

ABSTRACT

A method for measuring a combination of Human Body Vital parameters including ECG, Blood Oxygen level, Cuffless Blood Pressure measurement, Temperature, Activity tracker including pedometer and sleep monitor. The calculated data is transmitted remotely via a

CLAIMS

1. An automatic integrated wearable wireless device for measuring electrical activity of heart , blood oxygen, temperature, heart rate variability, activity in terms of number of steps taken and trends monitoring comprising of ,
 - a. Detecting the electrical activity of the heart using a 3-lead electrode based electrocardiograph (ECG), blood pulse wave using optical sensors, temperature using Infrared thermometer, activity measurement using 3-Axis accelerometer with the ECG and pulse detected over the fingers of the user.
 - b. Extracting and filtering the signals from the blood pulse wave sensor, Infrared sensor, 3-Axis accelerometer, electrocardiogram and finding the feature points from the signals.
 - c. Calculating the Pulse Transit time, Heart rate variability and steps taken from the extracted feature points.
 - d. Calculate the Blood pressure from the Pulse transit time using the polynomial regression coefficients.
 - e. Transmitting the captured data to a mobile/desktop computing device for further processing.

2. The method of claim 1 where the blood oxygen value is calculated using reflective principle where in,
 - a. Visual and Infrared wavelength signals are captured by toggling the visual and infrared LED's on and off every few milliseconds and capturing the signal reflected from the surface.
 - b. Filtering the signal using a band-pass filter.
 - c. Finding the AC and DC components of the visual and infrared signals to get the blood oxygen value.
3. The method of claim 1 where the electrocardiograph feature signal is extracted by,
 - a. Capturing the ECG signal and passing it through a series of filters and differentiators to get a noise free signal.
 - b. Extracting the R of the QRS complex based on dynamic threshold.
4. The method of claim 3 where the Blood Pressure is calculated by,
 - a. Finding the Pulse Transit time which is time taken the peak of the R-wave to the peak of Pulse Wave.
 - b. Passing this resultant time to a polynomial regression model compromising of the age and height of the user to calculate the Systole and the Diastole values.
5. The method of claim 1 wherein using a 3-axis accelerometer is used to detect the number of steps made by the user and monitoring the movement characteristic's during sleep.
6. The method of claim 5 where the result from the movement during sleep and the blood oxygen level values are calculated to map the sleep characteristics of the user.
7. The method of claim 1 where the software sent to the mobile/desktop computing device provides an integrated health dashboard which displays all the measured parameters along with trends over the period of time the invention was sending data and uploading the health and activity data to an external or to a series of servers connected together using Internet and Intranet.
8. The method of claim 7 where other users of the program running different mobile/desktop computing devices has the ability to download, view and compare activity and health data of different users based on the different levels of permission given by the individual user.
9. The method of claim 7 where the health parameters received are analyzed with older data of the same user to identity health conditions and activity status in relation with different health parameters.
10. The method of claim 7 where the analyzed trends data could be compared to detect arrhythmia, stress, sleep patterns, activity factors causing blood pressure changes at different intervals of time.
11. The method of claim 1 where the invention can communicate with mobile/desktop computing unit wireless using Bluetooth, WiFi or any other wireless communication scheme.

wireless interface to a mobile or desktop computing device and the final result is also uploaded to a central server for further data analytics.

Images:

Fig 1:-

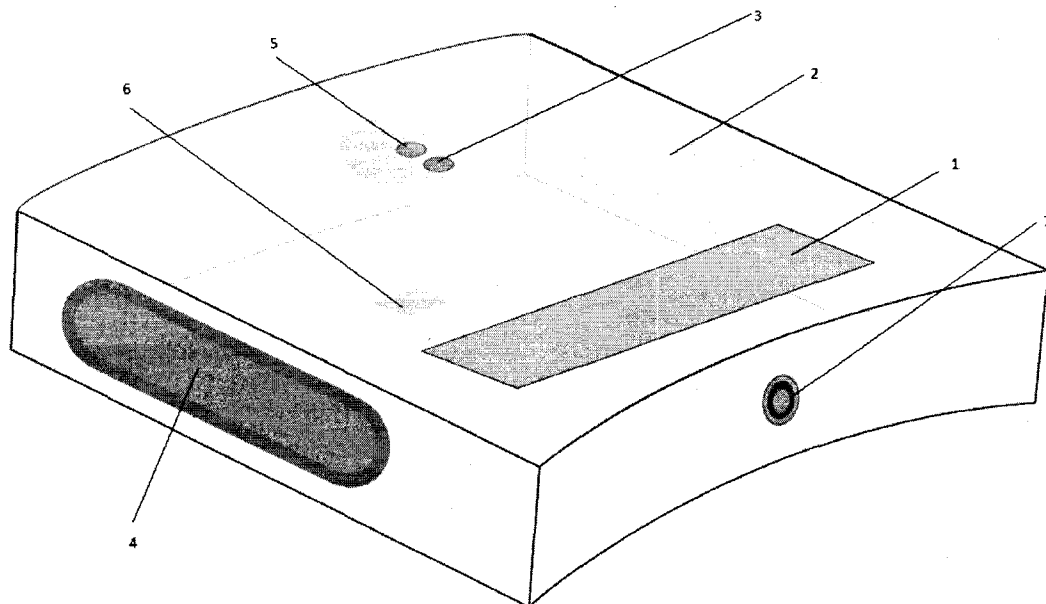


Fig 2:-

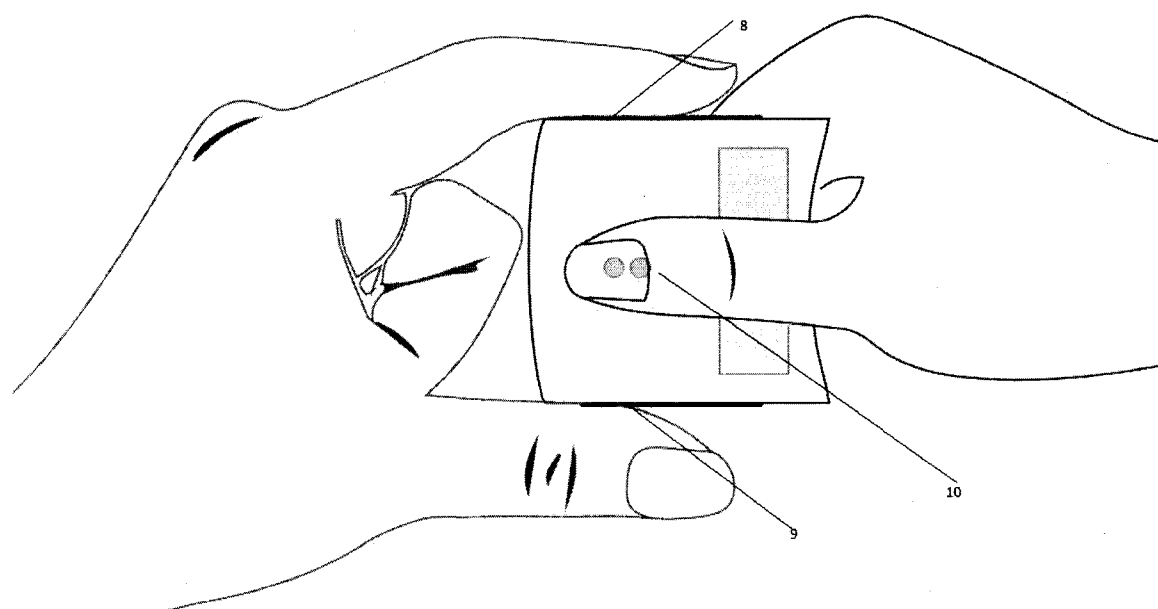


Fig 3:-

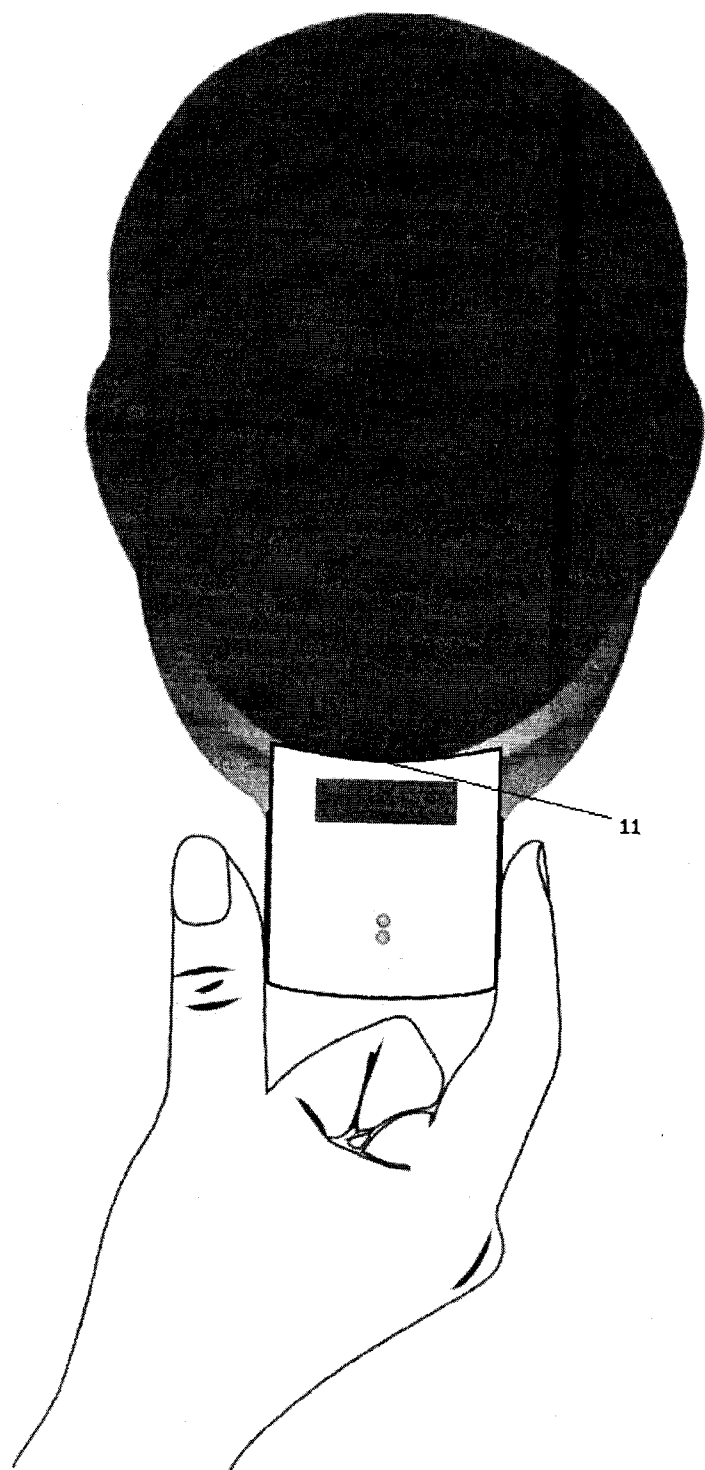


Fig 4:-

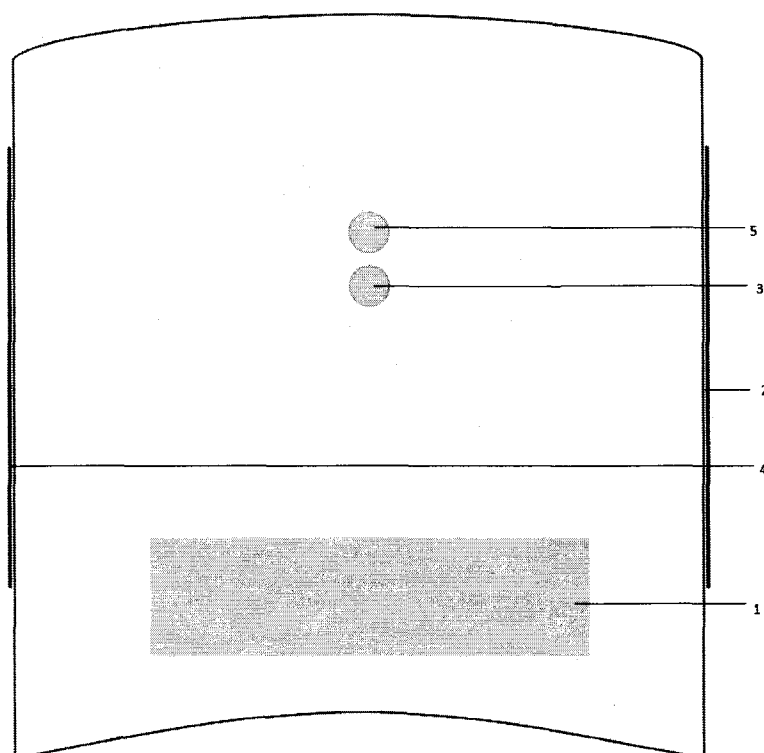


Fig 5:-

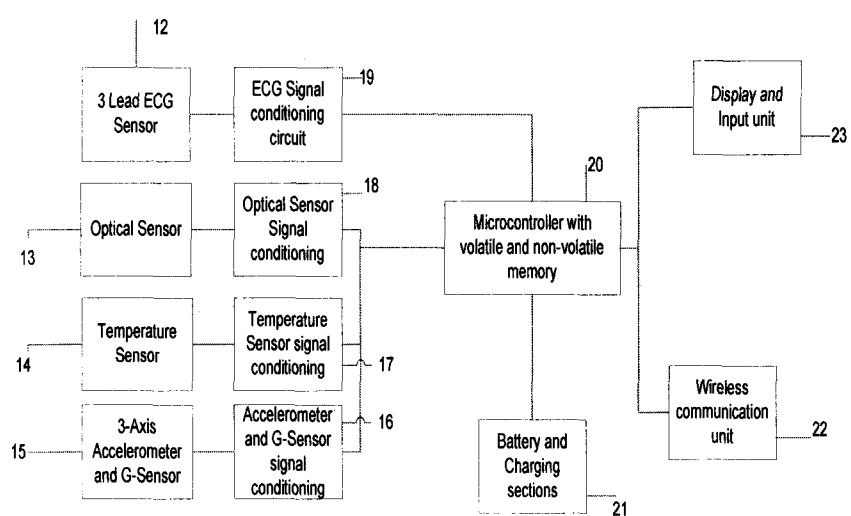


Fig 6:-

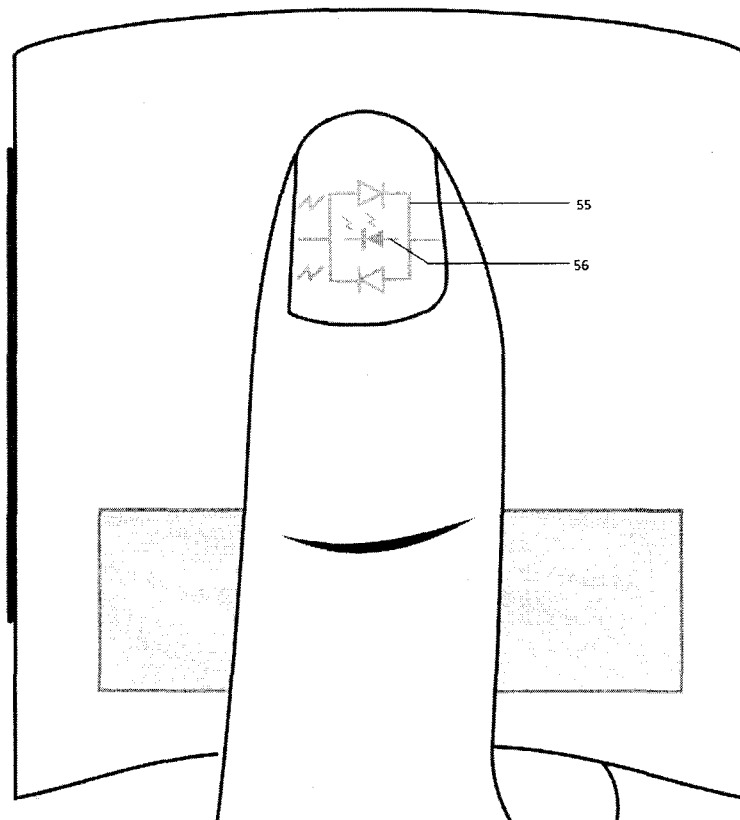


Fig 7:-

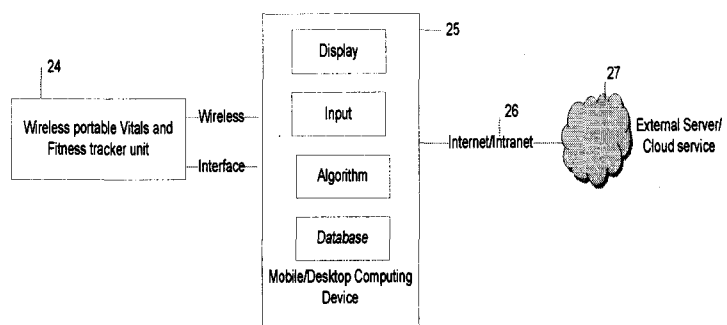


Fig 8:-

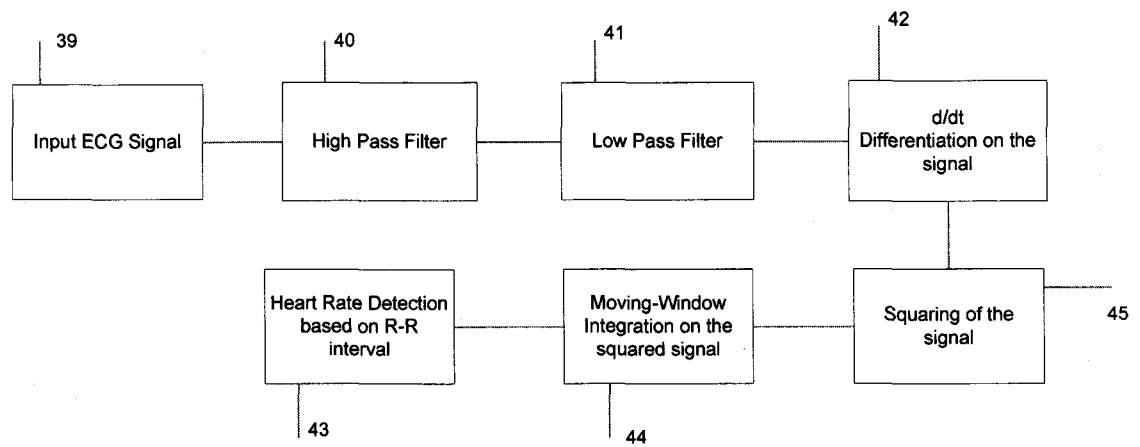


Fig 9:-

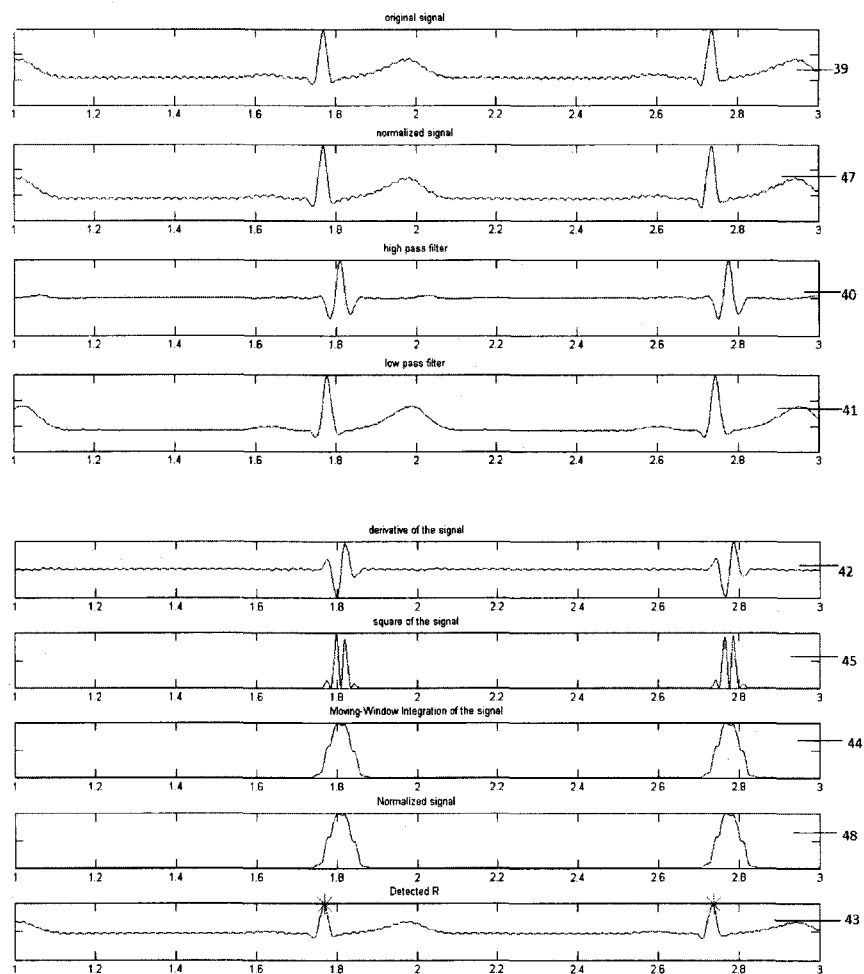


Fig 10:-

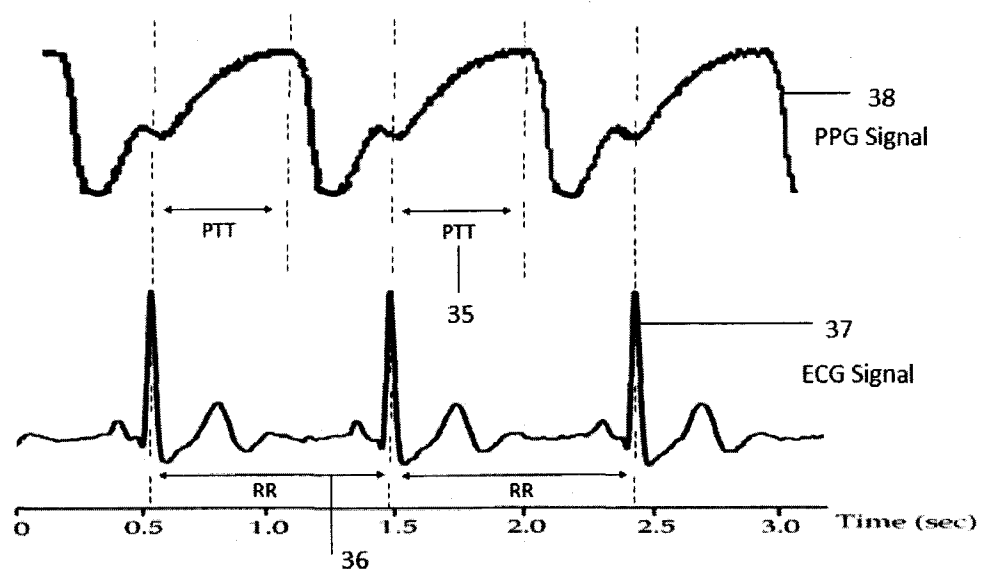


Fig 11:-

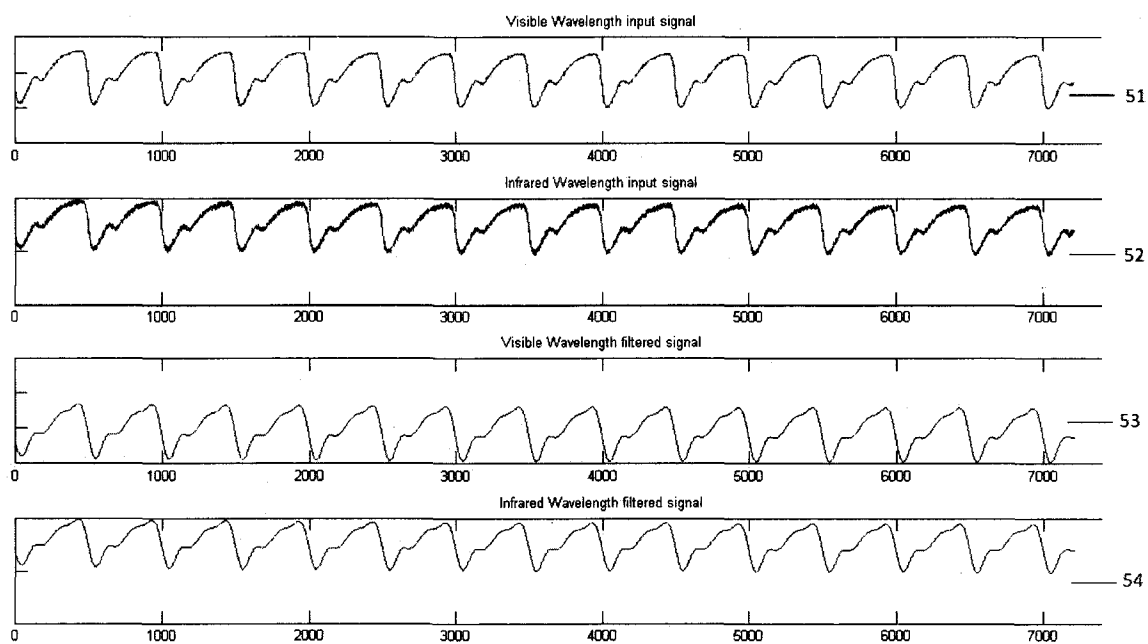


Fig 12:-

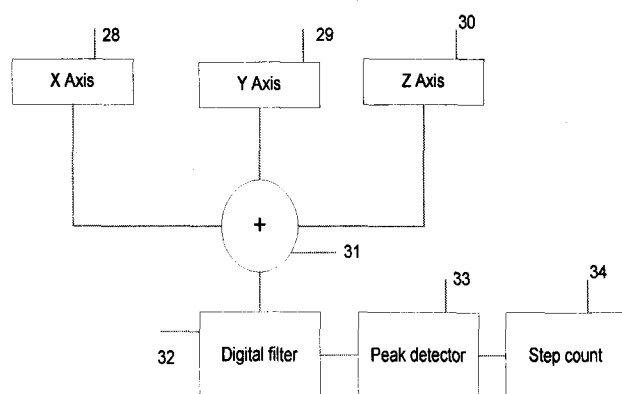


Fig 13:-

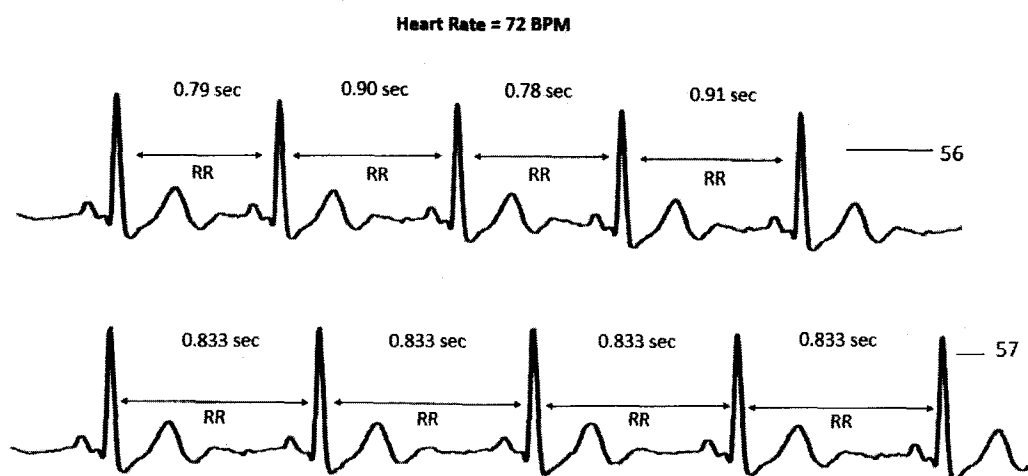


Fig 14:-

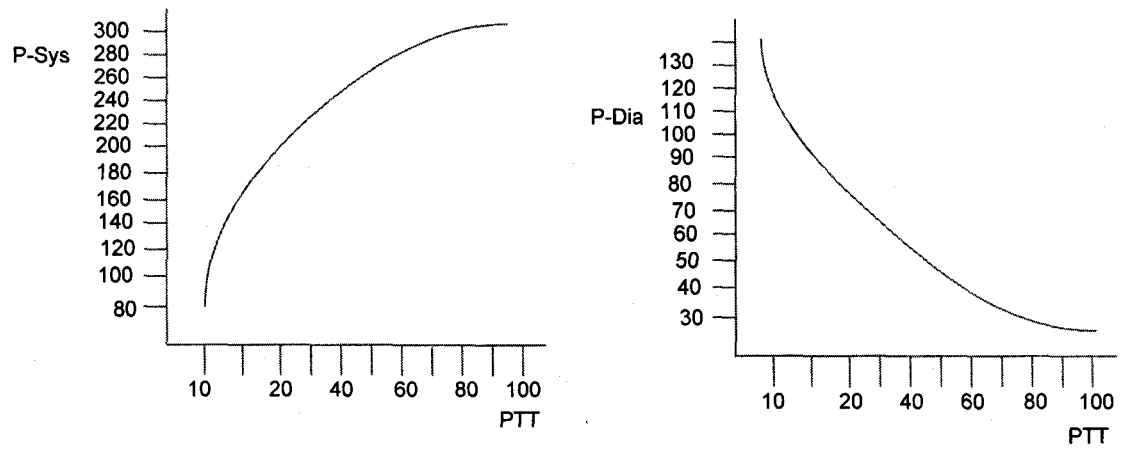


Fig 15:-

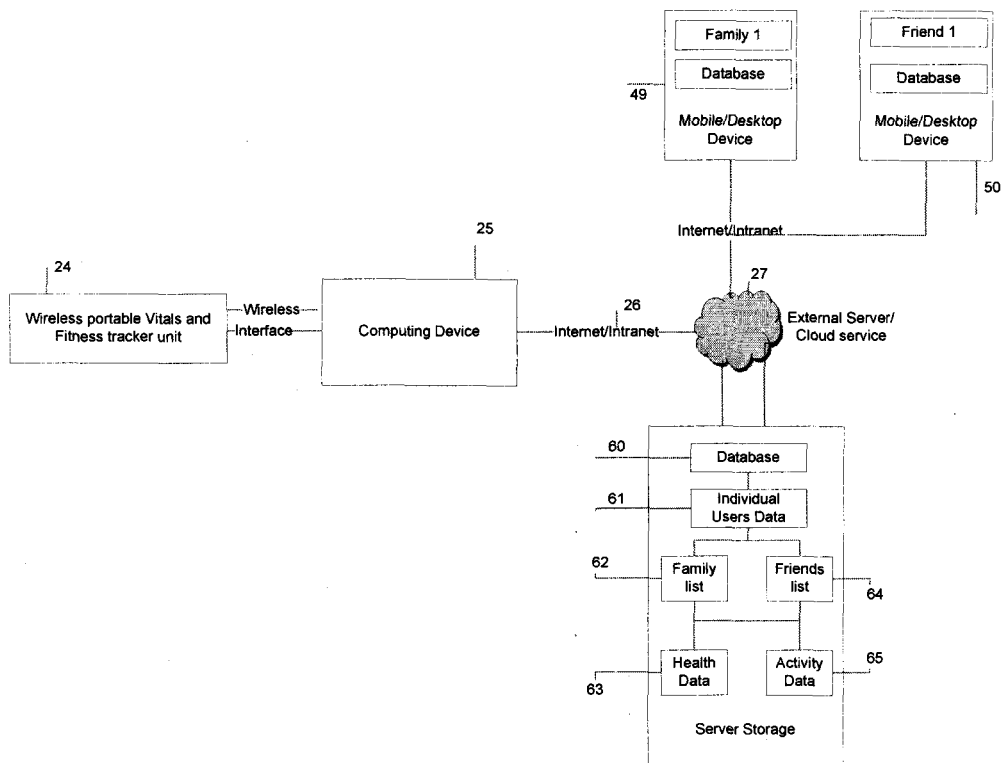


Fig 16:-

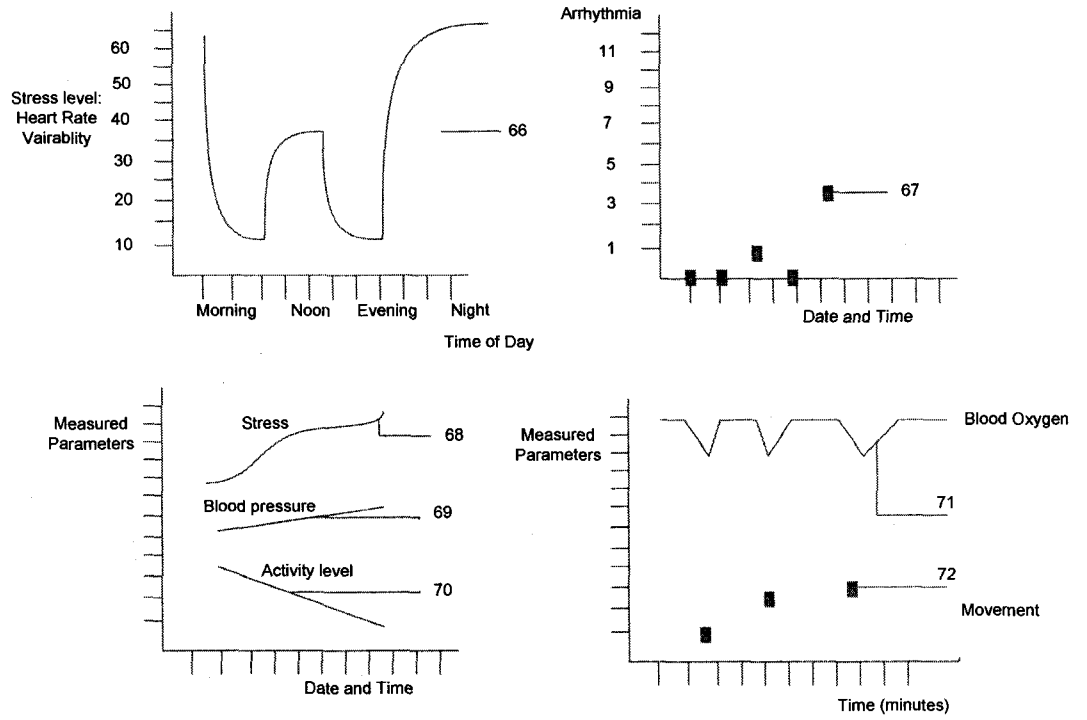
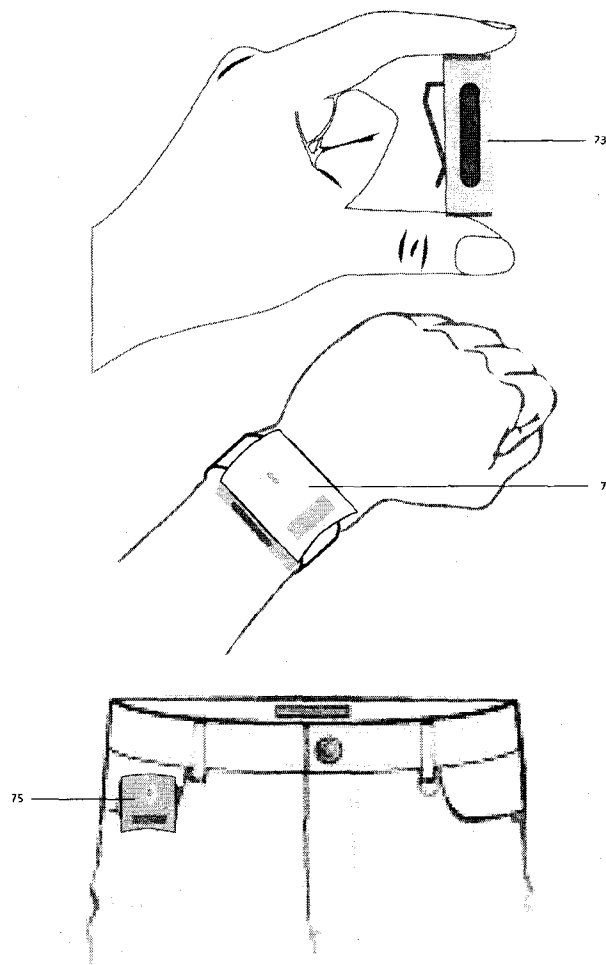


Fig 17:-



WIRELESS WEARABLE VITAL AND ACTIVITY TRACKER

BACKGROUND OF THE INVENTION

1. Field of invention

This invention relates to an apparatus and method for acquiring electrocardiogram, pulse wave, temperature and number of steps taken to analyze and compute the Blood Pressure, Heart Rate Variability, Blood Oxygen and Activity in terms of number of steps taken and Sleep analysis of the user using this invention.

2. Description of related art

In present day and age due to both the lack of exercise and dietary habits Health ailments like high blood pressure, heart problems, stress and other related health conditions are on the rise.

Conventional electrocardiogram measurements rely on bulky wires connected to the patient's chest and the data analyzed in a clinical environment which makes unsuitable to be used in a simple efficient manner. For Blood pressure two methods are employed one of which is an invasive measurement using a catheter inserted into the artery of the patient in a clinical environment by trained physicians and other method involves the use of trying an occluding bladder called as a cuff over the brachial artery and measuring the blood pressure. While the invasive catheter method is not possible in a home setting, the cuff based method has significant errors due to changes in Arm sizes, disturbance in the environment, old or young patients and with infants and hence the requirement for an alternate method of Blood Pressure measurement. Activity trackers typically do not offer any information on health conditions.

There has been many attempts to provide cuffless Blood pressure monitoring and as referred in U.S. Pat. No. 6,413,223, U.S. Pat. No. 6,669,648 and U.S. Pat. No. 8,086,301 but these are specific to only blood pressure measurement or they are difficult to affix along with requiring a pressure sensor with constant calibration of the equipment and neither provides information on other health conditions nor tracks the user's activity level along with correlating with other health parameters to provide a single consolidated health and activity measurement reading like the current invention.

Since the measurement of health parameter's and activity provides important information on a user health and general well-being there has been long need to provide an integrated, wearable solution for both activity and health vital parameters tracking and data analytics system which is the current invention aims to address.

SUMMARY OF THE INVENTION

The current invention is intended to be an integrated, portable, wireless health and activity tracker which interface's to a mobile or desktop computing device using a wireless interface to send and receive the collected and compute data. In its exemplary embodiment the invention includes an electrocardiogram, pulse wave detection optical visual and infrared probes, Infrared temperature sensor and 3-Axis accelerometer using which Heart Rate Variability analysis, Blood Oxygen, Temperature, Stress and activity level is detected.

In another exemplary embodiment the result from the electrocardiogram and the pulse wave detected by the visual and infrared probes is correlated to calculate the Blood pressure of the individual.

Another exemplary embodiment is that the user's physical activity is tracked in terms of number of steps taken by the user is logged, the number of sleep hours along with the other tracked health parameters and sent to the mobile/desktop computing device for data logging and analysis.

By another exemplary embodiment, using the electrocardiogram the user's heart rate variability analysis is calculated with both resting and active electrocardiogram taken at different time intervals and the stress level of the user is calculated.

Another exemplary embodiment, the calculated health parameter data is stored in the Mobile/Desktop computing device and the data and trends of the user are analyzed over the course of the usage of the invention with the ability to set goals to be achieved by the user and to track the health and activity data.

Yet another exemplary embodiment of the invention is to provide for sharing the health and activity data with other users with the ability to control the amount and type of data which could be shared selected dynamically.

BRIEF DESCRIPTION OF THE DRAWINGS

Figure 1 shows the isometric view of the invention with section 1 inside figure 1 showing the display screen, sections 2, 3 and 4 shows the three electrodes of the electrocardiogram, section 5 shows the placement of the optical sensors for pulse wave measurement, section 6 shows the placement of the 3-axis accelerometer and section 7 shows the placement of Infrared sensor for temperature measurement.

Figure 2 shows the invention in usage where section 8 and 9 shows two fingers of the hand pressing on the two electrodes and in section 10 the finger in the other hand pressing on the third electrode and optical sensors.

Figure 3 section 11 shows the invention pressed against the forehead of the user to measure the temperature.

Figure 4 shows the 2-Dimensional view of the invention with section 1 shows the display screen, sections 2, 3 and 4 showing the electrodes and section 5 showing opening for the optical probe.

Figure 5 shows the block diagram of the hardware section of the invention including the signal processing and conditioning sections, microcontroller, wireless, display and battery charging sections.

Figure 6 shows the operation of the Pulse wave detector with the Visual and Infrared Light Emitting diodes and light detector based on reflectance principle.

Figure 7 shows the block diagram of the invention communicating with the external mobile/desktop computing device which acts as the display, input, algorithm processing and database section along with the ability to upload to a cloud or external storage server via internet/intranet.

Figure 8 shows the block diagram of the ECG algorithm running in the microprocessor which is used to detect the peaks and heart rate variability.

Figure 9 shows the result of the ECG algorithm operation on an actual signal taken from a laboratory condition.

Figure 10 shows the relation between the electrocardiogram signal's peak and pulse wave signal peak called as Pulse Wave Transit time.

Figure 11 shows the output signal from the visual and infrared probes for Pulse wave detection called as Photoplethysmogram (PPG) signal (38) and the filtered output of these two input signals.

Figure 12 shows the algorithm of the step and activity counter block of the current invention with the 3-Axis data input from the accelerometer and input to the device.

Figure 13 shows the Heart Rate Variability with section 57 showing an example of less variability and section 56 showing an example of high heart rate variability.

Figure 14 shows the graph of the polynomial regression on the pulse transit time value to get the relation to the Systole and Diastole values calculate the Blood pressure.

Figure 15 shows the block diagram of the data sharing feature which is allowed by the invention with the ability of the user to dynamically select the type of data which could be shared.

Figure 16 shows the example different trends monitoring with the data captured from the invention.

Figure 17 shows the example of different methods of placing the invention on the user.

DETAILED DESCRIPTION

A new approach to provide an integrated solution for human Vital parameters, Activity tracking and Trends reporting is described in the below sections with the design and methods described.

From Figure 1 and Figure 4 the isometric view and two-dimensional figure of the invention is shown where the invention has a display (1) , three electrodes for electrocardiogram measurement (2,3 and 4) , optical and infrared detectors for pulse wave detection (5), 3-axis accelerometer (6) and an Infrared sensor (7) and the whole sensor arrangement is placed and soldered in a Printed Circuit Board(PCB) (Figure 5) with the mechanical casing shown in Figure 1 covering the PCB and other components like the battery, display and connectors.

Figure 2 shows an exemplary embodiment of the device in operation to measure the health vital parameters where in Figure 2 shows the left thumb (9) along with left index finger (8) pressing against the two electrodes of the electrocardiogram (2 and 4) and the right thumb (10) pressing against the third electrode of the electrocardiogram (3) and optical sensor (5) used to measure both the electrocardiogram and pulse waves simultaneously and sent for processing. Figure 3 shows the measurement of human temperature where the invention is held against the forehead of the used and using Infrared waves the temperature is measured and displayed.

Referring to figure 17 shows an exemplary embodiment of placing this invention in different positions with section 73 showing the invention held in the hand, section 74 showing the invention connected to a wrist band and placed in the arm and section 75 shows the invention connected to the apparel of the user.

Figure 5 shows the block diagram of the hardware section of the invention in which the components are soldered on printed circuit board with the 3-lead ECG electrodes (12) connected to an ECG signal conditioning circuit (19), Optical sensor (13) its respective signal conditioning section (18), Infrared temperature sensor (14) with its signal conditioning section (17), 3-Axis accelerometer (15) with its signal conditioning section (16) , battery and charging

section (21), wireless communication section (22), display and input (23) are connected to a microcontroller with non-volatile memory like flash memory and Random access memory (20) forms the hardware part of the invention.

Figure 7 shows the overall block diagram of the invention (24) communicating with mobile/desktop computing unit (25) wirelessly and via the mobile/desktop computing unit which could be a Desktop PC , Mobile phone or a Tablet and communicate to a central server or cloud storage (27) using either wired or wireless internet (26).

The mobile/desktop computing unit (25) in addition to sending captured data to a central server also acts as a the Display section to display the results of the vital and health data captured, input section to enter the users details like age, height, gender, weight and other related parameters, has an algorithm section to compute the different health and activity conditions based on the data received from the invention and has a local database to store vital, activity and other related parameter's. The invention works in tandem with the mobile/desktop computing unit for operation and relies on the mobile/desktop computing unit for configuration, synchronizing the data and transmitting vital parameters and activity details.

Referring to Figure 6 shows the Pulse Wave detector with Visual wavelength and Infrared wavelength Light Emitting Diodes LED's (55) and Optical detector also known as a Photo Diode (56) working on reflectance principle where the reflected light from the LED's hitting on the user's finger is captured and analyzed. In this scenario the Visual and Infrared LED's are switched on and off alternatively every few milliseconds and the reflected light along with the ambience is captured both in Visual wavelengths and Infrared wavelengths. For example, from Figure 11 the captured light is available both in the visible light spectrum (51) and Infrared spectrum (52). This is then passed through a band pass filter to remove noise to get Filtered visible light spectrum signal (53) and infrared light spectrum signal (54).

This signal contains both DC and AC components and different signal characteristics based on Photo Diode response curves. Hence the signal is normalized and the final response curve is calculated based on the formula,

$$R = (\text{Visual}_{AC}/\text{Visual}_{DC})/(\text{IR}_{AC}/\text{IR}_{DC})$$

The resulting Ratio values are compared with a pre-existing lookup table and the Blood Oxygen values are calculated

From Figure 8 and 9, the Input ECG signal (39) which is received from the electrodes is processed to perform Heart Rate Variability analysis of the user. As shown in the Figure 9 the original signal is first normalized (47) and then passed through a cascaded digital band pass filter that is a high pass filter(40) followed by a low pass filter(41). The filtered signal is then differentiated (Figure 9, 42) to obtain information about the slope of the QRS wave which is followed by squaring stage (45) which intensifies the slope of the frequency response curve of the derivative and restricts false T waves. This is followed by the signal integrated over a Moving Window (44). The resultant signal contains information of both the slope and width of the QRS complex. On the integrated signal peak R of the QRS complex is detected based on a dynamically calculated threshold (43). Based on the interval between two consecutive R waves one can detect the variability in the Heart Rate at various interval of time.

From Figure 10 Pulse Transit Time (PTT) is the time taken between the Peak of the R wave (37) and the peak of the Pulse Wave (38) which corresponds to the time takes for the blood to

flow from heart to the Finger. This PTT is directly proportional to Blood Pressure using the relation,

$$\text{Blood Pressure} = \text{Constant1} + \text{Constant2} * \text{PTT}.$$

The factors which cause the constant differences are due to the height and age of the user. By running a set of laboratory experiments from a set of volunteers from whom their Age, Height is entered and Pulse Transit time (PTT) measured and a corresponding BP reading using conventional equipment's like either a manual or automated sphygmomanometers the volunteers Systole and Diastole is calculated. Then using polynomial regression between PTT, height, age and the measured Systole and Diastole, two sets of regression coefficient's calculated with one for Systole and other for Diastole calculation from PTT.

Referring to Figure 14, the polynomial regression relation is then stored in the software of the mobile/desktop computing device and when the user measures the Blood Pressure from the invention the PTT(35) is calculated and fed into the pre-calculated regression formula to find the Systole and the Diastole values which corresponds to the Blood Pressure of the Individual.

Figure 12 shows the algorithm of the Step detection mechanism where data from 3-Axis accelerometer (Figure 5 , section 15) the X axis (28), Y-Axis (29) and Z-Axis (30) received and summed (31) and passed through a digital filter and dynamic peak detector to remove any false steps and the number of steps is counted. The same principle is used to measure the number of hours a user has slept when using the invention which is counted as the number of times the sensor recognized movement when the user wears the invention in the hand or wrist when going to sleep which would estimate sleep parameters.

Figure 13 shows the signal form laboratory conditions on the captured heart signal in two conditions where time between the two R-peaks is calculated referred to RR time interval. In first condition (56) in figure 13 shows the maximum time difference between two R-peaks and the second condition (57) shows very less time difference between two R-peaks for same average heart rate of 72 Beats per minute. This time difference between two peaks is called as Heart Rate Variability and measured by the invention. From the calculated heart rate variability if the variability is high between subsequent readings then user has less stress and if the variability is less between subsequent readings then the user more stress. This value is compared with the calculated blood pressure from Figure 14 to give the stress level of the user. Also the stress level is mapped to different time intervals and using location services from the connected computing device (figure 7, section 25) to the time and place where the user had maximum stress could be computed and displayed the user for further analysis.

Figure 15 shows another exemplary embodiment of the invention by the ability to share the captured data with other users with different levels of data sharing ability. The invention (24) transmits the data mobile/desktop computing unit (25) which is then via Internet or Intranet (26) to an external server or a series of servers connected together providing a cloud based storage and processing mechanism (27). Data from multiple users are collected and stored in the database (60) and each individual's data (61) has the option for selecting different sharing levels. For example the user can select from a list of people using the same type program running in the computing device as belonging to family (62) or friends (64) with the ability of user to select and send the type and extent of data to be shared with each member in the list, like the users in family would be able to get the full Health (63) and Activity data (65) while the members in the friends list would be able to view only the Activity data of the user or at a level decided by the user. The program running in the Family list (49) or Friends list (50) would

also have the ability synchronize the data records periodically with the ability for offline viewing.

The present invention from the program running in the mobile/desktop computing unit (25) provides the ability to monitor trends and diagnose conditions as then when they appear based on past data records. To illustrate this idea, referring figure 16 shows four different example graphs based on data captured by the invention. The first graph (66) shows Heart Rate Variability (HRV) called as stress plotted against time with the readings measured by the invention. From the example graph it is clear that the HRV is less in the morning and in evening, which is captured by the program running on the computing device and displayed to the user. Similarly the second graph (67) shows Arrhythmia also called as Cardiac dysrhythmia is a condition where the electrical activity is not normal which is that the heart activity could be either faster or slower which is captured by the inventions electrocardiograph. This data is analyzed to show the time and place where the Arrhythmia occurred and display the type of arrhythmia. Another example of trend monitoring is from the third graph (68) which shows the plot of increased stress levels (68), blood pressure (69) and physical activity (70) captured by the invention where the stress increase is inversely proportional to the decrease in physical activity (70). Yet another example of trend monitoring would be sleep monitoring from the fourth graph where the user wears the invention on the wrist and goes to sleep and the invention monitors both the blood oxygen (71) and movement (72) and displays the sleep pattern and sleep duration of the user.

It is understood by those skilled in the art that details regarding some specific exemplary embodiments described above was provided only for clarification in the overall understanding and the scope of the present invention and the invention is not limited only to examples and methods described and hence various changes on size, form or methodologies could be made without deviating from the real scope of the invention and the claims mentioned below.