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Wong et al.(10) **Pub. No.: US 2019/0282105 A1**(43) **Pub. Date: Sep. 19, 2019**(54) **A METHOD FOR OBTAINING THE BLOOD PRESSURE OF A PERSON, AND A DEVICE THEREOF****Publication Classification**(51) **Int. Cl.***A61B 5/021* (2006.01)*A61B 5/024* (2006.01)*A61B 5/00* (2006.01)(52) **U.S. Cl.**CPC *A61B 5/02116* (2013.01); *A61B 5/02125*(2013.01); *A61B 5/1122* (2013.01); *A61B**5/6824* (2013.01); *A61B 5/02416* (2013.01)(71) Applicant: **Well Being Digital Limited**, Shatin,
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New Territories (HK)

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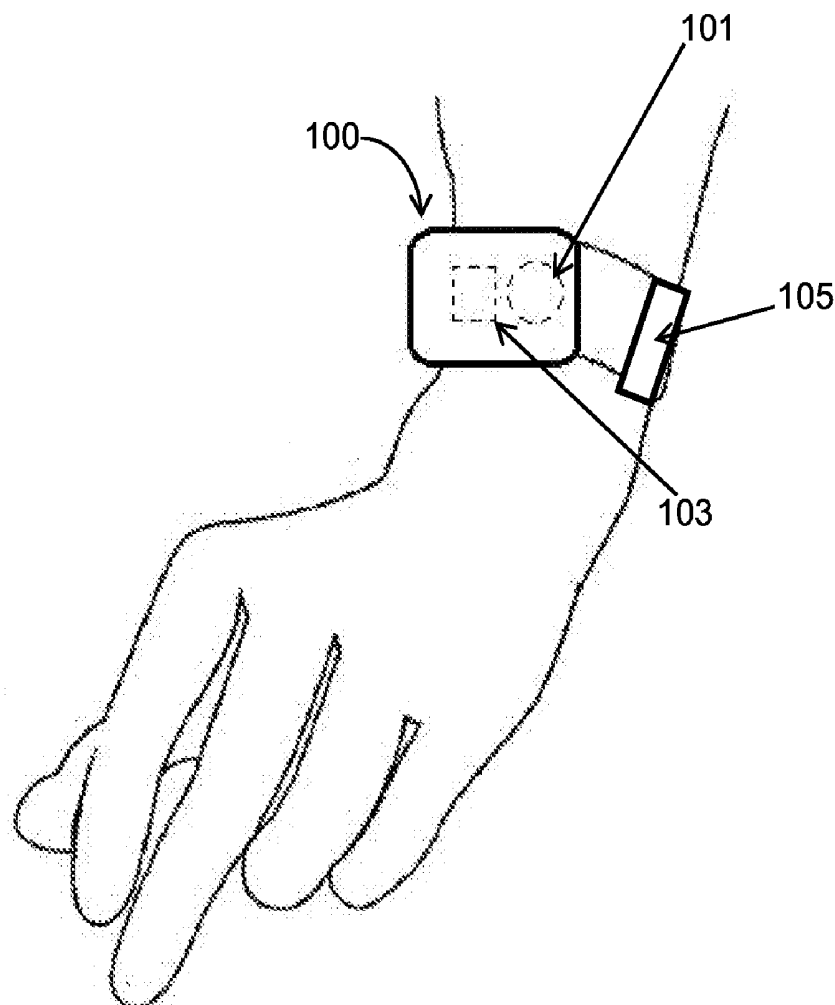
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§ 371 (c)(1),

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A method, and a related device, for obtaining the blood pressure of a person. The method comprising steps of providing a light source (101), and an optical sensor (103) configured to detect light from the light source which has propagated through the wrist of a wearer of the device. The amount of light propagating through the wrist depends on the amount of blood in the wrist. Blood pressure is then observed by monitoring the difference in the amplitude of blood pulsation within the wrist when the wrist is lifted above heart level, and when the wrist is lowered below heart level.



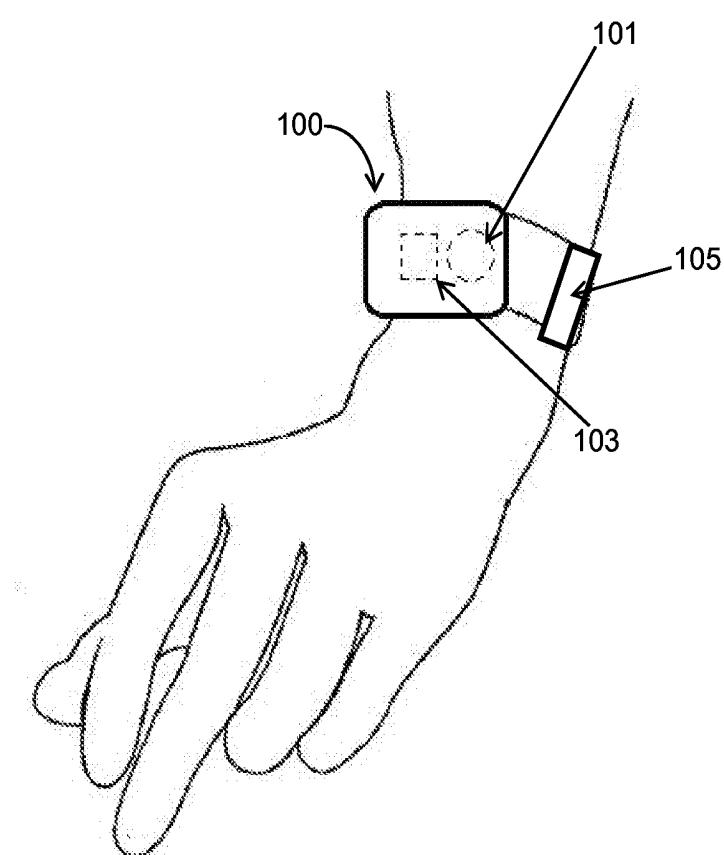


Figure 1

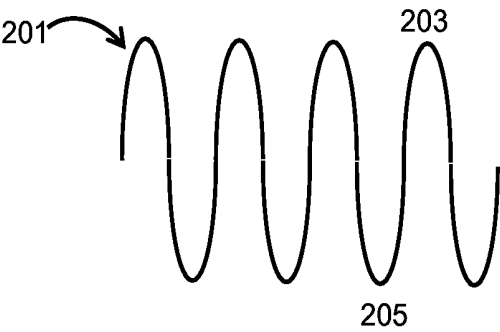


Figure 2

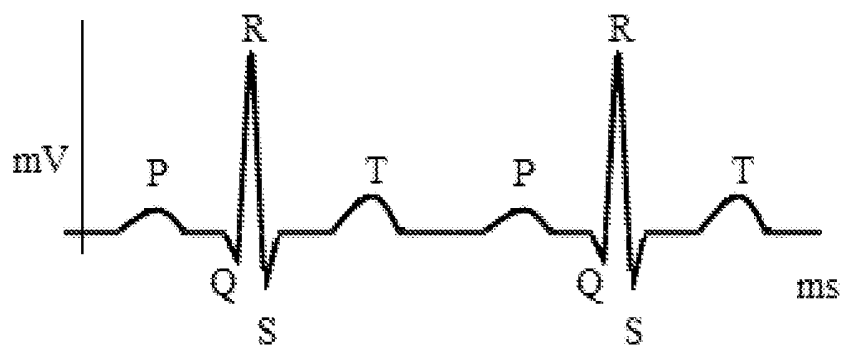


Figure 3

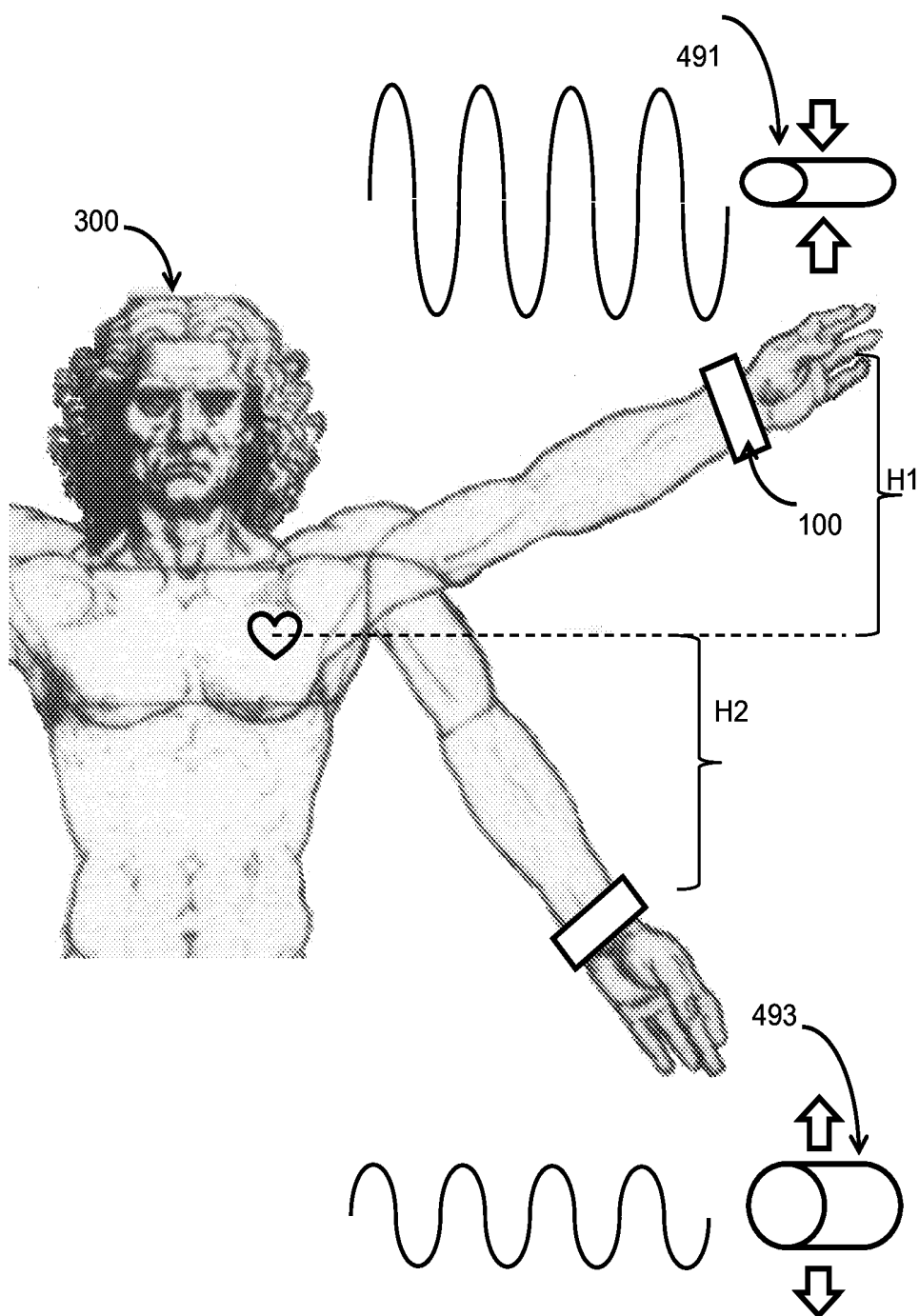


Figure 4

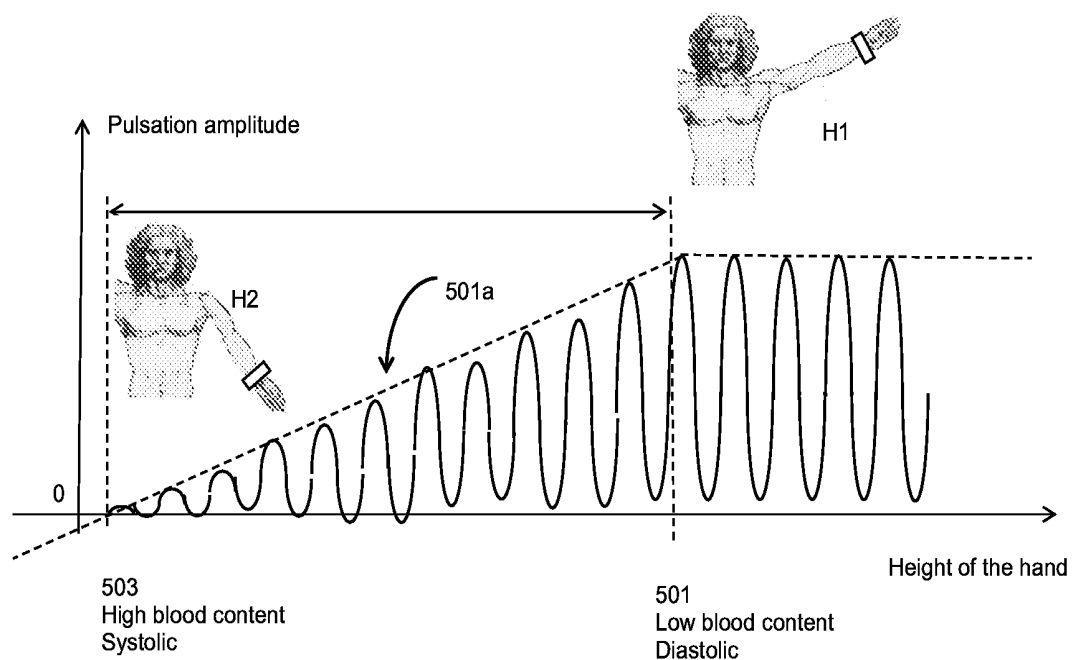


Figure 5

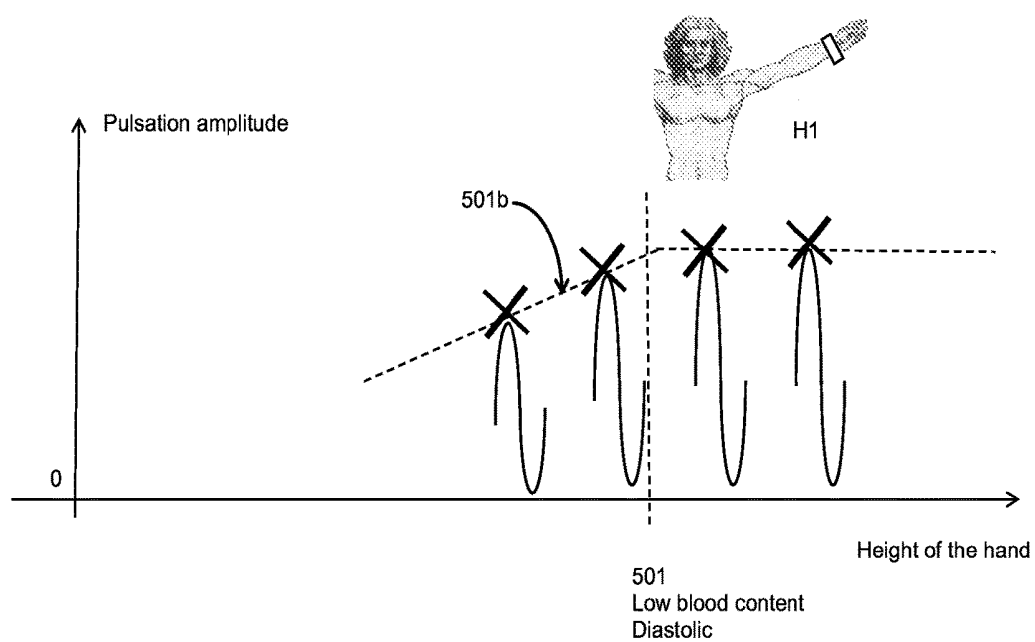


Figure 5a

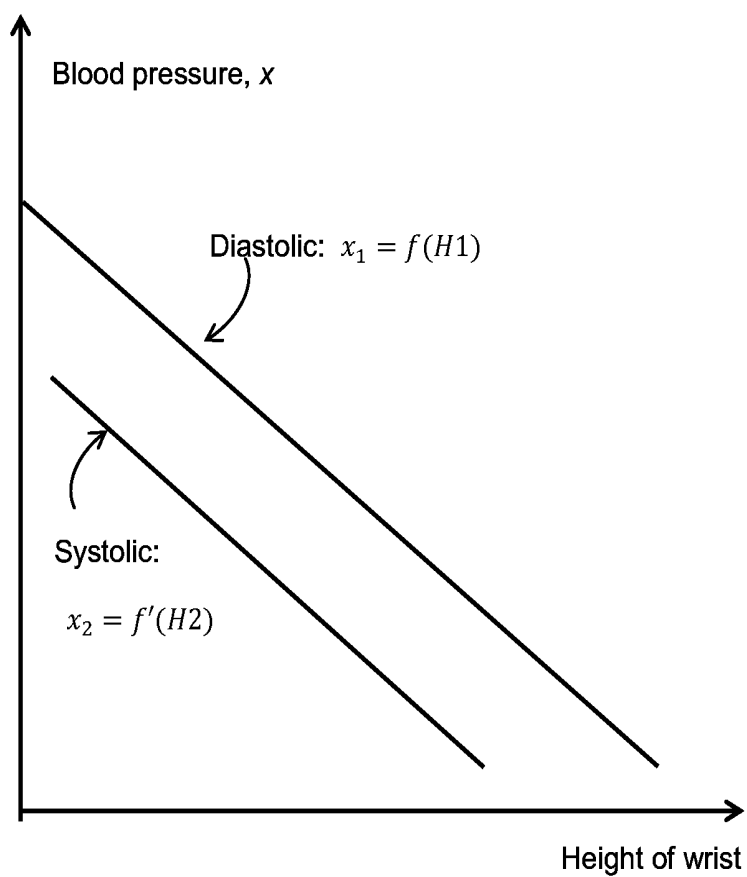


Figure 6

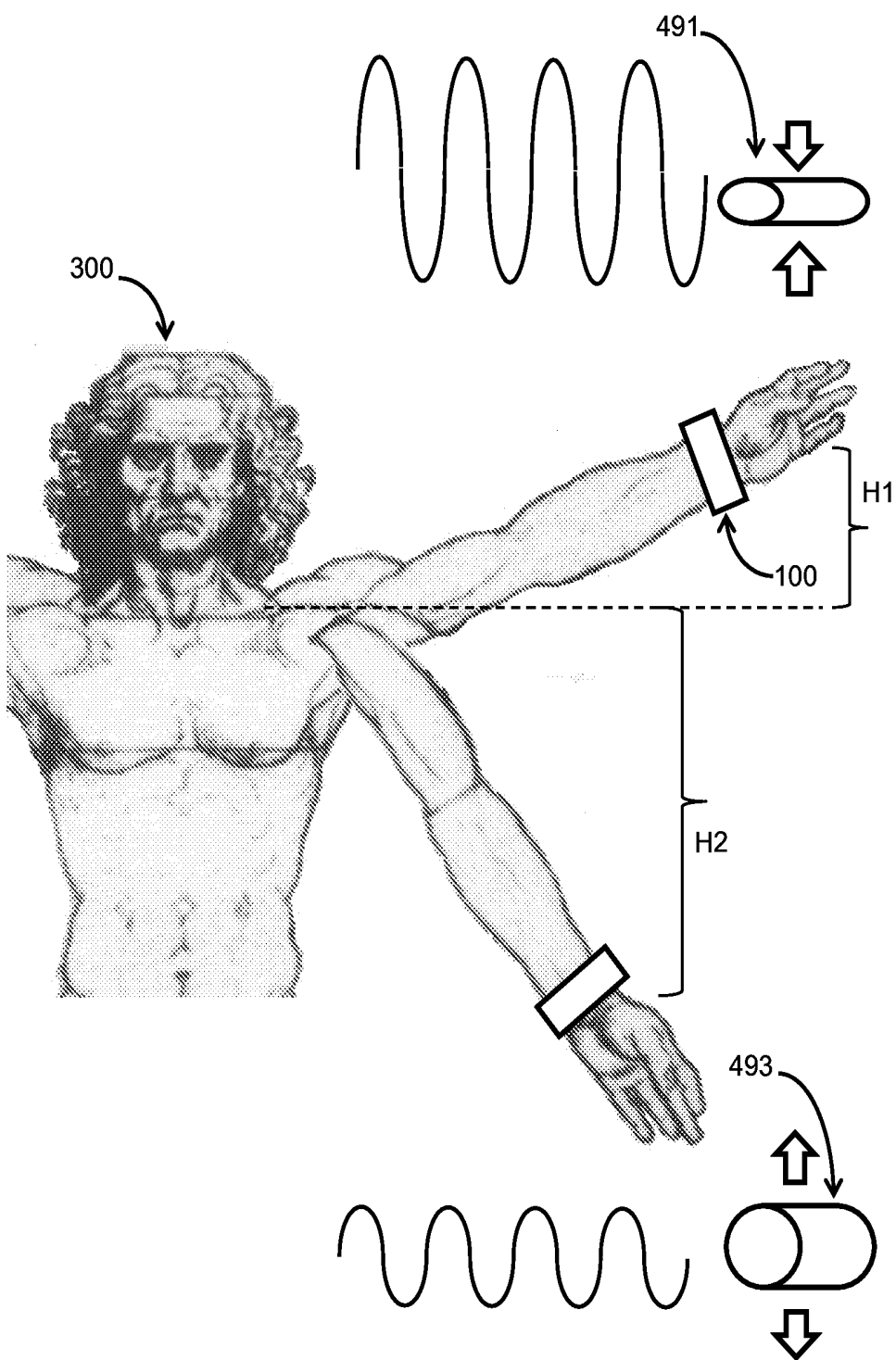


Figure 7

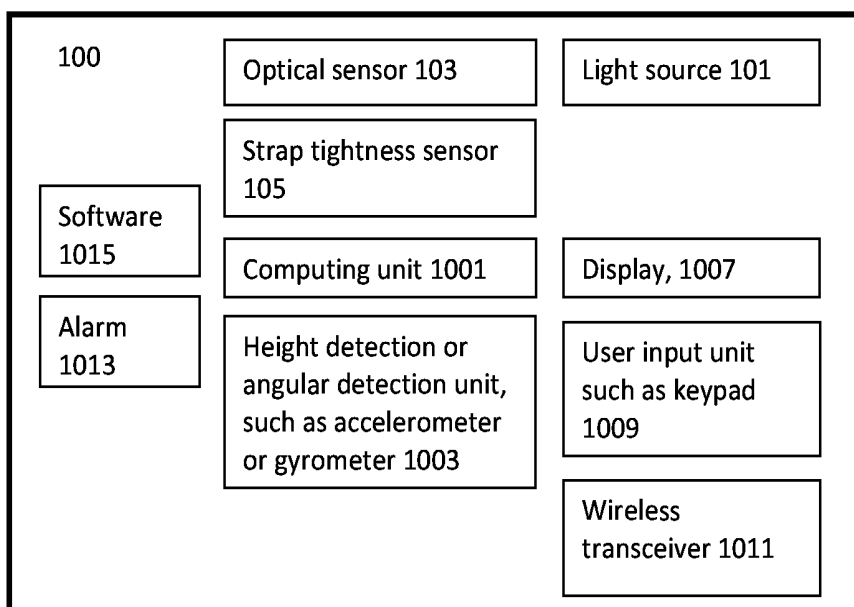


Figure 8

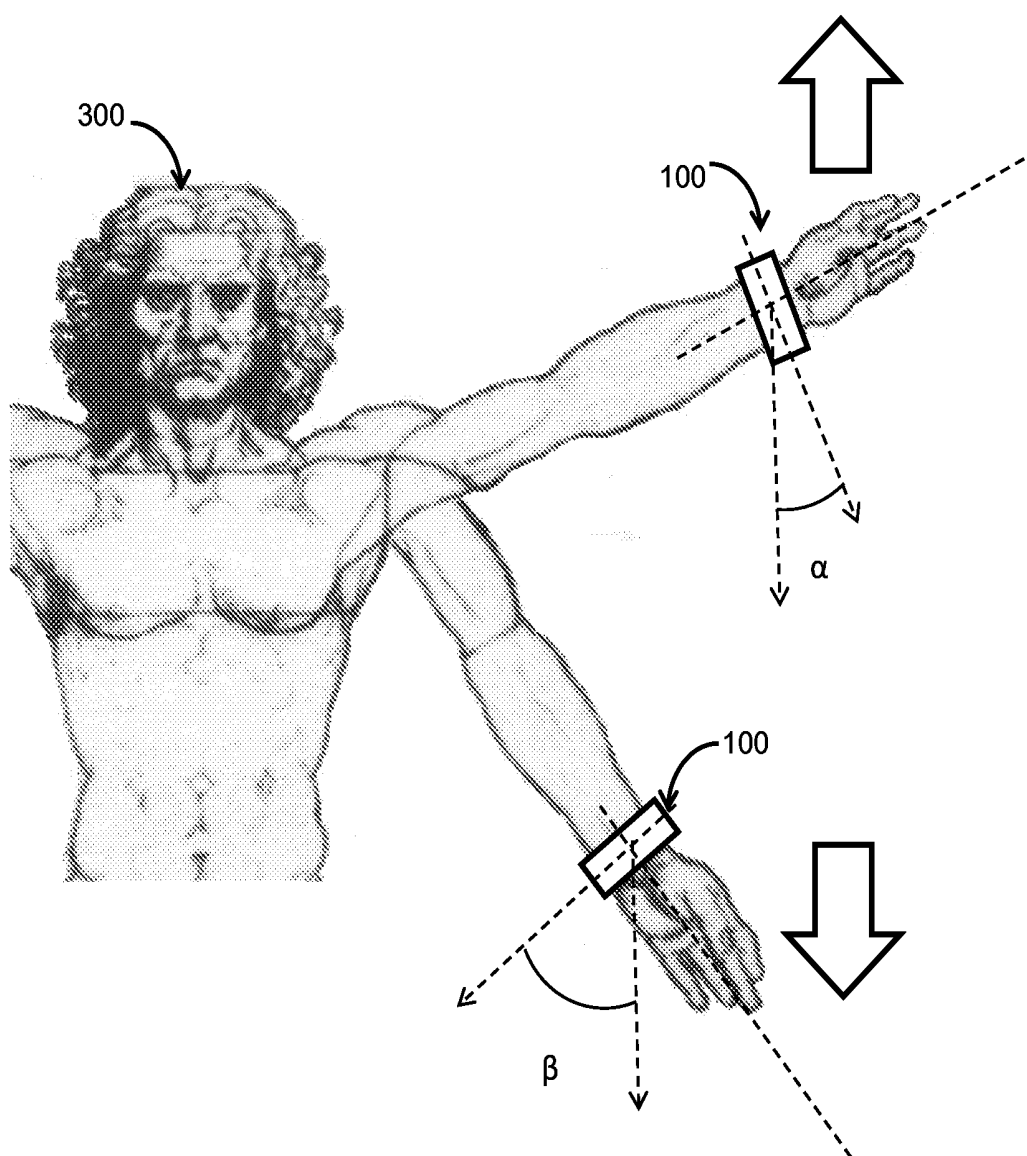


Figure 9

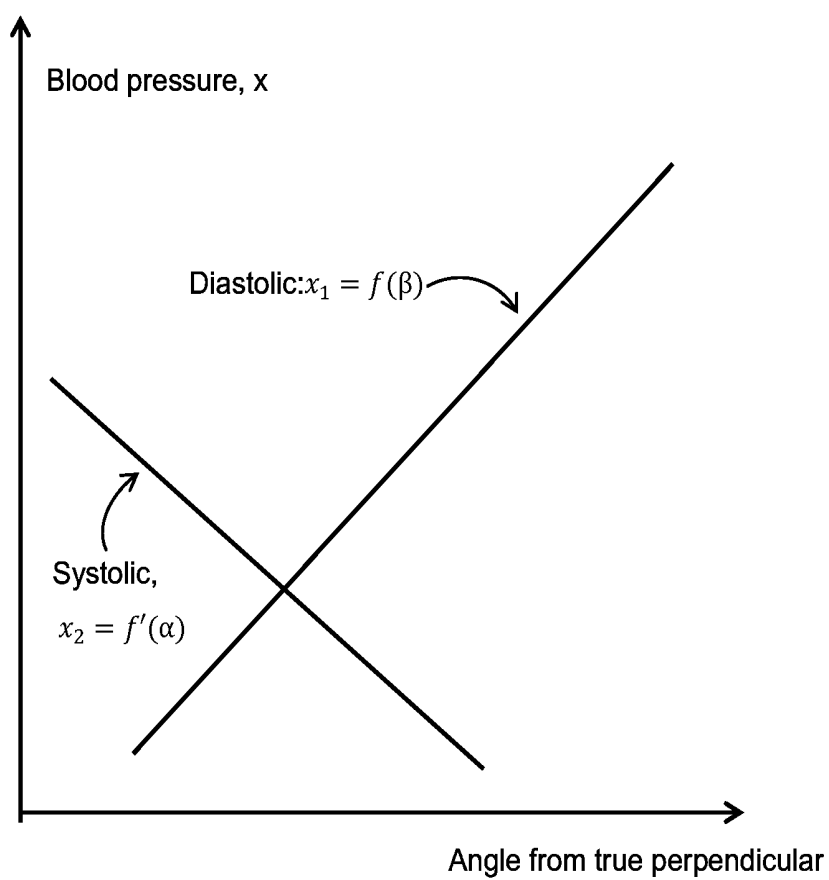


Figure 10

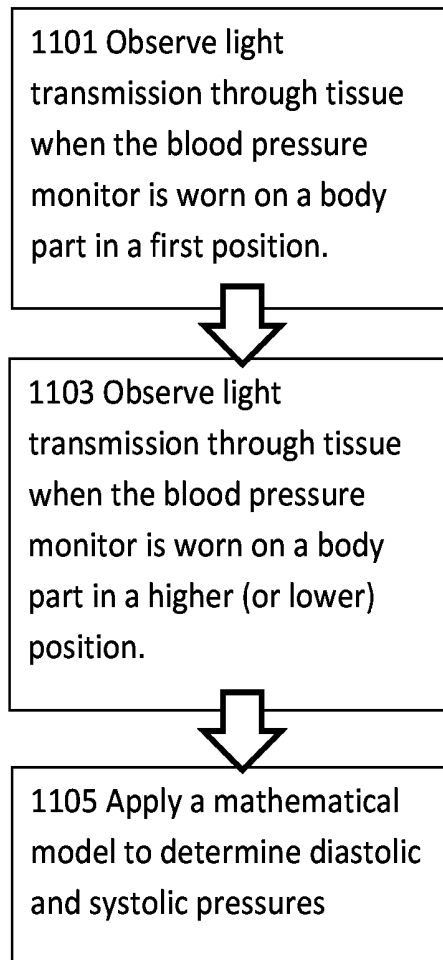


Figure 11

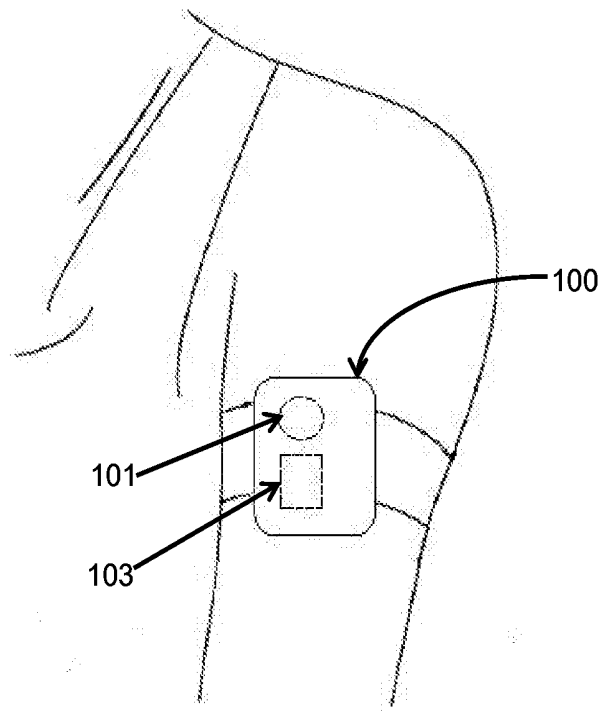


Figure 12

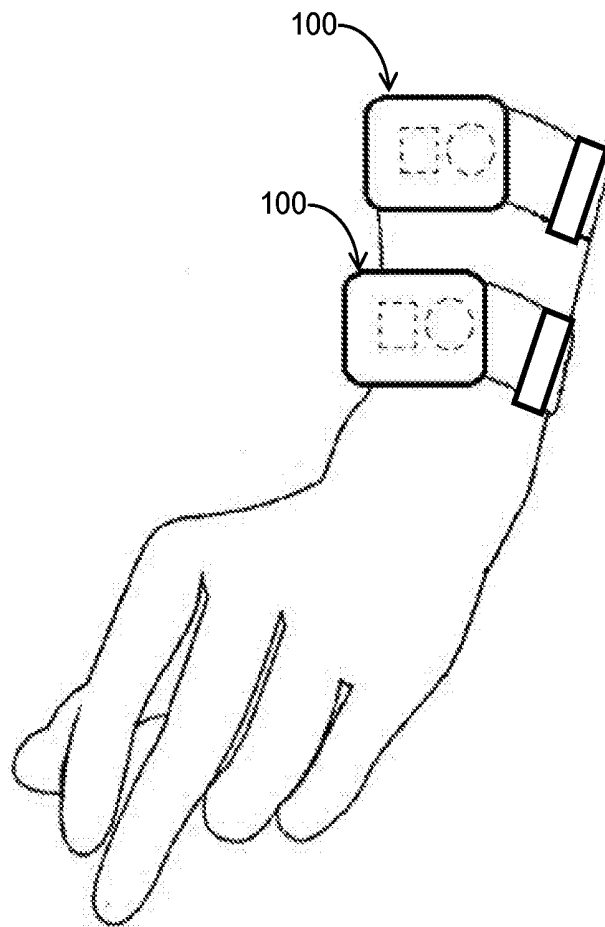


Figure 13

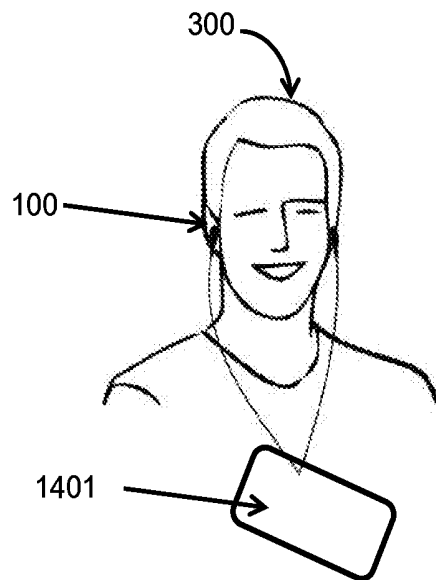


Figure 14

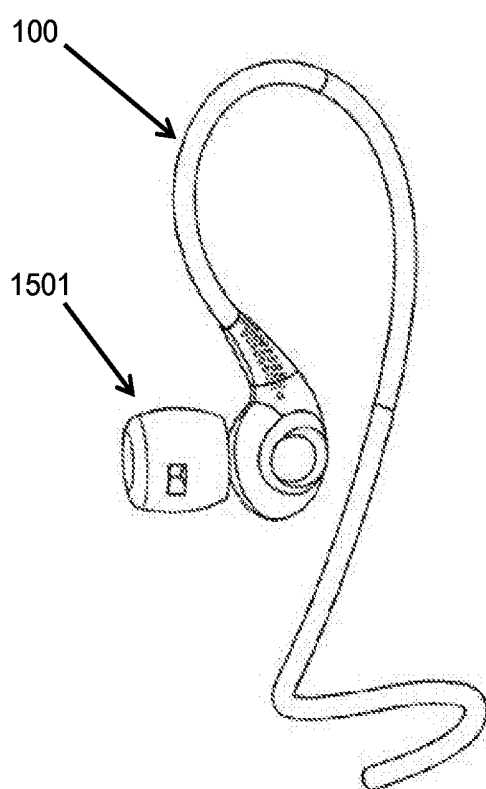


Figure 15

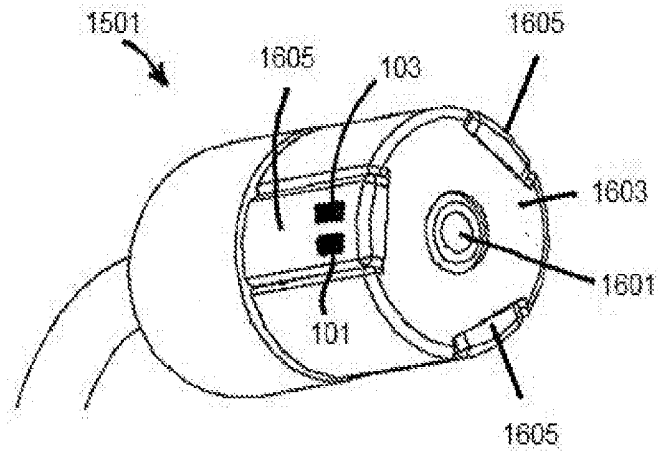


Figure 16

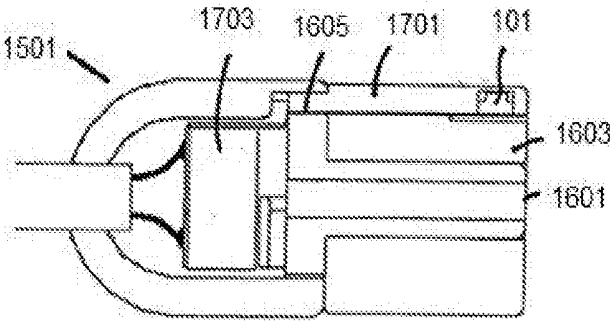


Figure 17

A METHOD FOR OBTAINING THE BLOOD PRESSURE OF A PERSON, AND A DEVICE THEREOF

FIELD OF INVENTION

[0001] This invention relates to an apparatus for monitoring blood pressure, and more particularly to wearable blood pressure monitors.

BACKGROUND OF THE INVENTION

[0002] Blood pressure is measured as part of routine and basic medical examination. Knowing the blood pressure of a subject aids medical diagnosis, and the medical practitioner may be alerted to invisible ailments if the blood pressure of a subject is off limits.

[0003] Blood pressure is fully measured when both systolic blood pressure and diastolic blood pressure are measured. Systolic blood pressure refers to pressure in blood vessels when the heart contracts while diastolic blood pressure refers to pressure in blood vessels when the heart is relaxed.

[0004] A device for measuring blood pressure is called a sphygmomanometer. There are manual and digital sphygmomanometers. A manual sphygmomanometer comprises a cuff to be applied around the bicep tightly, positioned at roughly the same level as the heart while the subject is seated. The cuff is tightened to strangle the bicep. The tightness is released slowly while the practitioner listens to the flow of pounding blood in the brachial artery at the elbow using a stethoscope. The cuff pressure beginning at which sound of pounding blood may be heard is recorded as the systolic blood pressure. The manual sphygmomanometer is installed with a mercury column to allow the operator to read the cuff pressure. As the cuff pressure is released further, the cuff pressure beginning at which the sound of pounding blood can no longer be heard is recorded as the diastolic blood pressure.

[0005] While this method of taking blood pressure is generally accurate, inaccuracies do arise from operator error, poor use of the equipment, and inadequate equipment maintenance.

[0006] The digital sphygmomanometer was developed for portability, and for obviating the need to use mercury and the need for operator training. While lacking the fine accuracy of a mercury column, the digital sphygmomanometer has been found accurate enough for use in a domestic environment by the subject himself. Most digital sphygmomanometers require a pressurised cuff to be tightened around the bicep of the subject, in the same way as a manual sphygmomanometer. Some digital sphygmomanometers require only the cuffing of the wrist or a finger. In any case, the part which is cuffed must be positioned at the same level as the heart. Both the systolic and diastolic pressures are sensed indirectly using piezoelectric, capacitive or electrostatic pressure sensors. The actual reading is calculated by comparing pressure readings against a calibration. Despite the perceived portability, a somewhat elaborate routine is required for the subject to put on the cuff in order to allow the digital sphygmomanometers to operate. Therefore, the subject must find a seat and a table for resting himself against before he may use a digital sphygmomanometer. This is often inconvenient for a subject who needs to have his blood pressure level measured rather urgently in a

crowded urban location. In other words, blood pressure monitors which afford a certain level of privacy and discretion would be welcome.

[0007] Accordingly, it is desirable to provide a device and method for evaluating general blood pressure while providing an improved degree of usability, speediness of use, portability or privacy for the user.

SUMMARY OF THE INVENTION

[0008] In a first aspect, the invention proposes a method for obtaining the blood pressure of a person comprising steps of monitoring pulsation of blood in a body part of the person while moving the body part from a first height to a second height, detecting a first position in which the intensity of the pulsation of blood changes if the body part moves from the first position in one direction, and in which the intensity of blood pulsation remains generally constant if the body part moves from the first position in the reverse direction, and providing the first position as input to a first calculation model suitable for obtaining the person's blood pressure.

[0009] Intensity of pulsation of blood in most embodiments refers to the amplitude of pulsation rather than the frequency of pulsation.

[0010] The invention provides a possibility to monitor blood pressure without need of a pressure cuff to be applied around the bicep of the subject. As a result, the invention also provides a possibility of having a truly portable and wearable blood pressure monitor.

[0011] In some embodiments, the step of detecting the intensity of pulsation of blood in the body part comprises providing a light source configured for illuminating the body part, providing an optical sensor configured to detect light from the light source which has propagated through the body part, and measuring the amplitude of the propagated light. Alternatively, the step of detecting the intensity of pulsation of blood in the body part comprises providing a tonometer on the body part.

[0012] Preferably, the body part is a part of a limb of the person and more preferably his wrist. This provides a wrist-worn pressure monitor which can be worn at all times for someone who requires regular monitoring of blood pressure. Alternatively, the body part is an ear canal of the person. The ear canal is not commonly embellished and is likely to be out of the way of other wearable devices competing for a spot on the body.

[0013] Preferably, the detection of a first position comprises a step of detecting an angular displacement of the body part. Angular displacement of a body part such as the rotation of an upper limb about the shoulder as the origin is virtually the same, despite measurements taken from varying locations along the upper limb. Therefore, determining the first position in terms of angular displacement is preferably to change in height, as this allows data of different people of different body height to be cross-referenced for study.

[0014] In some embodiments, the first position is level to the person's heart or below the person's heart, and the first position is suitable for obtaining the systolic pressure of the person. In other embodiments, the first position is above the person's heart, and the first position is suitable for obtaining the diastolic pressure of the person.

[0015] However, it is preferred that the method for obtaining the blood pressure of a person further comprises steps of

monitoring pulsation of blood in the body part of the person while moving the body part from a third height to a fourth height, detecting a second position in which the intensity of the pulsation of blood changes if the body part moves from the second position in one direction, and in which the intensity of blood pulsation remains generally constant if the body part moves from the second position in the reverse direction, and providing the second position as input to a second calculation model suitable for obtaining the person's blood pressure, wherein the first position is suitable for obtaining one of either the systolic pressure of the person or the diastolic pressure of the person, and the second position is suitable for obtaining the other one of either the systolic pressure of the person or the diastolic pressure of the person.

[0016] Therefore, embodiments which only measures one of either the systolic pressure of the person or the diastolic pressure of the person, and embodiments which measure both the systolic pressure of the person and the diastolic pressure of the person are within the contemplation of the invention.

[0017] In a second aspect, the invention proposes a blood pressure monitor suitable for being worn on a body part of a person, comprising a blood pulsation monitor, a movement detector configured to detect a first height position of the body part in which the blood pulsation monitor observes that intensity of pulsation of blood in the body part changes if the body part moves from the first height position in one direction, and in which the blood pulsation monitor observes that pulsation of blood remains generally constant if the body part moves from the first height position in the reverse direction, and a data treatment module for calculating the person's blood pressure based on the first height position.

[0018] Intensity of pulsation of blood in most embodiments refers to the amplitude of pulsation rather than the frequency of pulsation.

[0019] Optionally, the data treatment module is capable of wirelessly communicating the first height position to a remote computing module for calculating the person's blood pressure based on the first height position.

[0020] Optionally, the blood pulsation monitor comprises a light source configured for illuminating the body part, an optical sensor configured to detect light from the light source which has propagated through the body part in order to detect the intensity of pulsation of blood in the body part. Alternatively, the blood pulsation monitor comprises a tonometer to detect the intensity of pulsation of blood in the body part.

[0021] Preferably, the body part is an upper limb of the person and more preferably one of his wrists. The wrist is a convenient location for wearing a device comfortably for a long time. This provides that the blood pulsation monitor may be used as a long term wearable device.

[0022] In some embodiments, the blood pressure monitor is configured to operate as one of a pair of blood pressure monitors, wherein the first one of the pair is configured to be worn on one location on the body part and the second one of the pair is configured to be worn adjacent the first one of the pair on the body part.

[0023] In other embodiments, the body part is an ear canal of the person.

[0024] Optionally, the movement detector is also configured to detect a second height position of the body part in which the blood pulsation monitor observes that intensity of pulsation of blood in the body part changes if the body part

moves from the second height position in one direction, and in which the blood pulsation monitor observes that pulsation of blood remains generally constant if the body part moves from the second height position in the reverse direction, and the data treatment module also being suitable for calculating the person's blood pressure based on the second height position, in which the first position is based upon for calculating one of either the systolic pressure of the person or the diastolic pressure of the person, and the second position is based upon for calculating the other one of either the systolic pressure of the person or the diastolic pressure of the person.

BRIEF DESCRIPTION OF THE FIGURES

[0025] It will be convenient to further describe the present invention with respect to the accompanying drawings that illustrate possible arrangements of the invention, in which like integers refer to like parts. Other arrangements of the invention are possible, and consequently the particularity of the accompanying drawings is not to be understood as superseding the generality of the preceding description of the invention.

[0026] FIG. 1 shows a first embodiment of the invention;
[0027] FIG. 2 shows a signal obtained by the embodiment of FIG. 1;

[0028] FIG. 3 shows a standard cardiogram for explaining the signal of FIG. 2;

[0029] FIG. 4 shows how the embodiment of FIG. 1 is used by a user;

[0030] FIG. 5 shows how signals obtain by the embodiment of FIG. 1;

[0031] FIG. 5a shows how a mathematical model fitting may be used in the embodiment of FIG. 5;

[0032] FIG. 6 shows how signals obtained, as illustrated in FIG. 5, are applied against a calibration;

[0033] FIG. 7 shows an alternative to the embodiment of FIG. 4;

[0034] FIG. 8 is a schematic diagram of the parts within the embodiment of FIG. 1;

[0035] FIG. 9 shows a further alternative to the embodiment of FIG. 4;

[0036] FIG. 10 shows a further alternative the calibration in FIG. 6;

[0037] FIG. 11 shows a flowchart of the method employed in the embodiment of FIG. 1;

[0038] FIG. 12 shows another embodiment alternative to that of FIG. 1;

[0039] FIG. 13 shows yet another embodiment alternative to that of FIG. 1;

[0040] FIG. 14 shows yet another embodiment alternative to that of FIG. 1;

[0041] FIG. 15 shows yet another embodiment alternative to that of FIG. 1;

[0042] FIG. 16 illustrates a part of the embodiment of FIG. 15; and

[0043] FIG. 17 further illustrates the part shown in FIG. 16.

DETAILED DESCRIPTION OF THE INVENTION

[0044] FIG. 1 shows a wrist wearable blood pressure monitor 100 shaped like a watch. The underside of the blood pressure monitor 100 comprises a PPG (photoplethys-

mocharty) sensor. FIG. 8 is a schematic diagram showing some functional modules which are preferably provided within the blood pressure monitor 100.

[0045] A typical PPG sensor comprises at least one light source 101 such as an LED (light emitting diode), which is illustrated by the circle in broken line, and at least one corresponding optical sensor 103 normally placed next to the light source 101, which is illustrated by the square in broken line. The broken lines represent the invisibility of the light source 101 and the optical sensor 103 from the side of the blood pressure monitor 100 facing away from the wearer.

[0046] The blood pressure monitor 100 has a strap by which it may be worn on the wrist. It is advisable that the PPG is tightly secured against the wrist in order to avoid ambient light from affecting detections of the optical sensor 103. The strap is designed to apply a known, pre-determined pressure around the wrist. The pressure is predetermined by using a pressure sensor 105 provided on the strap. An example of such a pressure sensor 105 is a MEMS (micro-electromechanical systems) barometer. The MEMS barometer operates as a mechanical pressure release device, which releases pressure slowly when the strap is overly tightened around the wrist until the pre-determined pressure remains. Alternatively, the pre-determined pressure is provided by using a pre-selected material for the strap, the material having a specific elasticity or resilience which repeatedly applies the same pressure around the wrist every time the blood pressure monitor 100 is worn. Whichever the methods used, the same pressure is applied to the wrist repeatedly every time the same person wears the blood pressure monitor 100.

[0047] Light emitted by the light source 101 into the wrist is scattered in all directions by wrist tissue. A portion of the scattered light propagates towards the optical sensor 103. Blood, skin and tissue all absorb a portion of the light. However, the effect of skin and tissue on light propagation is consistent and the extent of light absorbed by skin and tissue does not change noticeably. The amount of blood in the wrist pulsates as the heart pumps. Hence, the amount of light absorbed when the wrist is full of blood is more than the amount of light absorbed when the tissue is relatively depleted of blood.

[0048] FIG. 2 schematically illustrates the pulsating pattern of light propagation through the person's wrist. The pulsation is cyclical and virtually periodic, corresponding to the heart beat. The peaks 203 in the signal 201 are moments when the heart is relaxed and wrist tissue is relatively depleted of blood, such that more light propagates through the wrist to reach the optical sensor 103. FIG. 3 shows a standard cardiogram having several peaks which can be detected as electric signals from the different heart chambers, represented by PQRST. Each peak 203 of the signal 201 in FIG. 2 corresponds to a period between two adjacent R peaks.

[0049] The troughs 205 in the signal 201 in FIG. 2 are moments when the heart contracts and pumps blood into the body, and the wrist tissue is full of blood. A lower amount of light reaches the optical sensor 103 because a significant portion of light from the light source 101 has been absorbed by blood.

[0050] FIG. 4 shows a person 300 wearing the blood pressure monitor 100 of FIG. 1. The strap of the monitor 100 is tied and tightened around his wrist. The consistent pressure applied by the strap acts as a counter-pressure against

pressure in blood vessels within the wrist. The counter-pressure is applied as long as the blood pressure monitor 100 is worn. The counter-pressure causes blood vessels within the wrist to deform slightly. The extent of deformation depends on pressure within the blood vessels and affects the amount of blood which may be pumped into the wrist.

[0051] It is well-known that pressure is height-related. There is lower pressure in greater heights above the ground, and there is greater pressure nearer the ground. The same phenomenon can be seen within the wrist. When the person 300 lifts his hand into an elevated position above his heart, blood pressure in his wrist will be lower. A lower blood pressure is relatively weaker against the constant counter-pressure applied by the strap. Therefore, blood vessel deformation due to the counter-pressure from the strap is more pronounced, see label 491 in FIG. 4, and a smaller amount of blood is pumped into blood vessels in the wrist.

[0052] Conversely, when the person 300 lowers his hand into a position below his heart, the pressure in blood vessels within the wrist is relatively greater. The greater blood pressure exerting against the counter-pressure allows blood vessels within the wrist to recover a little from their deformation, see label 493 in FIG. 4, and more blood is pumped into blood vessels in the wrist.

[0053] Accordingly, FIG. 4 also shows two light propagation signals accompanying the respective blood vessel deformations labelled 491 or 493. The signal at the top of FIG. 4 has greater pulsation amplitudes as the wrist has less blood in the elevated hand position; more light is able to propagate through wrist tissue to reach the optical sensor 103. The signal at the bottom of FIG. 4 has smaller pulsation amplitudes as the wrist has more blood; more blood in the wrist means more of light is absorbed and less light is able to propagate through wrist tissue to reach the optical sensor 103.

[0054] FIG. 5 shows how systolic pressure and diastolic pressure are determined by elevated hand position and lower hand position. The left side of the horizontal axis shows the lower hand position and the right side of the horizontal axis shows the elevated hand position.

[0055] To begin monitoring his blood pressure, the person 300 gets himself into a ready position by standing upright and stretching out his hand wearing the pressure monitor 100. The hand is stretched away from his side and lifted to shoulder level. Subsequently, when the person moves his hand down from shoulder level and closes it towards his side, and his wrist eventually moves below the heart. Pressure within blood vessels in the hand increases as he moves his hand downwards and blood pumped into the wrist increases steadily, see the gradient labelled 501a. Thus, the pulsation amplitude of light propagating through wrist tissue reduces as the hand is placed lower. When the hand is lowered to a certain point below the heart, pressure within blood vessels in the wrist is able to overcome the counter-pressure and blood pumped in the wrist is at a maximum amount. At this point, the pulsation amplitude of the light propagating through wrist tissue reaches zero, which is where the gradient of the graph 501a crosses the horizontal axis. The height of the wrist at this crossing as indicated by the dashed line labelled 503 is the height of the wrist at which systolic pressure is manifested. In the unlikely event that the hand has moved and closed against the side of the person 300 but the gradient 501a has not crossed the horizontal axis, the gradient can be extrapolated to do so.

[0056] Starting again from shoulder level, the person now moves his out-stretched hand upward. As the hand moves upwards, blood pressure decreases and less blood is pumped in the wrist due to the counter-pressure from the strap. See again gradient labelled **501a**. Eventually, the blood pressure is so low that only the diastolic pressure remains in the raised hand. Therefore, when the hand is raised to a certain point above the heart, a steady-state appears: blood pumped into the hand is at a minimum even if the hand is raised further. The diastolic blood pressure provides this minimum blood content in the hand, which translates into minimum light absorption and hence maximum light transmission. The point labelled **501** at which the pulsation of light through the wrist begins to show a steady, maximum amplitude represents the height of the wrist at which diastolic pressure is manifested.

[0057] The hand does not need to be raised starting with the wrist below heart level. The hand may be raised starting from shoulder level even though the shoulder is already above the heart. This is because the hand normally needs to be raised well above the shoulder to manifest the diastolic pressure.

[0058] The skilled man understands that by steady maximum amplitude and steady minimum amplitude, natural variation of signal amplitudes falling above and below the mean levels may be observed.

[0059] The actual hand positions for manifesting both diastolic pressure and systolic pressure is actually measured from the wrist wearing the blood pressure monitor **100**, and the term 'hand' is used loosely herein.

[0060] It is most easily appreciated if the height of the wrist is measured against the ground. Theoretically, however, the height of the wrist may be referenced from a selected point representing the person's heart position instead. FIG. 4 illustrates this option, showing an elevated wrist height expressed as H1. H1 is the distance between the height of the wrist and the height of the heart that manifests the diastolic pressure. That is, H1 is measured perpendicularly to the ground. Furthermore, FIG. 4 shows a lowered wrist height expressed as H2, where H2 is the distance between the height of the wrist and the height of the heart that manifests the systolic pressure.

[0061] The blood pressure monitor **100** described so far may be used to determine diastolic and systolic blood pressures of a person generally, and may be provided to users as such. However, to evaluate blood pressure more accurately, the amplitude of the light propagating through the wrist may be referenced against a mathematical model or a calibration.

[0062] The concept of calibration is illustrated by a schematic mathematical model in FIG. 6. The horizontal axis of the graph shown in FIG. 6 represents the height of the wrist. The vertical axis represents blood pressure deduced from the height of the wrist. The relationship between the two axes is described by the following equations, (1a) and (1b).

$$x_1 = f(h) \quad (1a)$$

[0063] where

[0064] x_1 =diastolic pressure, defined as the minimum value of blood pressure

[0065] h =height of elevation (which is H1 in FIG. 4)

$$x_2 = f'(h) \quad (1b)$$

[0066] where

[0067] x_2 =systolic pressure, defined as the maximum value of blood pressure

[0068] h =height of elevation (which is H2 in FIG. 4)

[0069] The two functions, f and f' , typically give graphs of similar shapes.

[0070] As explained using FIG. 5, H1 is found by the person elevating his hand to discover the point labelled **501** at which light propagation begins to show steady maximum amplitude. H2 is found by the person lowering his hand to discover the point labelled **503** at which the amplitude of light propagation is reduced to zero or crosses the horizontal axis. Accordingly, any change in H1 and H2 for the same person may be attributed to change in his blood pressure, provided that the counter-pressure applied by the strap has been repeated with sufficient precision and accuracy.

[0071] In practice, the calibration or mathematical model can be obtained by proposing a theory or by observing a sampled population of users wearing the blood pressure monitor **100** and having known systolic and diastolic blood pressures. This relates to statistical methods which do not require any exposition in this specification.

[0072] In some embodiments, the point labelled **501** may be found using a series of discrete positioning of the hand, and applying a mathematical model to the discrete positioning of the hand. As shown in FIG. 5a, the amplitude of the propagated light is observed when the hand is lifted to four different levels of height, marked by crosses. None of the four different levels of height coincide with the point labelled **501**. Nevertheless, the point labelled **501** is found by applying a known mathematical model **501b** to the crosses, instead of relying on the blood pressure monitor **100** to detect it actually.

[0073] As shown in FIG. 8, the blood pressure monitor **100** may comprise a computing module **1001** and suitable software module **1015** for calculating the person's blood pressure from H1 and H2, and a display screen **1007** for displaying the person's systolic and diastolic blood pressures. Alternatively, the blood pressure monitor **100** relies on a remote device to calculate the systolic and diastolic blood pressures instead of any computing module contained within itself **100**. The remote device can be a smart phone which is in wireless communication with the blood pressure monitor **100**, and which is able to obtain H1 and H2 from the blood pressure monitor **100** to calculate the person's systolic blood pressure and diastolic blood pressures. In this case, the blood pressure monitor **100** comprises a wireless transceiver **1011** to communicate with a smart phone.

[0074] Optionally, an accelerometer or its likes **1003** may be used to determine the exact height that the hand has been raised or lowered to. Of course, an operator may also measures H1 and H2 manually, and enters H1 and H2 into the blood pressure monitor **100** via a keypad **1009** provided on the blood pressure monitor **100**.

[0075] FIG. 6 illustrates equation (1a) and equation (1b) as linear. However, the linearity is simply an illustration. The case may well be that the equations are non-linear. It suffices for the skilled reader to note that actual blood pressure of a person **300** may be expressed as functions of H1 and H2.

[0076] FIG. 7 shows a modification of the embodiment of FIG. 4, wherein H1 and H2 are measured against the shoulder level of the person **300** instead of the ground or from a point representing his heart. This is a more conve-

nient variation of the embodiment as the person's shoulder is more visible than his heart, and the diastolic pressure and systolic pressure normally manifest in wrist positions well above and below the shoulder. The skilled reader will understand that equation (1a) and equation (1b) may be easily adapted to this varied definition of H1 and H2.

[0077] One advantage of the described embodiments is that they provide the possibility of using a PPG sensor to observe pulsation of blood and then to calculate blood pressure from the pulsation. One of the reason why this can be done lies in the use of a PPG sensor to take different readings from the same body part in different positions. Tissue make-up of the person **300** is the same whether a body part is placed in any position. Therefore, the effects of skin and tissue on propagation of light may be eliminated by taking readings in the different positions, and any change in light propagation between the positions is due to blood content in the body part.

[0078] An advantage of using a distance between two different wrist positions to determine blood pressure is the possibly greater precision which may be had over a mercury column for reading blood pressure. Blood pressure observed by measurement of body fluid, assumed to be equivalent to water, may be more precise due to greater measurement graduation than that of a mercury column. Mercury has a relative density of 13.56 to water, and therefore, any error of 13.56 mm in the wrist position to the shoulder or heart will translate to 1 mm of error in the mercury column. If a manual reading of the mercury column is mis-read by 2 mm, for example, it is the equivalent of mis-reading the position of the wrist by 27.2 mm in the present embodiment, which is an error unlikely to escape notice of any operator of the described embodiments.

[0079] To ensure that H1 and H2 are measured properly, the accelerometer **1003** or any height detection unit in the blood pressure monitor **100** is used. An alarm **1013** is provided in the blood pressure monitor **100** to issue a suitable calibration alarm if the accelerometer **1003** shows too much deviation at a known height.

[0080] Nevertheless, it may be difficult to measure H1 and H2, whether they be referenced against the ground, the shoulder or the heart. FIG. 9 shows a more preferable embodiment which overcomes this difficulty, comprising a gyroscope **1003** installed inside the blood pressure monitor **100** to detect angular deviation from the true perpendicular to the ground. The gyroscope **1003** is tuned to be aligned to the true perpendicular pointing to the ground when the wrist wearing the blood pressure monitor **100** is outstretched horizontally. Therefore, when the person wearing the embodiment of FIG. 9 raises his hand from the heart level, the gyroscope is able to detect an angular movement of the blood pressure monitor **100**.

[0081] When the person stretches his hand outright and raises his hand, at the point where the amplitude of the pulsating light propagating through the wrist reaches a steady maximum, which indicates that blood pulsation in the wrist is at the minimum, a first angle α representing the angular deviation of the blood pressure monitor **100** from the true perpendicular is measured. Accordingly, α is the angle at which diastolic pressure manifests. The skilled reader will understand that α can be used to calculate the extent of upward rotation of the hand or upper limb from the horizontal, about the person's shoulder as the origin.

[0082] Conversely, when the person stretches his hand outright and then lowers his hand from his shoulder level, at the point where the amplitude of the pulsating light propagating through the wrist is reduced to zero and crosses the horizontal axis, which indicates that blood pulsation in the wrist is at the maximum, a second angle β representing another angular deviation of the blood pressure monitor **100** to the true perpendicular is measured. β is the angle at which systolic pressure manifests. The skilled reader will understand that β can be used to calculate the extent of downward rotation of the hand or upper limb from the horizontal, about the person's shoulder as the origin.

[0083] The angles α and β are different for people with different blood pressure levels. As illustrated in the graph of FIG. 10, a person with high diastolic blood pressure has a small α , that is,

$$\alpha \propto \frac{1}{\text{diastolic blood pressure}}$$

[0084] The higher the hand needs to be raised above the shoulder to manifest the diastolic pressure, at **501**, the greater the angular deviation of α from the true perpendicular, and the lower the person's diastolic blood pressure; the lower need the hand be raised above the shoulder to manifest the diastolic pressure, at **501**, the lower the angular deviation of α from the true perpendicular, and the greater the person's diastolic blood pressure.

[0085] Conversely, a person with high systolic blood pressure has a greater β . The lower the hand is dropped below the shoulder (and the heart) to manifest the systolic pressure, at **503**, the greater the angular deviation of β from the true perpendicular.

[0086] Accordingly,

$$\beta \propto \text{systolic blood pressure}$$

[0087] In other words, the greater β the greater the systolic blood pressure; a person with low systolic blood pressure needs only to lower his hand slightly to a relatively small β to manifest the systolic blood pressure.

[0088] By measuring angular displacement to determine blood pressure, the absolute height of the hand position to the person's heart, shoulder or to the ground does not need to be measured. This is particularly advantageous over the earlier embodiments, as the position on the wrist where the blood pressure monitor **100** is worn may vary easily between different occasions of blood pressure measurement and cause measurements of H1 and H2 to be imprecise. In one application of this embodiment, the person may simply hold on to a door handle and allow himself to stand (so that his hand is below heart level) and squat (so that his hand is above heart level) to determine blood pressure; the gyrometer is able to measure the position of his hand overhead or below the shoulder by angular displacement.

[0089] FIG. 11 is a flowchart showing one possible general procedure of determining blood pressure using the embodiment of FIG. 1. At first, in step **1101**, light propagation level through a body part, which may be the wrist, is read when the body part is in a first position. This may relate to the hand when it is raised in the afore-described embodiments. Then, in step **1103**, light propagation level is read again but when the same part is in a second position, and this may relate to the hand when it is lowered. Of course, the

reverse in starting from a hand lowered position and then proceeding to a hand raised position is also within the contemplation of the embodiments. The positions of the body part in which the amplitude of light pulsation is at maximum, at **501**, and in which amplitude of light pulsation is zero, at **503**, are noted and applied against a calibration or mathematical model to determine the diastolic blood pressure and the systolic blood pressure, in step **1105**.

[0090] FIG. 12 shows another embodiment which is a blood pressure monitor **100** comprising a PPG sensor and is worn around the arm or biceps of the person. In order that this blood pressure monitor **100** may be moved across the heart when the arm is raised and lowered, the blood pressure monitor **100** is preferably worn as near to the elbow as possible. Similar to the afore-described embodiments, **H1** and **H2** are measured as the distance between the blood pressure monitor **100** and the ground, the person's shoulder or heart level, and a calibration or mathematical model used to calculate blood pressure. Alternatively, the blood pressure monitor **100** may contain a gyrometer for determining angular deviations α and β .

[0091] Other parts of limb on the upper body may be used, such as the finger or other parts of the forearm other than the wrist, as long as the part may be lifted above the heart or lowered below the heart.

[0092] FIG. 13 yet shows another embodiment which comprises a pair of blood pressure monitors **100**, worn such that a blood pressure monitor **100** is located on the wrist and another one **100** adjacent to the first one **100**, on the forearm of the same hand. The configuration of the blood pressure monitor **100** to be worn on the forearm may comprise a longer strap and perhaps a stronger light source **101** for illuminating the thicker tissue layers of the forearm, and perhaps a more sensitive optical sensor **103** for detecting light propagation through the thicker forearm. Any inaccuracies or reading discrepancies between the two blood pressure monitors **100** may be mathematically treated and removed, resulting in a more accurate reading of blood pressure. The benefits of the embodiment of FIG. 9 will be more easily appreciated. In this embodiment, since the angular displacement from the true perpendicular is the same for both the blood pressure monitors **100** no matter where they are placed along the same limb, whereas **H1** and **H2** measured from the heart, shoulder or ground are different for the two blood pressure monitors **100** which thus require a different calibration each.

[0093] While embodiments have been described as monitoring the amount of light propagating through the person's skin, blood and tissue, the actual measurement may be taken on either light transmission or light absorption.

[0094] Where it has been described that measurement of wrist position starts from shoulder level to move below the shoulder level, the skilled reader understands that the direction of movement is a matter of choice, and the wrist may well start moving from the side of the person towards shoulder level. Similarly, other described limb movements may be executed in the direction which is the reverse of that which has been described.

[0095] Although drawings provided in this specification shows a sideways raising and lowering of the person's hand, it is possible that the hand be raised and lowered when stretched to the front of the person.

[0096] The amount of light absorbed by blood in the person's tissue depends on the selected frequency of the

light used. Therefore, an optimal frequency is typically selected and used in the embodiments for optimal performance. In some embodiments, however, two or more different light frequencies or frequency ranges are used at once to better discriminate blood pulsation reading from the influence of noise contributing factors such as ambient light and so on. For example, one monochromatic near-infrared frequency and a far infrared frequency are used at the same time.

[0097] Although embodiments have been described showing a person **300** wearing a blood pressure monitor **100** in an upright position, and moving his hand up and down vertically, it is possible in other embodiments for the person to be wearing the blood pressure monitor **100** lying on a bed. In such embodiments, the person moves his hand wearing the blood pressure monitor **100** from his back to his front, and therefore also moving his hand passed his heart vertically.

[0098] In yet a further embodiment, the embodiment is ankle-worn instead of wrist-worn. The person simply lies down on a bed to monitor his blood pressure. One reading is taken when the leg wearing the embodiment is rested on the bed and leveled with the heart, and another when the leg is lifted up into the air and raised above the heart.

[0099] Although amplitude of light propagation is used in the afore-mentioned embodiments to monitor pulsation of blood, it is possible that non-optical measurement is used instead. For example, the blood pressure monitor **100** may comprise a tonometer in place of the PPG. A tonometer is an instrument for measuring the pressure in a part of the body or a blood vessel. The amplitude of the pulsation can be correlated to the blood pressure in a similar way as the pulsating amplitude of propagated light. The skilled reader will note that a greater amplitude in the afore-described embodiments using a PPG refers to greater light transmission and hence less blood in the wrist whereas, if a tonometer is used, a greater amplitude represent more blood pumped into the wrist. Both calibration and equations as discussed will have to be adapted accordingly.

[0100] In yet another embodiment, a blood pressure monitor **100** can be provided in the form of an ear worn device, as illustrated in FIG. 14. This ear worn device comprises an ear bud which is installed with a light source **101** and an optical sensor **103**, as well as a gyrometer. The ear bud is shaped to be suitable for being inserted into the ear canal. The blood pressure monitor **100** has either wired or wireless connection to a device such as a display screen or smart phone **1401** which can display the readings of the blood pressure monitor **100**. The display screen or the smart phone **1401** also provides the person **300** with interface for controlling the operation of the blood pressure monitor **100**. Furthermore, a smart phone may provide the processing and memory resource for calculating blood pressure based on the readings observed by the optical sensor **103** in the ear bud **1501**. This allows the ear bud **1501** to be small, as a processor is not needed to be installed into the ear bud **1501**. In contrast, the embodiment of FIG. 1 is large enough to contain its own processor and memory, and therefore the embodiments like that which is in FIG. 1 may be easily operated with need of an accompanying smart phone. The requirement of a suitable application in the smart phone **1401** for operating the blood pressure monitor **100** is a well-known concept and does not require any exposition in this specification.

[0101] Optionally, it may be the sole function of the blood pressure monitor 100 of FIG. 14 to measure the blood pressure of the person 300 wearing it. Alternatively, however, the ear bud type blood pressure monitor 100 is also an ear phone. FIG. 15 shows this variation of the embodiment of FIG. 14 as a hook-on earphone, the speaker of which is encased in an ear bud 1501 meant for insertion into the ear canal. As with the embodiment of FIG. 14, the ear bud 1501 is installed with a light source 101 and sensor for monitoring blood pulsation in the ear canal.

[0102] FIG. 16 and FIG. 17 show how a light source 101 and an optical sensor 103 may be arranged in the ear bud 1501 of the embodiment of FIG. 15. Typically, the ear bud 1501 is made of a deformable resilient outer part 1701 sized to fit within the ear canal of a person.

[0103] FIG. 16 illustrates the core parts of the ear bud 1501 with the resilient outer part removed. FIG. 17 shows the resilient outer part 1701 assembled into the embodiment.

[0104] Within the ear bud 1501 is a speaker 1703, a hollow inner core 1601 for sound conduction from the speaker in to the ear, an resilient inner foam structure 1603 for softness and flexibility, thin wirings (not illustrated) for connection to the light source 101 and optical sensor 103. The resilient outer part 1701 provides increased comfort and protection of the light source 101 and optical sensor 103s. The resilient inner foam 1603 may be compressed during insertion of the ear bud 1501 into the ear to provide further support in the ear canal. FIG. 16 illustrates three sets 1605 of light source 101 and optical sensor 103 pairs, spaced 120 degree around the ear bud. One set is facing the reader showing clearly the light source 101 and optical sensor 103, while the other sets face away from the reader.

[0105] To obtain the blood pressure of the person 300 wearing the embodiment 100 of FIG. 14 or FIG. 15, the person 300 lies down to take a first reading of light propagation through his ear tissue, and then sits up to take another reading of light propagation through his ear tissue. In other words, change in blood pulsation in the ear canal between the positions of lying down and sitting up is noted by observing an accompanying change in the amplitude of light propagation through ear tissue. When the person is lying down, the ear is just about level with the heart and has a similar effect on blood pressure within the ear canal as if the ear canal is below heart level. When the person sits up, the ear is well above the heart. Therefore, this embodiment also comprises a gyroscope to detect the lying down and sitting up of the person 300 and to obtain a and 3 for calculating the systolic pressure and diastolic blood pressure, or to obtain the height of the ear canal when the person 300 sits up to determine H1 to calculate diastolic pressure. In this embodiment, there is no counter-pressure applied against wall of the ear canal.

[0106] It is also possible that a tonometer is used in the ear canal instead of the light source 101 and optical sensor 103.

[0107] Although a human has been described as the subject for blood pressure monitoring, the embodiments may be adapted to monitor the blood pressure of any animal which is capable of wearing a device configured to detect blood pulsation, and wherein the body part is capable of moving between two positions relative to the animal's heart.

[0108] Accordingly, as one of the simplest embodiment, a method has been described for obtaining the blood pressure of a person 300 comprising steps monitoring pulsation of blood in a body part of the person while moving the body

part from a first height to a second height, detecting a first position in which the intensity of the pulsation of blood changes if the body part moves from the first position 501 (or 503) in one direction, and in which the intensity of blood pulsation remains generally constant if the body part moves from the first position 501 (or 503) in the reverse direction, and providing the first position as input to a first calculation model suitable for obtaining the person's blood pressure.

[0109] Furthermore, as another one of the simplest embodiment, a blood pressure monitor 100 suitable for being worn on a body part of a person 300 has been described, which comprises a blood pulsation monitor, a movement detector configured to detect a first height position of the body part in which the blood pulsation monitor observes that intensity of pulsation of blood in the body part changes if the body part moves from the first height position 501 (or 503) in one direction, and in which the blood pulsation monitor observes that pulsation of blood remains generally constant if the body part moves from the first height position 501 (or 503) in the reverse direction, and a data treatment module for calculating the person's blood pressure based on the first height position.

[0110] While there has been described in the foregoing description preferred embodiments of the present invention, it will be understood by those skilled in the technology concerned that many variations or modifications in details of design, construction or operation may be made without departing from the scope of the present invention as claimed.

1. A method for obtaining the blood pressure of a person comprising steps of:

monitoring pulsation of blood in a body part of the person while moving the body part from a first height to a second height;

detecting a first position in which the intensity of the pulsation of blood changes if the body part moves from the first position in one direction, and in which the intensity of blood pulsation remains generally constant if the body part moves from the first position in the reverse direction; and

providing the first position as input to a first calculation model suitable for obtaining the person's blood pressure.

2. A method for obtaining the blood pressure of a person as claimed in claim 1, wherein

the step of detecting the intensity of pulsation of blood in the body part comprises:

providing a light source configured for illuminating the body part;

providing an optical sensor configured to detect light from the light source which has propagated through the body part; and

measuring the amplitude of the propagated light.

3. A method for obtaining the blood pressure of a person as claimed in claim 1, wherein

the step of detecting the intensity of pulsation of blood in the body part comprises:

providing a tonometer on the body part.

4. A method for obtaining the blood pressure of a person as claimed in claim 1, wherein

the body part is a part of a limb of the person.

5. A method for obtaining the blood pressure of a person as claimed in 4, wherein

the part of a limb is a wrist of the person.

6. A method for obtaining the blood pressure of a person as claimed in claim 1, wherein the body part is an ear canal of the person.

7. A method for obtaining the blood pressure of a person as claimed in claim 1, wherein the detecting of a first position comprises a step of: detecting an angular displacement of the body part.

8. A method for obtaining the blood pressure of a person as claimed in claim 1, wherein the first position is level to the person's heart or below the person's heart; and the first position is suitable for obtaining the systolic pressure of the person.

9. A method for obtaining the blood pressure of a person as claimed in claim 1, wherein the first position is above the person's heart; and the first position is suitable for obtaining the diastolic pressure of the person.

10. A method for obtaining the blood pressure of a person as claimed in claim 1, further comprising steps of: monitoring pulsation of blood in the body part while moving the body part from a third height to a fourth height;

detecting a second position in which the intensity of the pulsation of blood changes if the body part moves from the second position in one direction, and in which the intensity of blood pulsation remains generally constant if the body part moves from the second position in the reverse direction; and

providing the second position as input to a second calculation model suitable for obtaining the person's blood pressure; wherein

the first position is suitable for obtaining one of either the systolic pressure of the person or the diastolic pressure of the person; and

the second position is suitable for obtaining the other one of either the systolic pressure of the person or the diastolic pressure of the person.

11. A blood pressure monitor suitable for being worn on a body part of a person, comprising:

a blood pulsation monitor;

a movement detector configured to detect a first height position of the body part in which the blood pulsation monitor observes that intensity of pulsation of blood in the body part changes if the body part moves from the first height position in one direction, and in which the blood pulsation monitor observes that pulsation of blood remains generally constant if the body part moves from the first height position in the reverse direction; and

a data treatment module for calculating the person's blood pressure based on the first height position.

12. A blood pressure monitor suitable for being worn on a body part of a person as claimed in claim 11, wherein the data treatment module is capable of wirelessly communicating the first height position to a remote com-

puting module for calculating the person's blood pressure based on the first height position.

13. A blood pressure monitor suitable for being worn on a body part of a person as claimed in claim 11, wherein the blood pulsation monitor comprises:

a light source configured for illuminating into the body part;

an optical sensor configured to detect light from the light source which has propagated through the body part.

14. A blood pressure monitor suitable for being worn on a body part of a person as claimed in claim 11, wherein the blood pulsation monitor comprises a tonometer.

15. A blood pressure monitor suitable for being worn on a body part of a person as claimed in claim 12, wherein the body part is the person's wrist.

16. A blood pressure monitor suitable for being worn on a body part of a person configured to operate as one of a pair of blood pressure monitors each as claimed in claim 11; wherein

the first one of the pair is configured to be worn on one location on the body part and the second one of the pair is configured to be worn adjacent the first one of the pair on the body part.

17. A blood pressure monitor suitable for being worn on a body part of a person as claimed in claim 11, wherein the body part is an ear canal of the person.

18. A blood pressure monitor suitable for being worn on a body part of a person as claimed in of claim 11, wherein the movement detector comprises a gravity sensor capable of detecting angular displacement of the body part; and the first height position is represented by angular displacement of the body part.

19. A blood pressure monitor suitable for being worn on a body part of a person as claimed in claim 11, wherein the movement detector is also configured to detect a second height position of the body part in which the blood pulsation monitor observes that intensity of pulsation of blood in the body part changes if the body part moves from the second height position in one direction, and in which the blood pulsation monitor observes that pulsation of blood remains generally constant if the body part moves from the second height position in the reverse direction; and

the data treatment module also being suitable for calculating the person's blood pressure based on the second height position; in which

the first position is based upon for calculating one of either the systolic pressure of the person or the diastolic pressure of the person; and

the second position is based upon for calculating the other one of either the systolic pressure of the person or the diastolic pressure of the person.

20. (canceled)

21. (canceled)

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专利名称(译)	一种获得人的血压的方法及其装置		
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摘要(译)

一种用于获得人的血压的方法和相关设备。该方法包括提供光源 (101) 和光学传感器 (103) 的步骤, 该光学传感器被配置为检测来自光源的光, 该光已经通过手腕传播。该设备的佩戴者。通过手腕传播的光量取决于手腕中的血液量。然后, 当手腕抬高到心脏水平以上, 并且当手腕降低到心脏水平以下时, 通过监测手腕内血液脉动幅度的差异来观察血压。

