correlated data indicating a glucose concentration higher than 180 mg/dL.

[0034] In some example embodiments, the controller may determine a predicted health state based on the correlated data being within a predetermined range or following a predetermined trend. For example, the correlated data may be indicative of an increasing variability in the glucose concentration of an individual. In such a scenario, a predicted health state may include pre-diabetes. Other predicted health states may be possible.

[0035] The controller may provide an indication based on the health state or predicted health state. In the above scenario, the controller may cause a display to provide a high glucose level alert indication. Other types of indications are possible, for example, the controller may cause a display to provide a historical graph or another type of aggregated data regarding the health state. In some example embodiments, the controller may be configured to provide various healthcare directives to a user. For instance, the indication may include a notification via a smartphone such as, "High Glucose Concentration, please administer insulin."

[0036] In the example in which the controller may determine a predicted health state, the indication may include a notification to make an appointment with a medical doctor or to carry out other actions, e.g. exercise, eat less sugary foods, etc. Other indications based on predicted health states are possible.

[0037] Additionally or alternatively, the controller may be operable to cause a transdermal patch to deploy a substance via one or more microneedles. That is, determination of a particular health state may trigger a deployment of a beneficial medicine so as to alleviate the health state. Other actions by the controller are possible in response to determining the health state.

[0038] In some embodiments, the controller may be communicatively coupled to a cloud computing network. In such a scenario, the controller and/or another computer system may be configured to aggregate anonymized health information from a plurality of individuals. As such, the controller and/or the other computer system may be configured to provide analytical and/or statistical data about particular types of sensor data. In an example embodiment, data may be aggregated so as to help healthcare providers and patients to manage various health conditions, e.g. diabetes or other diseases/symptoms.

[0039] By obtaining correlated data from multiple sensors, the systems and methods herein may improve the reliability of biometric sensor data while reducing sensor calibration operations and/or repeated applications of transdermal patches.

System Examples

[0040] Figure 1 is a block diagram of a system 100 according to an example

embodiment. System 100 includes a mobile device 110 and a plurality of sensors, which include a first sensor 132, a second sensor 134, an optional implanted sensor 136, and optional other sensors 138. The plurality of sensors may be in proximity to a living body 140. For example, the plurality of sensors may be physically coupled to an epidermal skin surface 142 of the living body 140. Some or all of the plurality of sensors may include transdermal sensors such as first sensor 132 and second sensor 134. Such transdermal sensors may include one or more respective microneedle arrays 133 and 135 configured to contact a dermal skin layer 144. Additionally or alternatively, the plurality of sensors may include one or more implanted sensors 136 implanted within the living body 140 and/or other sensors 138 that may be optionally coupled to an external surface of the living body 140.

[0041] In an example embodiment, at least two sensors may be collocated in a transdermal sensor patch. For example, a transdermal patch may include a 5x5 array of transdermal microneedle sensors, which may represent several sensors of the plurality of sensors. Additionally or alternatively, other sensors (e.g. a temperature sensor) may be included in the transdermal patch.

[0042] In a further embodiment, several transdermal patches, each of which may include a plurality of sensors, may be attached in various locations on the body. Other combinations of sensors and bodily attachment locations are possible

[0043] The plurality of sensors may include one or more types of sensors, which may include, but are not limited to transdermal sensors, adhesive sensors, body-mountable sensors, wearable sensors, clip-on sensors, implantable sensors, or other sensors configured to provide information indicative of a health state of a living body. The sensors of the plurality of sensors may be configured to measure one or more physiological parameters of the living body. For example, the sensors may be configured to measure one or more of: a concentration of glucose, a heart rate, a blood pressure, or a temperature.

[0044] The mobile device 110 may include a user interface 112, a display 114, a communication interface 116, and a controller 120. The communication interface 116 may be operable to provide a one or more communication links. The communication links may include one or more of a near field communication (NFC) link, a BLUETOOTH Low Energy (BLE) link, an ultra high frequency (UHF) radio frequency identification (RFID) link, or a WiFi link.

[0045] For example, at least some sensors from the plurality of sensors may be configured as a passive RFID tag, so as to communicate with the mobile device 110 via a

UHF (e.g. 860-960 MHz) RFID link. In such a scenario, the mobile device 110 may act as a reader device for the sensors. That is, the mobile device 110 may transmit an interrogating electromagnetic field. In response to the interrogating electromagnetic field, the sensor(s) may transmit stored sensor data to the mobile device 110. Active RFID tags are also contemplated in the scope of the present disclosure. Other types of communication links are possible.

[0046] The controller 120 may include a processor 122, a non-transitory computer-readable medium 124 (e.g., memory) that may store program instructions 126 and data 128. The program instructions 126 may be executable by the processor 122 to cause the controller 120 to perform operations, as discussed below.

[0047] The program instructions 126 may include instructions for receiving, from the first sensor 132 of the plurality of sensors, first sensor data indicative of the physiological parameter. That is, the controller 120 may receive the first sensor data, which may relate to a concentration of an analyte, such as glucose. The program instructions 126 may include instructions for receiving, from the second sensor 134 of the plurality of sensors, second sensor data indicative of the physiological parameter. In other words, the controller 120 may receive the second sensor data, which may also relate to the concentration of the same analyte (e.g. glucose).

[0048] The program instructions 126 may include instructions for correlating the first sensor data and the second sensor data to provide correlated data. For instance, the first and second sensor data may be averaged. Additionally or alternatively, other operations may be carried out so as to correlate the first and second sensor data. For example, the first and second sensor data may be weighted according a predicted or determined reliability. That is, sensor data received from the plurality of sensors may be weighted, discounted, and/or dismissed based on one or more factors such as an operational age of the respective sensor, an outlying data set/point, historical data trends/ranges, calibration data, and/or an operational state of the sensor.

[0049] The program instructions 126 may include instructions for determining a health state based at least on the correlated data. The health state may include any sort of characterization of the health of a living body. For example, the health state may include a "normal" state, a hyperglycemic/hypoglycemic state, a fever, an elevated stress state, and/or a high blood pressure state. Many other health states are possible.

[0050] The program instructions 126 may include instructions for providing an indication based on the determined health state. That is, the controller 120 may cause the

user interface 112 and/or the display 114 to display an indication related to the determined health state.

[0051] Figure 2A illustrates sensors 210, 220, 230, and 240 and respective mounting locations on a living body 200 according to an example embodiment. As illustrated, the living body 200 may include a human body, however living bodies of other species are contemplated herein. In an example embodiment, sensors 210, 220, and 230 may include transdermal sensors configured to sense a concentration of an analyte, such as glucose, in the living body 200. The sensors 210, 220, and 230 may be removably coupled to the living body 200 near the shoulder, bicep, and forearm, respectively. Sensor 240 may be an implanted sensor implanted beneath a skin portion 242 on a shoulder of the living body 200. Sensor 240 may be configured to sense a body temperature.

[0052] In some example embodiments, the sensors described herein need not be of the same type. For instance, the plurality of sensors may include a variety of sensors configured to sense various physiological parameters of a living body. Furthermore, sensor data received from a first sensor may help to calibrate and/or adjust sensor data received from a second sensor, or vice-versa. For example, a first sensor may include an implanted temperature sensor, e.g. sensor 240, and a second sensor may be one or more of sensors 210, 220, or 230. In such a scenario, the second sensor may exhibit a temperature-dependent sensor offset and/or temperature-dependent sensor performance. As such, temperature data received from the first sensor (sensor 240) may be used to adjust and/or calibrate the data (e.g. glucose concentration data) received from the second sensor (sensor 210). In other words, the temperature-dependent performance of the second sensor (or other sensors providing similar data) may be corrected, calibrated, or adjusted based on a measured body temperature. Other types of calibration and/or adjustment are possible. For instance, sensor data may be adjusted based on humidity, a sensor location, sensor movement, or other factors. In such ways, the data indicative of a physiological parameter may be adjusted so as to be more reliable, accurate, and/or reproducible.

[0053] Figure 2B illustrates graphs of sensor data 250 and 260 according to example embodiments. Sensor data 250 illustrates a histogram of the number of received sensor data values that are within the blood sugar concentration ranges along the x-axis. In an example embodiment, a controller may be communicatively coupled to 28 glucose sensors applied on a living body. In such a scenario, data point 252 may represent receiving sensor data indicative of a blood sugar (glucose) concentration between 90 to 94 mg/dL from three sensors of the 28 total glucose sensors. The sensor data 250 may further include six sensors

providing data indicative of a blood sugar concentration between 95-99 mg/dL, nine sensors providing data indicative of a blood sugar concentration between 100-104 mg/dL, six sensors providing data indicative of a blood sugar concentration between 105-109 mg/dL, three sensors providing data indicative of a blood sugar concentration between 110-114 mg/dL. The sensor data 250 may yet further include a single sensor providing data indicative of a blood sugar concentration between 120-124 mg/dL.

[0054] The range of data values in the sensor data 250 may vary based at least on sensor location, sensor operational age, sensor temperature, sensor battery state, sensor error, sensor-specific offset, environmental conditions, etc. It will be understood that the sensor data 250 is hypothetical and not necessarily representative of the actual range of data values that may be received by the controller. The range of data values may be greater or smaller than that illustrated by sensor data 250. Furthermore, the respective data values may be greater or smaller than those illustrated by sensor data 250. Yet further, while the illustrated scenario describes a blood sugar concentration, it should be understood that receiving a plurality of data values indicative of another physiological parameter may also include a range of data values. In some embodiments, the range of data values may tend to approximate a normal (or Gaussian) distribution, a Poisson distribution, a log-normal distribution, or another type of statistical distribution. However, in other embodiments, the range of data values need not follow a particular distribution.

[0055] As described herein, the correlated data may be determined based on a statistical analysis of the plurality of data values. For example, upon receiving sensor data from the plurality of sensors, the controller may determine an average or arithmetic mean of the values of the sensor data received. That is, the controller may add the values and then divide by the total number of values received to determine a global arithmetic mean 254. With respect to sensor data 250, the global arithmetic mean 254 may be determined to be approximately 102.7 mg/dL.

[0056] The controller may determine values that fall within a predetermined number of standard deviations based on the global arithmetic mean 254. As such, the controller may determine a standard deviation for the distribution of sensor data values and then determine which sensor data values fall within the predetermined number of standard deviations.

[0057] For example, the predetermined number of standard deviations may be two. In sensor data 250, the standard deviation may be determined to be approximately ±6.9 mg/dL. That is, approximately 68% of the sensor data values of sensor data 250 may fall

within the range of 95.8 mg/dL to 109.6 mg/dL (one standard deviation from the global arithmetic mean 254). Furthermore, approximately 95% of the sensor data values of sensor data 250 may be within two standard deviations (±13.8 mg/dL) of the global arithmetic mean 254. In such a scenario, the controller may determine that sensor data values between 88.9 and 116.5 mg/dL are within two standard deviations of the global arithmetic mean 254.

[0058] The controller may discount or dismiss data values that fall outside the predetermined number of standard deviations. In the above scenario, the controller may dismiss data values of sensor data 250 indicating blood sugar concentrations outside the range from 88.9 to 116.5 mg/dL. That is, the controller may dismiss data point 258 at least because it indicates a blood sugar concentration greater than 116.5 mg/dL. In some embodiments, the controller may discount outlying data points (e.g. data point 258) by reducing a weight or by otherwise adjusting how the outlying data point is handled or considered in subsequent statistical analysis. In some examples, such dismissal or discounting of the outlying data points may reduce spurious or inaccurate data points due to, for instance, a malfunctioning sensor.

[0059] After dismissing and/or discounting outlying data points, the controller may determine a local arithmetic mean 257 based on the remaining set of data points falling within the predetermined number of standard deviations. For example, after dismissing data point 258, the controller may determine the local arithmetic mean 257 to be 102 mg/dL.

[0060] In some embodiments, the controller may determine the local arithmetic mean 257 based on a weighted average of the entire set of data points, but with outlying data points (e.g. data point 258) receiving less weight. Other ways to determine the local arithmetic mean 257 are considered within the scope of this disclosure.

[0061] In some example embodiments, the local arithmetic mean 257 may represent a more accurate and/or a more reliable indication about the physiological parameter (e.g. blood sugar concentration) at least by considering a plurality of data points and/or dismissing or discounting outlying data points.

[0062] Based on the local arithmetic mean 257, the controller may determine a health state to be "normal" at least because the blood sugar concentration is within a predetermined normal range. In such a scenario, the controller may provide an indication about the health state. For example, the controller may cause a display of a mobile device to display a message, such as "Blood Sugar: Normal".

[0063] As described herein, the correlated data may be determined based, additionally or alternatively, on an operational age of each sensor of the plurality of sensors.

For example, the sensor data 270 illustrates hypothetical data of the number of sensors within various ranges of operational age. That is, the sensor data 270 includes a histogram of 28 sensors based on their operational age. For example, data point 272 indicates that eight sensors are between 0-4 days since transdermal patch application. The other data points may indicate eight sensors between 5-9 days old, seven sensors between 10-14 days old, three sensors between 15-19 days old, one sensor between 20-24 days old, and one sensor between 30-34 days old.

[0064] The controller may discount or dismiss data points from the plurality of sensors based on the operational age of the respective sensor. For example, the controller may fully consider sensor data from sensors within a predetermined operational age range. With respect to sensor data 270, sensor data from sensors within a "normal" operational age range 274, e.g. less than or equal to 14 days of operational age, may be fully considered (undiscounted) in a statistical analysis, such as those described elsewhere herein.

[0065] Sensor data received from sensors within an "aging" operational age range 276, e.g. between 15-24 days of operational age, may be discounted in the statistical analysis. For example, the sensor data received from sensors in the aging operational age range 276 may receive reduced weight so as to be considered to a lesser degree compared to the sensor data from sensors in the normal operational age range 274.

[0066] Furthermore, sensor data from sensors in an "end-of-life" operational age range 278 may be discounted further or dismissed altogether. In other words, sensor data from sensors beyond the expected operational age may be given even less weight or completely discarded with respect to a subsequent statistical analysis.

[0067] In another embodiment, the operational age ranges may be determined and/or adjusted based on the reliability of data being provided by sensors within a given operational age range. That is, while sensor data may tend to become less reliable over time, the controller may periodically or continuously adjust the operational age ranges if the sensor data appears to remain reliable, even if the respective sensor is beyond a given "normal" operational age.

[0068] The one or more operational age ranges states may be predetermined or determined based on average battery life expectancy, mean time to sensor failure, environmental conditions, sensor placement location, average wear and tear conditions, sensor type, or other factors. For instance, a glucose sensor applied to a hand location may be more likely to fail before a glucose sensor applied to a back location due to factors such as wear and tear, body movement, exposure to the environment, etc.

[0069] In another embodiment, sensor data may be discounted or discarded based on another type of operational state of the respective sensor. For instance, if the respective sensor is malfunctioning (e.g. due to biofouling, temperature offset, environmental factors, or any other known or unknown reason), the corresponding data received from the malfunctioning sensor may be discounted or discarded altogether.

[0070] It will be understood that Figures 2A and 2B describe and illustrate examples of statistical analysis methods that may improve the reliability, redundancy, and/or accuracy of sensor data indicative of a physiological parameter. However, other statistical analysis methods may be applied to the set of sensor data so as to achieve such improvements and all such other methods and related systems are considered within the scope of this disclosure.

[0071] Figures 3A and 3B illustrate a mobile device 300 according to example embodiments. The mobile device 300 may be similar or identical to mobile device 110 as illustrated and described with respect to Figure 1. The mobile device 300 may include, without limitation, a smartphone, a wearable computer, a body-mountable device, or another type of computing device. The mobile device 300 may include a display 302.

[0072] Figure 3A illustrates example notifications 310 that may be displayed via display 302. For example, notifications 310 may include a sensor monitoring status message 312. The sensor monitoring status message 312 may include a number and type of sensors currently communicatively coupled to the mobile device 300. As an example, the sensor monitoring status message 312 may state "Currently monitoring three glucose sensors and one temperature sensor."

[0073] The notifications 310 may include messages related to sensor data. The messages may vary based at least on sensor type and/or the physiological parameter being measured. For example, a body temperature message 314 may state "Body Temperature: 98.6°". In such a scenario, the body temperature message 314 may be based on sensor data from an implanted temperature sensor and/or a temperature sensor otherwise proximate to the living body.

[0074] Additionally or alternatively, an average glucose concentration message 316 may state "Average Glucose Concentration: 170 mg/dL [Normal]". In such a scenario, the average glucose concentration value may be similar or identical to the local arithmetic mean of the data points related to glucose concentration, as described elsewhere herein. Other types of messages related to sensor data are possible.

[0075] Figure 3B illustrates further notifications 320 that may be provided by the mobile device 300. For example, the mobile device 300 and/or the controller may

determine a malfunctioning sensor and request a user to replace it with a new sensor. In such a scenario, a sensor replacement message 322 may state "Glucose sensor #1 (shoulder) appears to be malfunctioning. REPLACE w/ NEW SENSOR."

[0076] In some examples, an indication or message may be provided in response to the controller determining a given health state. For example, in response to determining a hyperglycemic health state, the mobile device 300 may cause the display 302 to provide an alert message 324 that states "ALERT: Average Glucose Concentration: 210 ml/dL [Elevated]". Furthermore, the mobile device may provide an action message 326 that states "ACTION: Administer TWO units of insulin". It should be understood that a variety of indications and messages may be provided to a user related to one or more physiological parameters. In some embodiments, the indication may include a flashing or steady light, haptic feedback, a sound, or another type of indication to the user.

[0077] Figures 4A and 4B illustrate oblique and cross-sectional views of a body-mountable device 400 according to example embodiments. The body-mountable device 400 may be similar or identical to mobile devices 110 and 300 as illustrated and described in relation to Figures 1, 3A and 3B. As such, the body-mountable device 400 may be configured to obtain measurements related to one or more physiological parameters of a living body via a plurality of sensors. The body-mountable device 400 may be configured to be mounted to an external body surface 450 of a wearer and to enable a variety of applications and functions. The body-mountable device 400 may include a housing 430 (e.g. a rigid or semi-rigid enclosure) and a mount 420 (e.g. a strap, band, or adhesive) configured to mount a contact surface 410 of the housing 430 to the external body surface 450 of the wearer.

[0078] The body-mountable device 400 may include a plurality of sensors disposed on a portion of the contact surface 410. For instance, the sensors may include a first sensor 414 and a second sensor 418. While the contact surface 410 is mounted to the external body surface 450, the sensors may be configured to detect one or more physiological parameters related to the body of the wearer.

[0079] The first sensor 414 and/or the second sensor 418 may be configured to sense a concentration of an analyte 440 within a lumen or vasculature 452 of the wearer. In an example embodiment, the first sensor 414 and the second sensor 418 may be glucose sensors configured to measure a concentration of glucose within the body of the wearer. However, other analytes and other types of sensors are contemplated as described elsewhere herein.

[0080] The body-mountable device 400 may also include one or more drug-delivery devices 412 and 416. The drug-delivery devices 412 and 416 may be configured to deliver one or more substances to the body of the wearer of the body-mountable device. For example, the drug-delivery devices 412 and/or 416 may be configured to deliver a predetermined dose of insulin to the body of the wearer. Alternatively, the drug-delivery devices may be configured to administer other types of drugs and/or substances to the body of the wearer.

[0081] The body-mountable device 400 may include a display 432 and/or interaction devices 434 (e.g. one or more buttons, dials, touch screens, switches, etc.). In an example embodiment, the body-mountable device 400 may determine a hyperglycemic health state of a wearer. In response, the body-mountable device 400 may cause the display 432 to provide various indications and/or messages to the wearer. For example, in response to the determined hyperglycemic health state, an alert message 433 may include "Blood Sugar: 210 mg/dL."

[0082] Furthermore, in response to determining a given health state of a wearer, the body-mountable device 400 may cause an action so as to alleviate, mitigate, or otherwise manage the given health state. For example, in response to determining the hyperglycemic health state of the wearer, the body-mountable device 400 may be operable to automatically provide insulin to the wearer via the drug-delivery devices 412 and/or 416.

[0083] In such a scenario, the display 432 may provide an action indication 435. The action indication 435 may provide a notification that a drug, e.g. insulin, or another substance is being administered to the wearer. For example, the action indication 435 may state "ADMINSTERING TWO UNITS OF INSULIN". Other types of action indications are possible.

[0084] It should be understood that the body-mountable device 400 or any other similar device or system described herein may be operable to carry out a wide variety of other actions in response to determining a given health state. For example, the body-mountable device 400 may be operable to automatically contact emergency personnel in response to determining a life-threatening health state.

[0085] Figure 5 illustrates a system 500 according to an example embodiment. The system 500 may include a plurality of sensors, such as sensors 510, 520, and 530. The plurality of sensors may be communicatively coupled to a server 550 via one or more communication networks 540. The server 550 may represent a cloud computing platform, a computing network, or another type of computing device.

[0086] In some embodiments, sensors 510, 520, and 530 may represent the devices that aggregate sensor data from a respective plurality of sensors so as to determine a local and/or global arithmetic mean of a physiological parameter. Other network configurations are possible.

[0087] The plurality of sensors may be configured to provide sensor data indicative of one or more physiological parameters, e.g. glucose concentration, body temperature, etc., to the server 550. In such a scenario, the server 550 may be operable to receive a large amount of sensor data from the plurality of sensors. In some examples, the sensor data may be collected on a per-user account basis and the user account information may be anonymized for privacy concerns.

[0088] The server 550 may be configured to provide information, e.g. statistics, about health states within a population of anonymized user accounts. Such information may be useful to predict public health conditions and/or health trends. For example, the server 550 may be configured to predict a public health condition, such as an outbreak of influenza, increasing rate of diabetes, or heart disease. Other types of public health conditions may be determined by the server 550.

Method Examples

[0089] Figure 6 illustrates a method 600, according to an embodiment. The method 600 includes blocks that may be carried out in any order. Furthermore, various blocks may be added to or subtracted from method 600 within the intended scope of this disclosure. The method 600 may correspond to blocks or steps that may be carried out using any or all of the devices and/or systems illustrated and described in reference to Figures 1, 2, 3A, 3B, 4A, 4B, and 5.

[0090] Block 602 includes receiving, from a first sensor of a plurality of sensors, first data indicative of a physiological parameter. The first sensor may be identical or similar to first sensor 132 as illustrated and described in relation to Figure 1. The first data may include signals received via a wireless communication link. For example, the first data may be received via BLUETOOTH Low Energy (BLE) communication link or a near-field communication (NFC) link. The physiological parameter may include a concentration of an analyte, a body temperature, a galvanic skin response, a blood pressure, a pulse rate, etc. The analyte may include one or more analytes of interest so as to determine a health state condition. For example, the analyte may include glucose in blood, white blood cells, red blood cells, a biomarker, a fluorescent tag, or another indicator of a particular health state.

[0091] Example embodiments may include a mobile device (e.g. mobile device 110 as illustrated and described with respect to Figure 1) or another type of computing device receiving the first data from the first sensor. The first data may include information indicative of a glucose concentration in a living body.

[0092] Block 604 includes receiving, from a second sensor of the plurality of sensors, second sensor data indicative of the physiological parameter. The second sensor may be similar or identical to second sensor 134 as illustrated and described with respect to Figure 1. In other words, a mobile device, such as mobile device 110, may be operable to receive second sensor data from the second sensor. The second sensor data may include data indicative of the physiological parameter, such as a blood glucose concentration or a body temperature.

[0093] Each sensor of the plurality of sensors is removably attached to a respective location on an exterior surface of a living body. That is, the sensors may be associated with, or incorporated into a removable transdermal patch. In an example embodiment, the transdermal patch may include one or more sensors. The one or more sensors may interact with the body (e.g. sense one or more physiological parameters) via one or more microneedles. In some embodiments, the first sensor, the second sensor, or another sensor of the plurality of sensors may be configured to be implanted into the living body. For example, implantable temperature sensors, implantable glucose sensors, and/or other types of *in vivo* sensors configured to sense a physiological parameter are contemplated herein.

[0094] Block 606 includes correlating the first sensor data and the second sensor data to provide correlated data. The correlated data is indicative of the physiological parameter. For instance, the first sensor data and the second sensor data may both relate to the physiological parameter, such as a blood sugar (glucose) concentration. In such a scenario, the first sensor data and the second sensor data may provide information indicative of similar, but slightly different glucose concentrations from the same living body.

[0095] Correlating the first sensor data and the second sensor data may include averaging the first and second sensor data. For instance, a mobile device may receive sensor data from a plurality of sensors (e.g. 2, 10, 100, or more sensors) that could include a statistical range of values. As such, correlating the sensor data may include taking a statistical average (e.g. an arithmetic mean) of the plurality of sensor data values.

[0096] In some embodiments, correlating the sensor data may include weighting sensor data values based on a confidence level associated with one or more sensors. That is, a sensor may provide a data value more than a threshold number of standard deviations

away from the statistical average of the plurality of data values. In such a scenario, the data value from the "outlier" sensor may be discounted, discarded, or associated with a smaller weight compared to those data with values within the threshold number of standard deviations from the statistical average of data values.

[0097] Block 608 includes determining a health state based on the correlated data. That is, the correlated data may indicate that a physiological parameter is in a typical/normal/safe range or an atypical/abnormal/unsafe range. For example, the correlated data from a plurality of glucose sensors may indicate that an average concentration of blood sugar is 210 mg/dL. In such a scenario, the controller and/or the mobile device may determine a hyperglycemic health state. A variety of health states are contemplated herein, including, but not limited to: a normal/healthy health state, hypoglycemia, fever, drug overdose, poisoning, elevated stress, high blood pressure, hypertension, arterial blockage, myocardial infarction (heart attack), infection, lack of sleep, vitamin deficiency, etc.

[0098] Block 610 includes providing an indication based on the determined health state. The indication may include information about the physiological parameter and/or actions that should be taken in an effort to alleviate or otherwise change the determined health state. For example, in response to determining a hyperglycemic health state, the mobile device and/or the controller may cause a display of the mobile device to provide an indication such as, "Average Blood Sugar = 210 mg/dL, Please administer two units of insulin." It will be understood that the content of the indication may depend at least in part on the determined health state. Thus, the indication may include a variety of information and/or actions that should be taken. In another example embodiment, in response to the determined health state being an arterial blockage, the indication may include, "Arterial blockage detected, seek medical attention immediately!"

[0099] In some cases, the mobile device and/or the controller may take additional or alternative action in response to particular determined health states. For example, in response to a hyperglycemic health state, the mobile device may cause a drug administration device to administer a determined amount of insulin. The drug administration device may include an insulin pump and/or one or more microneedles configured to deliver insulin. In the arterial blockage scenario, the mobile device and/or the controller may be configured to alert emergency personnel to the user's physiological condition and position.

[00100] Figure 7 illustrates a method 700, according to an embodiment. The method 700 includes blocks that may be carried out in any order. Furthermore, various blocks may be added to or subtracted from method 700 within the intended scope of this disclosure. The method 700 may correspond to blocks or steps that may be carried out using any or all of the devices and/or systems illustrated and described in reference to Figures 1, 2, 3A, 3B, 4A, 4B, and 5.

[00101] Block 702 includes receiving, from a first sensor of a plurality of sensors, first sensor data indicative of a first physiological parameter. The first sensor is configured for implantation into a living body. In an example embodiment, the first sensor may include an implantable temperature sensor, however other types of sensors are contemplated. The first sensor is configured to detect the first physiological parameter. The first physiological parameter may include a body temperature or another measurable characteristic of the living body.

[00102] Block 704 includes receiving, from a second sensor of the plurality of sensors, second sensor data indicative of a second physiological parameter. The second sensor is configured for removable attachment to a respective location on an exterior surface of the living body. As such, the second sensor may be a transdermal sensor or another type of removable sensor that may be coupled to an outer surface of the body. The second sensor is configured to detect the second physiological parameter, which may be a concentration of glucose, a concentration of glycated hemoglobin, a pulse rate, a blood pressure, or another measurable physiological parameter described herein.

[00103] Block 706 includes adjusting the second sensor data based on the first sensor data to provide adjusted data. That is, the second sensor may have a temperature-dependent offset and/or temperature-dependent device performance. In such a scenario, temperature (or other relevant data) from the first sensor may be used to adjust, calibrate, or otherwise modify the second sensor data to form the adjusted data. In some embodiments, the adjusted data may represent a more accurate measurement of the physiological parameter (e.g. glucose concentration).

[00104] Block 708 includes determining a health state based on the adjusted data. As described elsewhere herein, a health state may be determined from information indicative of a physiological parameter. In the present scenario, the adjusted data may include information from the second sensor calibrated with respect to information obtained from the first sensor. Based on the adjusted data, a health state, such as a hypo- or hyperglycemic state may be determined. Other types of health states are possible and contemplated herein.

[00105] Block 710 includes providing an indication based on the health state. In some example embodiments, the indication may include displaying an alert notification or an action notification via a display of a mobile device. For instance, if the determined health state is a hyperglycemic state, the indication may include an alert notification via a smartphone or tablet that states: "Elevated glucose concentration, please administer insulin."

[00106] The particular arrangements shown in the Figures should not be viewed as limiting. It should be understood that other embodiments may include more or less of each element shown in a given Figure. Further, some of the illustrated elements may be combined or omitted. Yet further, an illustrative embodiment may include elements that are not illustrated in the Figures.

[00107] While various examples and embodiments have been disclosed, other examples and embodiments will be apparent to those skilled in the art. The various disclosed examples and embodiments are for purposes of illustration and are not intended to be limiting, with the true scope being indicated by the following claims.

CLAIMS

What is claimed is:

1. A system comprising:

a plurality of sensors for measuring a physiological parameter, wherein at least one sensor of the plurality of sensors is configured for removable attachment to a respective location on an exterior surface of a living body; and

a controller comprising a memory and a processor, wherein the memory stores instructions that are executable by the processor to cause the controller to perform operations comprising:

receiving, from a first sensor of the plurality of sensors, first sensor data indicative of the physiological parameter;

receiving, from a second sensor of the plurality of sensors, second sensor data indicative of the physiological parameter;

correlating the first sensor data and the second sensor data to provide correlated data, wherein the correlated data is indicative of the physiological parameter;

determining a health state based on the correlated data; and

providing an indication based on the determined health state.

2. The system of claim 1, wherein at least one sensor of the plurality of sensors is configured for removable attachment to the living body via a transdermal patch.

3. The system of claim 2, wherein the transdermal patch comprises at least two sensors of the plurality of sensors.

4. The system of claim 1, wherein the physiological parameter comprises a concentration of an analyte.

5. The system of claim 4, wherein the analyte comprises glucose.

6. The system of claim 5, wherein the health state is a hyperglycemic state or a hypoglycemic state, and wherein the indication comprises a high glucose alert or a low glucose alert.

7. The system of claim 1, wherein the plurality of sensors are configured to communicate with the controller via at least one of: a near field communication (NFC) link, a BLUETOOTH Low Energy (BLE) link, an ultra high frequency (UHF) radio frequency identification (RFID) link, or a WiFi link.

8. The system of claim 1, wherein correlating the first sensor data and the second sensor data to provide correlated data comprises discounting the first sensor data based on an operational state of the first sensor.

9. A system comprising:

a plurality of sensors, wherein a first sensor of the plurality of sensors is configured for implantation into a living body, wherein the first sensor is configured to detect a first physiological parameter, wherein a second sensor of the plurality of sensors is configured for removable attachment to a respective location on an exterior surface of the living body, wherein the second sensor is configured to detect a second physiological parameter; and

a controller comprising a memory and a processor, wherein the memory stores instructions that are executable by the processor to cause the controller to perform operations comprising:

receiving, from the first sensor, first sensor data indicative of the first physiological parameter;

receiving, from the second sensor, second sensor data indicative of the second physiological parameter;

adjusting the second sensor data based on the first sensor data to provide adjusted data, wherein the adjusted data is indicative of the second physiological parameter;

determining a health state based on the adjusted data; and

providing an indication based on the health state.

10. The system of claim 9, wherein the second sensor is configured for removable attachment to the living body via a transdermal patch.

11. The system of claim 10, wherein the transdermal patch comprises at least two sensors of the plurality of sensors.

12. The system of claim 9, wherein the second physiological parameter comprises a concentration of an analyte.

13. The system of claim 12, wherein the analyte comprises glucose.

14. The system of claim 13, wherein the health state is a hyperglycemic state or a hypoglycemic state, and wherein the indication comprises a high glucose alert or a low glucose alert.

15. The system of claim 9, wherein the plurality of sensors are configured to communicate with the controller via at least one of: a near field communication (NFC) link,

a BLUETOOTH Low Energy (BLE) link, an ultra high frequency (UHF) radio frequency identification (RFID) link, or a WiFi link.

16. The system of claim 12, wherein the first physiological parameter comprises a body temperature.

17. A method comprising:

receiving, from a first sensor of a plurality of sensors, first sensor data indicative of a physiological parameter;

receiving, from a second sensor of the plurality of sensors, second sensor data indicative of the physiological parameter, wherein at least one sensor of the plurality of sensors is removably attached to a respective location on an exterior surface of a living body;

correlating the first sensor data and the second sensor data to provide correlated data, wherein the correlated data is indicative of the physiological parameter;

determining a health state based on the correlated data; and

providing an indication based on the determined health state.

18. The method of claim 17, wherein at least one sensor of the plurality of sensors is removably attached to the living body via a transdermal patch.

19. The method of claim 18, wherein the transdermal patch comprises at least two sensors of the plurality of sensors.

20. The method of claim 17, wherein the physiological parameter comprises a concentration of an analyte.

21. The method of claim 20, wherein the analyte comprises glucose.

22. The method of claim 21, wherein the health state is a hyperglycemic state or a hypoglycemic state, and wherein the indication comprises a high glucose alert or a low glucose alert.

23. The method of claim 17, wherein the plurality of sensors are configured to communicate with the controller via at least one of: a Near Field Communication (NFC) link, a BLUETOOTH Low Energy (BLE) link, an ultra high frequency (UHF) radio frequency identification (RFID) link, or a WiFi link.

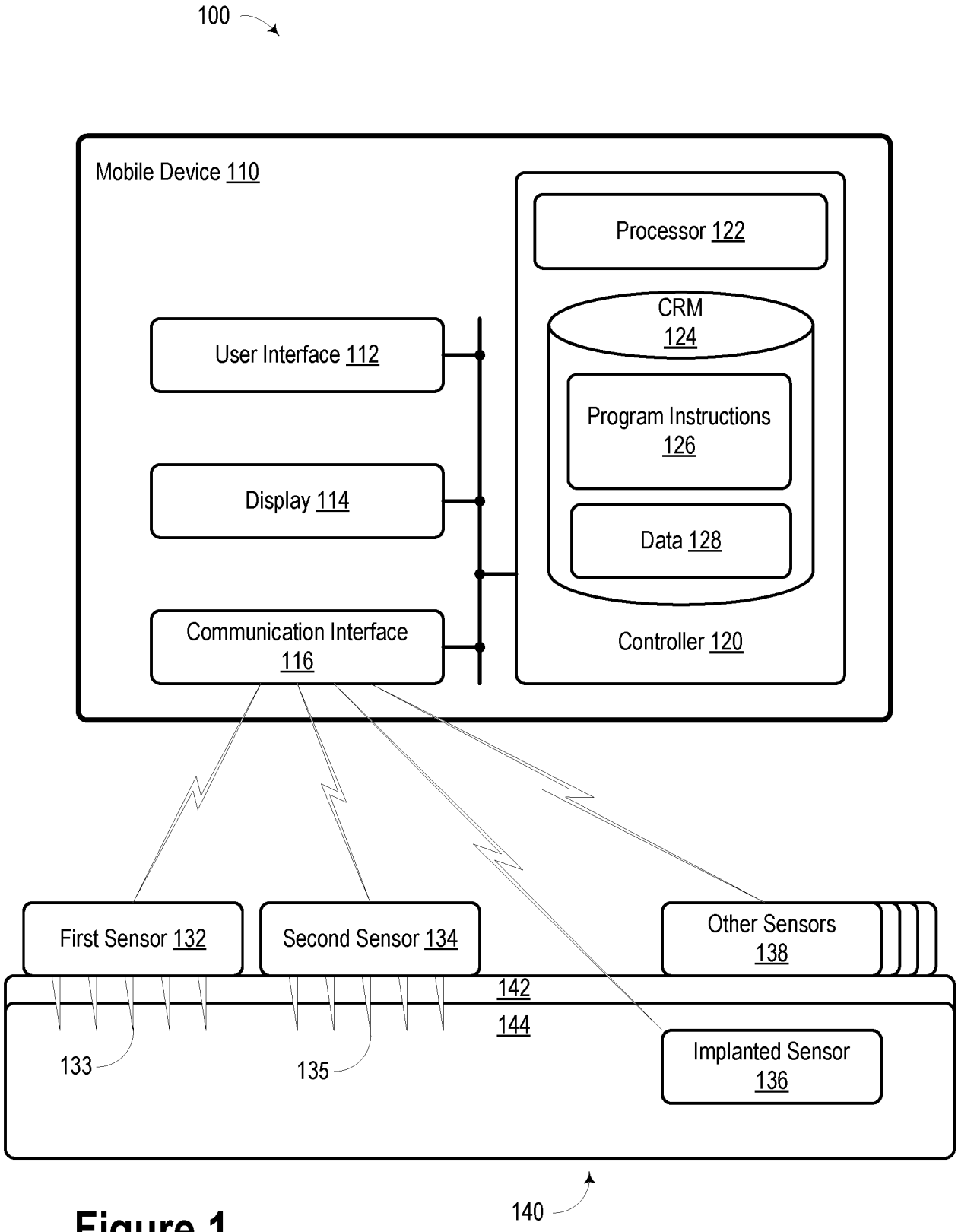

100
Mobile Device 110
Processor 122
CRM 124
User Interface 112
Program Instructions 126
Display 114
Data 128
Communication Interface 116
Controller 120
First Sensor 132
Second Sensor 134
Other Sensors 138
142
144
133
135
Implanted Sensor 136
140

Figure 1

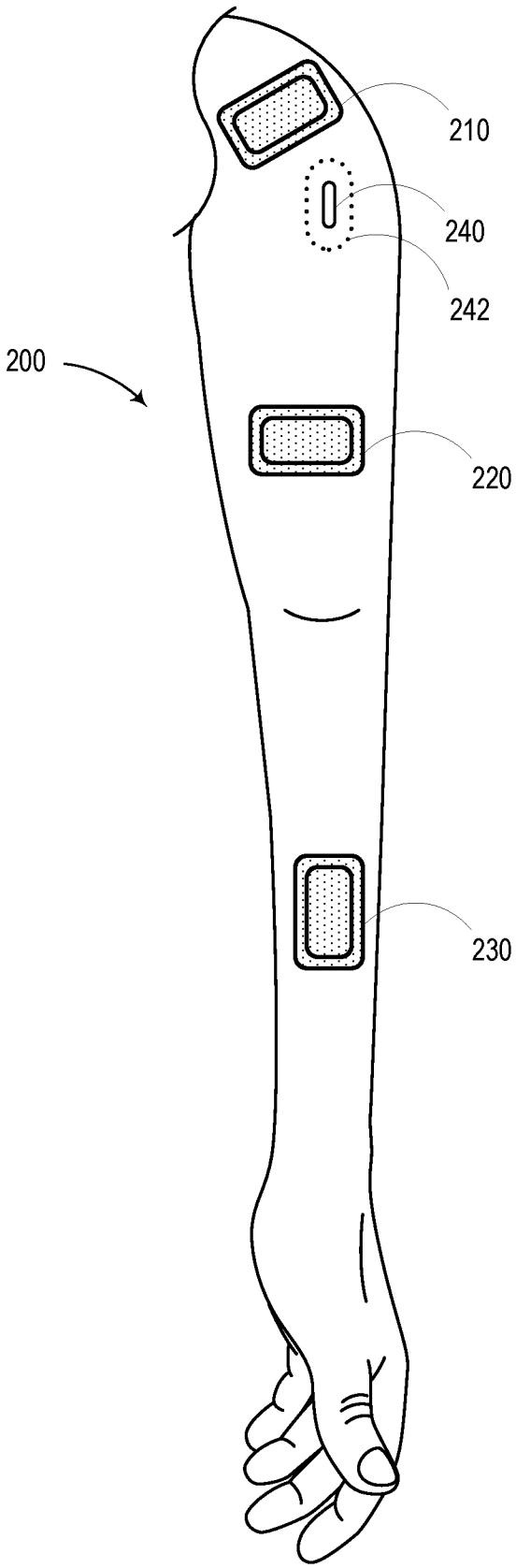
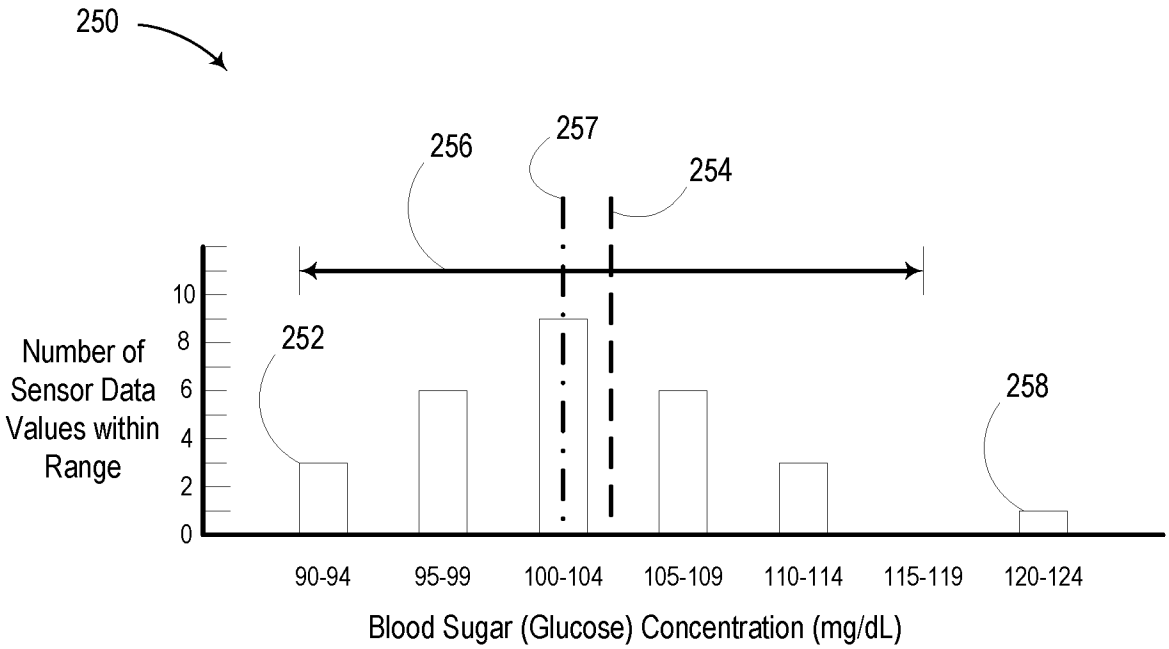


Figure 2A


250
256
257
254
252
258
Number of Sensor Data Values within Range
0
2
4
6
8
10
90-94
95-99
100-104
105-109
110-114
115-119
120-124
Blood Sugar (Glucose) Concentration (mg/dL)

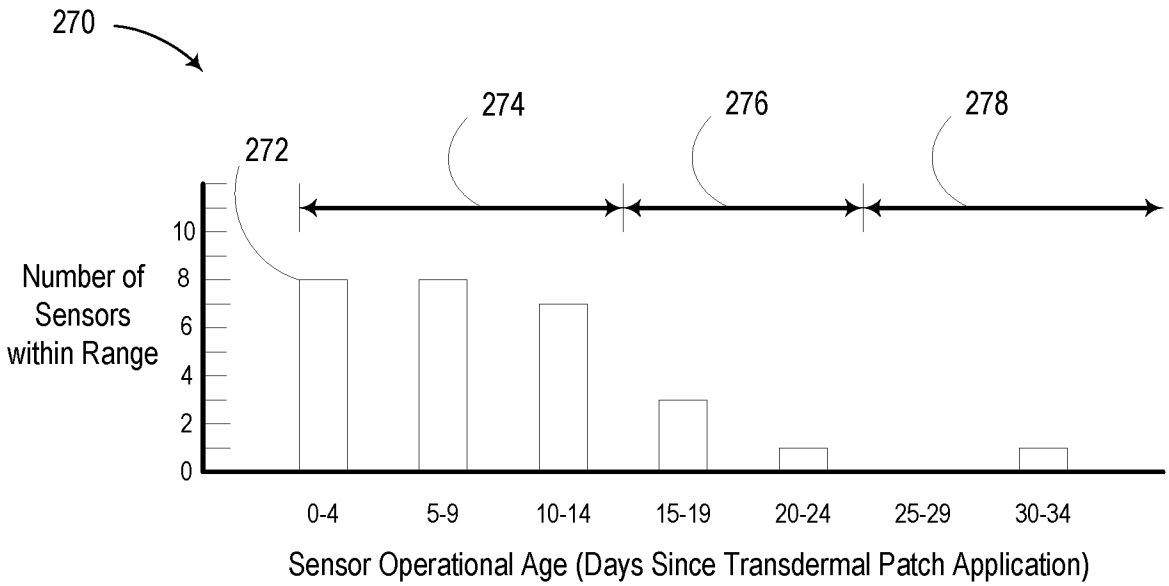

270
274
276
278
272
Number of Sensors within Range
0
2
4
6
8
10
0-4
5-9
10-14
15-19
20-24
25-29
30-34
Sensor Operational Age (Days Since Transdermal Patch Application)

Figure 2B

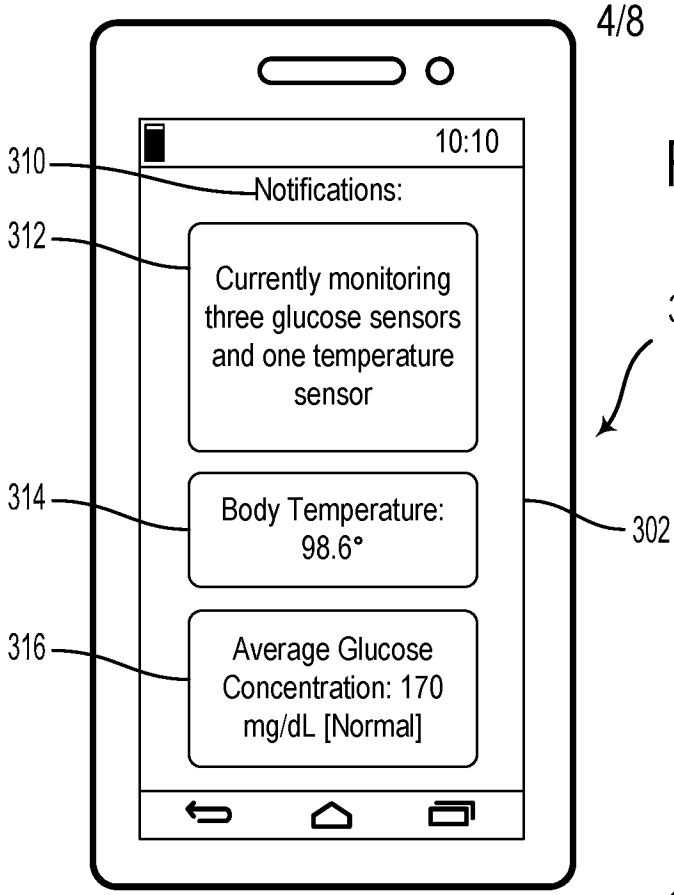


Figure 3A

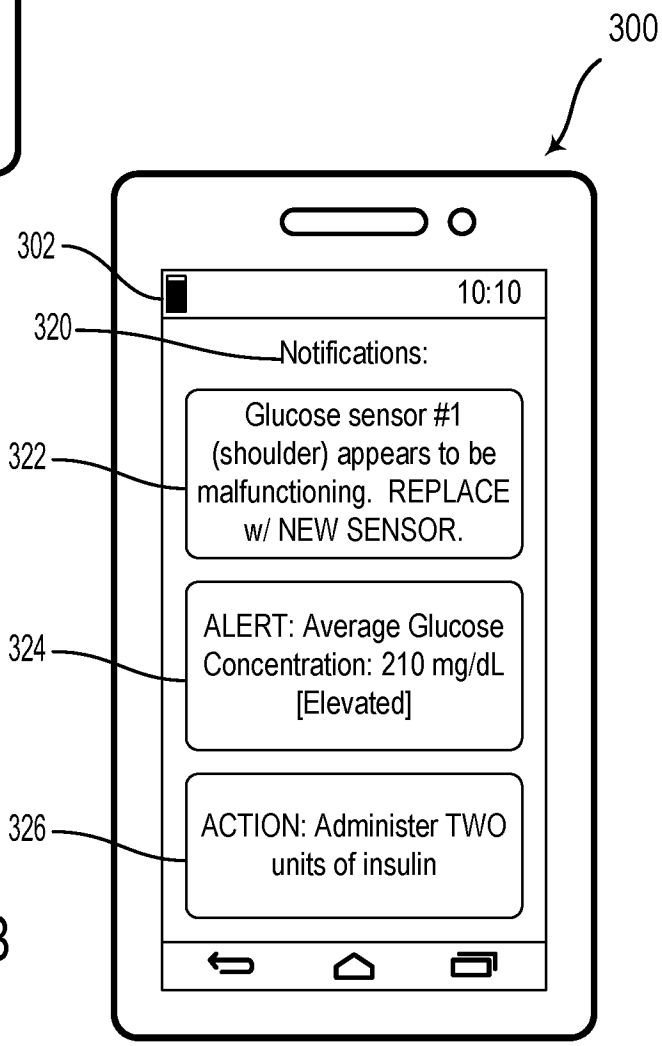


Figure 3B

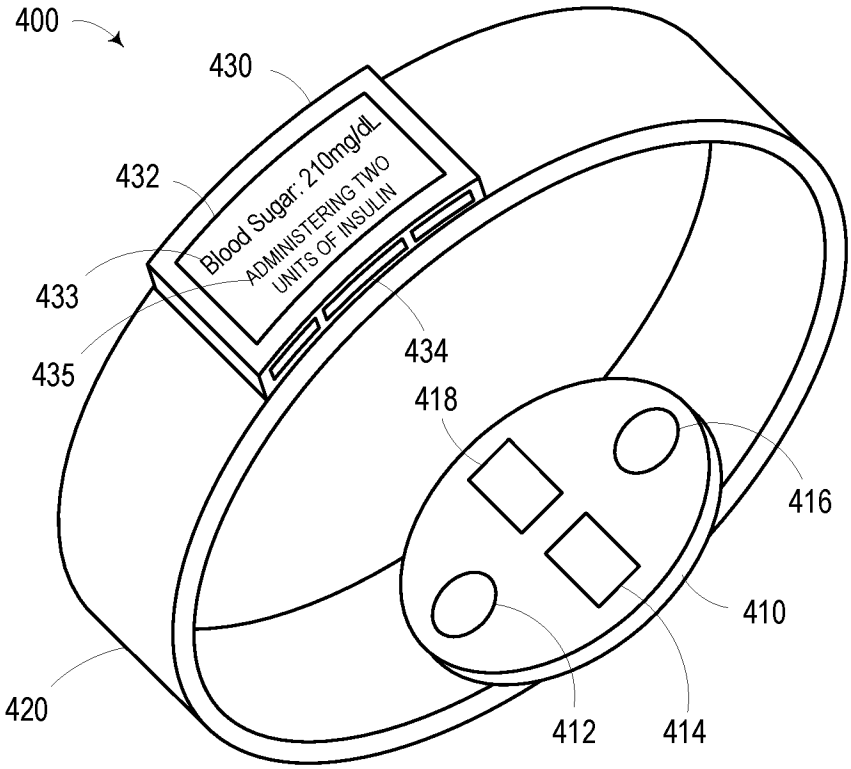


Figure 4A

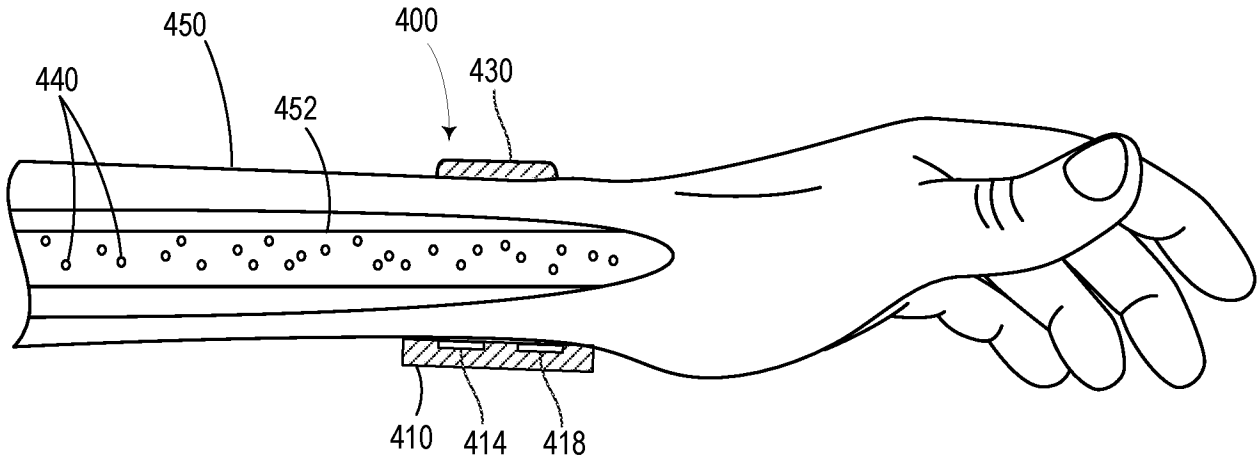


Figure 4B

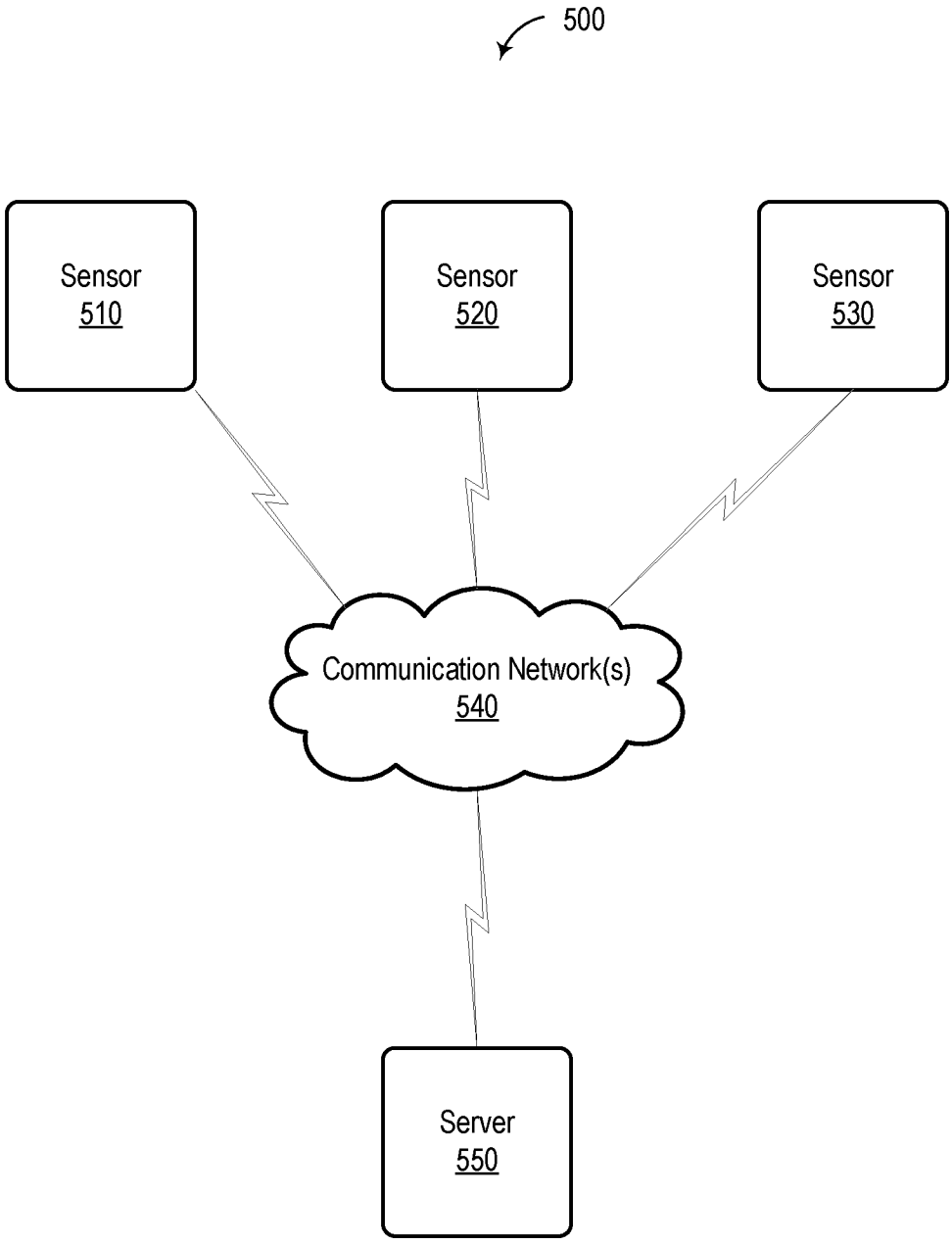

500
Sensor
510
Sensor
520
Sensor
530
Communication Network(s)
540
Server
550

Figure 5

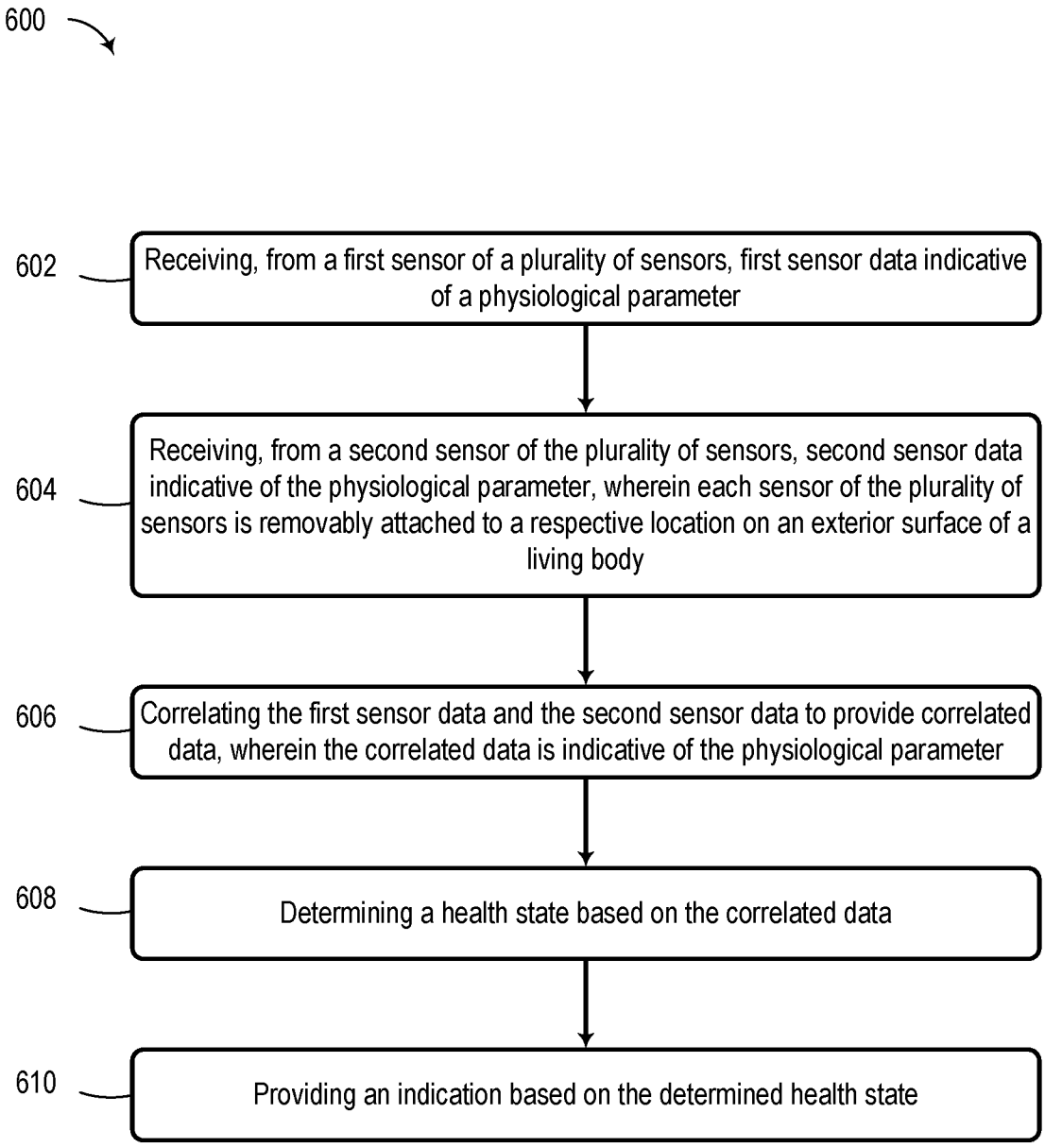

600
602
Receiving, from a first sensor of a plurality of sensors, first sensor data indicative of a physiological parameter
604
Receiving, from a second sensor of the plurality of sensors, second sensor data indicative of the physiological parameter, wherein each sensor of the plurality of sensors is removably attached to a respective location on an exterior surface of a living body
606
Correlating the first sensor data and the second sensor data to provide correlated data, wherein the correlated data is indicative of the physiological parameter
608
Determining a health state based on the correlated data
610
Providing an indication based on the determined health state

Figure 6

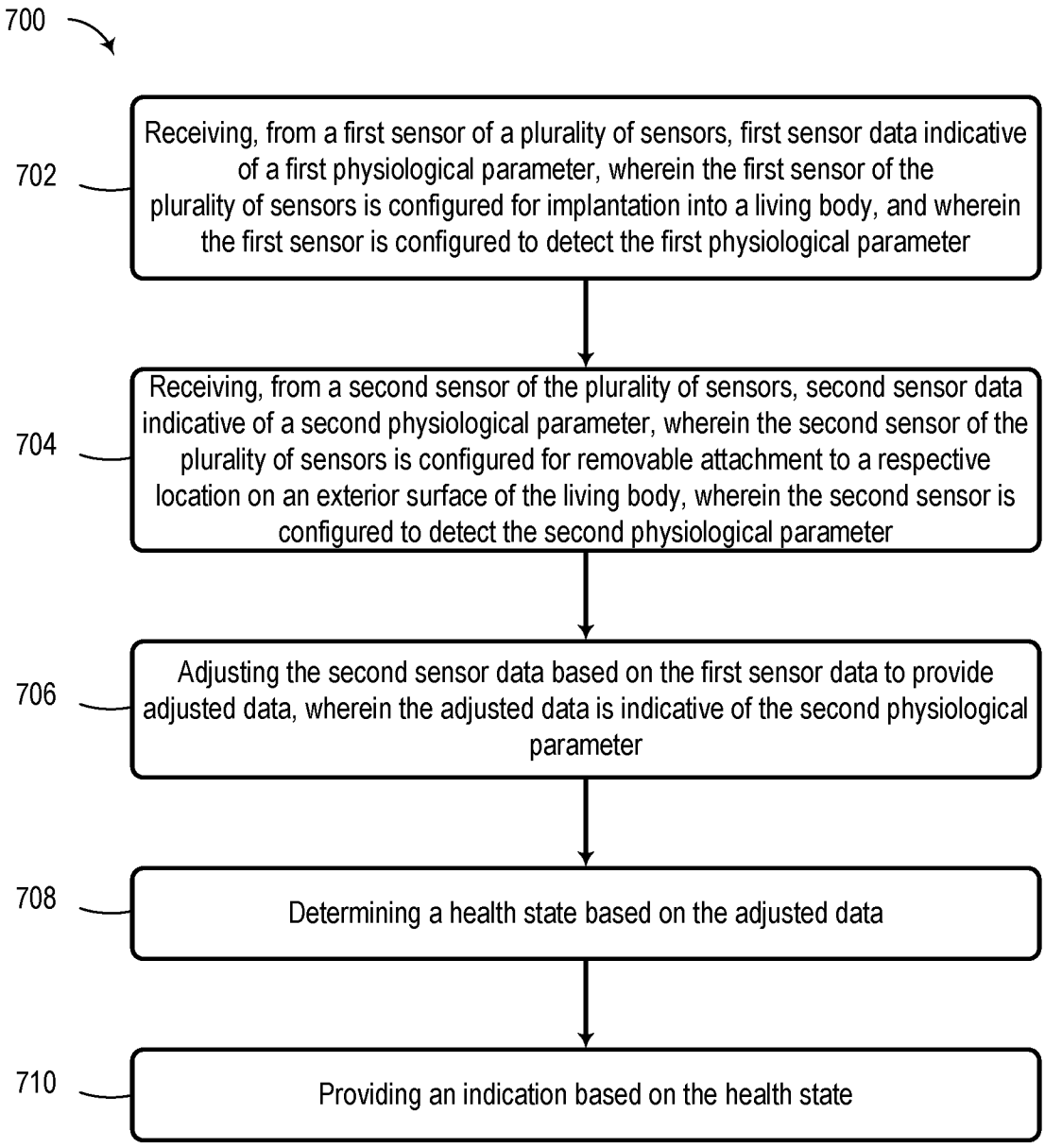

700
702
Receiving, from a first sensor of a plurality of sensors, first sensor data indicative of a first physiological parameter, wherein the first sensor of the plurality of sensors is configured for implantation into a living body, and wherein the first sensor is configured to detect the first physiological parameter
704
Receiving, from a second sensor of the plurality of sensors, second sensor data indicative of a second physiological parameter, wherein the second sensor of the plurality of sensors is configured for removable attachment to a respective location on an exterior surface of the living body, wherein the second sensor is configured to detect the second physiological parameter
706
Adjusting the second sensor data based on the first sensor data to provide adjusted data, wherein the adjusted data is indicative of the second physiological parameter
708
Determining a health state based on the adjusted data
710
Providing an indication based on the health state

Figure 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/US2016/040227

A. CLASSIFICATION OF SUBJECT MATTER
INV. G06F19/00
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
G06F

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2011/015510 A1 (SAY JAMES [US] ET AL) 20 January 2011 (2011-01-20) paragraphs 8, 292, 296, 312-315	1-23

A	Anonymous: "Sensor fusion - Wikipedia, the free encyclopedia", , 22 June 2015 (2015-06-22), XP055301366, Retrieved from the Internet: URL:https://en.wikipedia.org/w/index.php?title=Sensor_fusion&oldid=668209547 [retrieved on 2016-09-09] page 2	1-23

X	WO 2011/039745 A1 (HEALTHWATCH LTD [IL]; ROMEM YORAM [IL]) 7 April 2011 (2011-04-07)	1-5, 17-21
A	pages 2, 11-14	6-16,22, 23

☐ 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

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
23 September 2016	04/10/2016

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

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2016/040227

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

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

1. ☐ Claims Nos.:
because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

see additional sheet

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

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

1. claims: 1-23

determining and providing an indication of a health state using a controller, based on measurements of (a) physiological parameter(s) with a plurality of sensors.

1.1. claims: 1-8, 17-23

a plurality of sensors for measuring a physiological parameter and a controller receiving and correlating the data from at least two sensors, determining and providing a health state based on the correlated data

1.2. claims: 9-16

a plurality of sensors for measuring a first physiological parameter and a second physiological parameter and a controller receiving data from the sensors, adjusting the second sensor data based on the first sensor data, determining and providing a health state based on the adjusted data

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/040227

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2011015510 A1	20-01-2011	AU 2330799 A	23-11-1999
		DK 1075209 T3	19-01-2015
		EP 1075209 A1	14-02-2001
		EP 2305107 A1	06-04-2011
		EP 2305108 A1	06-04-2011
		JP 4574847 B2	04-11-2010
		JP 4778100 B2	21-09-2011
		JP 2002513602 A	14-05-2002
		JP 2010227601 A	14-10-2010
		US 6175752 B1	16-01-2001
		US 6565509 B1	20-05-2003
		US 2003187338 A1	02-10-2003
		US 2004106859 A1	03-06-2004
		US 2004106860 A1	03-06-2004
		US 2004236200 A1	25-11-2004
		US 2005121322 A1	09-06-2005
		US 2005199494 A1	15-09-2005
		US 2007149873 A1	28-06-2007
		US 2007149874 A1	28-06-2007
		US 2007161879 A1	12-07-2007
		US 2007161880 A1	12-07-2007
		US 2007179370 A1	02-08-2007
		US 2007179372 A1	02-08-2007
		US 2007191699 A1	16-08-2007
		US 2007203408 A1	30-08-2007
		US 2007203410 A1	30-08-2007
		US 2007203411 A1	30-08-2007
		US 2007208247 A1	06-09-2007
		US 2007213610 A1	13-09-2007
		US 2007244380 A1	18-10-2007
		US 2007249919 A1	25-10-2007
		US 2007249920 A1	25-10-2007
		US 2008033271 A1	07-02-2008
		US 2008091096 A1	17-04-2008
		US 2008167543 A1	10-07-2008
		US 2008214914 A1	04-09-2008
		US 2008262329 A1	23-10-2008
		US 2008269672 A1	30-10-2008
		US 2008319292 A1	25-12-2008
		US 2009062634 A1	05-03-2009
		US 2009069655 A1	12-03-2009
		US 2009069656 A1	12-03-2009
		US 2009069657 A1	12-03-2009
		US 2009069658 A1	12-03-2009
		US 2009089999 A1	09-04-2009
		US 2009093696 A1	09-04-2009
		US 2009099432 A1	16-04-2009
		US 2009099435 A1	16-04-2009
		US 2009163781 A1	25-06-2009
		US 2009163788 A1	25-06-2009
		US 2009163789 A1	25-06-2009
		US 2009171179 A1	02-07-2009
		US 2009173628 A1	09-07-2009
		US 2009177054 A1	09-07-2009
		US 2009177055 A1	09-07-2009
		US 2009177056 A1	09-07-2009
		US 2009177057 A1	09-07-2009
		US 2009177058 A1	09-07-2009

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/040227

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2009177059 A1	09-07-2009
		US 2009177060 A1	09-07-2009
		US 2009177061 A1	09-07-2009
		US 2009177062 A1	09-07-2009
		US 2009177063 A1	09-07-2009
		US 2009177064 A1	09-07-2009
		US 2009177065 A1	09-07-2009
		US 2009177066 A1	09-07-2009
		US 2009182212 A1	16-07-2009
		US 2009182213 A1	16-07-2009
		US 2009182214 A1	16-07-2009
		US 2009182215 A1	16-07-2009
		US 2009187088 A1	23-07-2009
		US 2009187089 A1	23-07-2009
		US 2009187090 A1	23-07-2009
		US 2009187091 A1	23-07-2009
		US 2009187092 A1	23-07-2009
		US 2009187093 A1	23-07-2009
		US 2009187094 A1	23-07-2009
		US 2009187095 A1	23-07-2009
		US 2009192368 A1	30-07-2009
		US 2009192369 A1	30-07-2009
		US 2009192370 A1	30-07-2009
		US 2009192371 A1	30-07-2009
		US 2009192372 A1	30-07-2009
		US 2009192373 A1	30-07-2009
		US 2009192374 A1	30-07-2009
		US 2009192375 A1	30-07-2009
		US 2009192376 A1	30-07-2009
		US 2009192377 A1	30-07-2009
		US 2009192378 A1	30-07-2009
		US 2009192379 A1	30-07-2009
		US 2009198115 A1	06-08-2009
		US 2009198116 A1	06-08-2009
		US 2009198175 A1	06-08-2009
		US 2009203978 A1	13-08-2009
		US 2009209838 A1	20-08-2009
		US 2009210164 A1	20-08-2009
		US 2009216101 A1	27-08-2009
		US 2009216102 A1	27-08-2009
		US 2009227940 A1	10-09-2009
		US 2009227941 A1	10-09-2009
		US 2009228214 A1	10-09-2009
		US 2009292189 A1	26-11-2009
		US 2009312619 A1	17-12-2009
		US 2010056889 A1	04-03-2010
		US 2010056890 A1	04-03-2010
		US 2010056891 A1	04-03-2010
		US 2010069729 A1	18-03-2010
		US 2010099967 A1	22-04-2010
		US 2010099968 A1	22-04-2010
		US 2010099969 A1	22-04-2010
		US 2010100078 A1	22-04-2010
		US 2010106001 A1	29-04-2010
		US 2010160748 A1	24-06-2010
		US 2010160761 A1	24-06-2010
		US 2010168658 A1	01-07-2010
		US 2010168659 A1	01-07-2010

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/US2016/040227

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
		US 2010179398 A1	15-07-2010
		US 2010222659 A1	02-09-2010
		US 2010222660 A1	02-09-2010
		US 2010223021 A1	02-09-2010
		US 2010234709 A1	16-09-2010
		US 2010240974 A1	23-09-2010
		US 2010241388 A1	23-09-2010
		US 2010256471 A1	07-10-2010
		US 2010256472 A1	07-10-2010
		US 2010268044 A1	21-10-2010
		US 2010268045 A1	21-10-2010
		US 2010268046 A1	21-10-2010
		US 2010268047 A1	21-10-2010
		US 2010268048 A1	21-10-2010
		US 2010268049 A1	21-10-2010
		US 2010268050 A1	21-10-2010
		US 2010274111 A1	28-10-2010
		US 2010280345 A1	04-11-2010
		US 2010280346 A1	04-11-2010
		US 2010292552 A1	18-11-2010
		US 2010292553 A1	18-11-2010
		US 2010292554 A1	18-11-2010
		US 2010292555 A1	18-11-2010
		US 2010298681 A1	25-11-2010
		US 2010298682 A1	25-11-2010
		US 2010312078 A1	09-12-2010
		US 2010324394 A1	23-12-2010
		US 2010324396 A1	23-12-2010
		US 2010324399 A1	23-12-2010
		US 2010324400 A1	23-12-2010
		US 2010324402 A1	23-12-2010
		US 2011015510 A1	20-01-2011
		US 2011077481 A1	31-03-2011
		US 2011077489 A1	31-03-2011
		US 2011077491 A1	31-03-2011
		US 2011092897 A1	21-04-2011
		US 2011112389 A1	12-05-2011
		US 2012238833 A1	20-09-2012
		US 2014051957 A1	20-02-2014
		US 2015065818 A1	05-03-2015
		WO 9956613 A1	11-11-1999
WO 2011039745 A1	07-04-2011	AU 2010302270 A1	17-05-2012
		CA 2776039 A1	07-04-2011
		CN 102665535 A	12-09-2012
		EP 2482715 A1	08-08-2012
		JP 2013526888 A	27-06-2013
		KR 20120094532 A	24-08-2012
		US 2012209088 A1	16-08-2012
		WO 2011039745 A1	07-04-2011