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(54) **PULSE WAVE MEASUREMENT DEVICE, PULSE WAVE MEASUREMENT METHOD, AND BLOOD PRESSURE MEASUREMENT DEVICE**

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A61B 5/00	(2006.01)

(52) **U.S. Cl.**

CPC ***A61B 5/02225*** (2013.01); ***A61B 5/02125*** (2013.01); *A61B 5/11* (2013.01); ***A61B 5/6831*** (2013.01); ***A61B 5/0225*** (2013.01)

(57) **ABSTRACT**

A first and second pulse wave sensor is mounted on the belt in a state of being separated from each other in the width direction. The belt is mounted around the measurement site, the member presses the first and second pulse wave sensors against the measurement site with a predetermined pressing force. Each of the pulse wave sensors detects a pulse wave in a facing portion of an artery passing through the measurement site. The body motion detection unit detects the presence or absence of body motion. When there is no body motion, the control unit sets a force of the pressing member to a pressing force to measure a pulse wave with the sensors. When there is body motion, the control unit sets a force of the pressing member to a second force lower than the first force and higher than zero and interrupts measurement of a pulse wave.

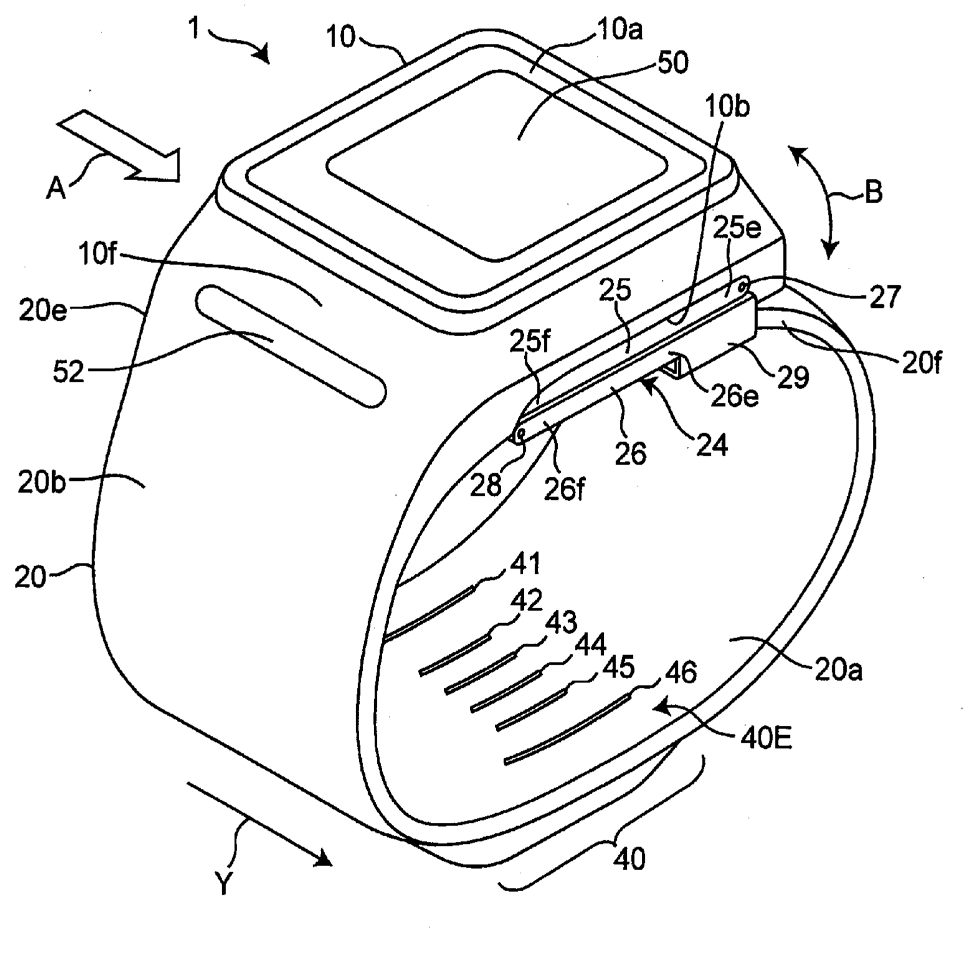


FIG.1

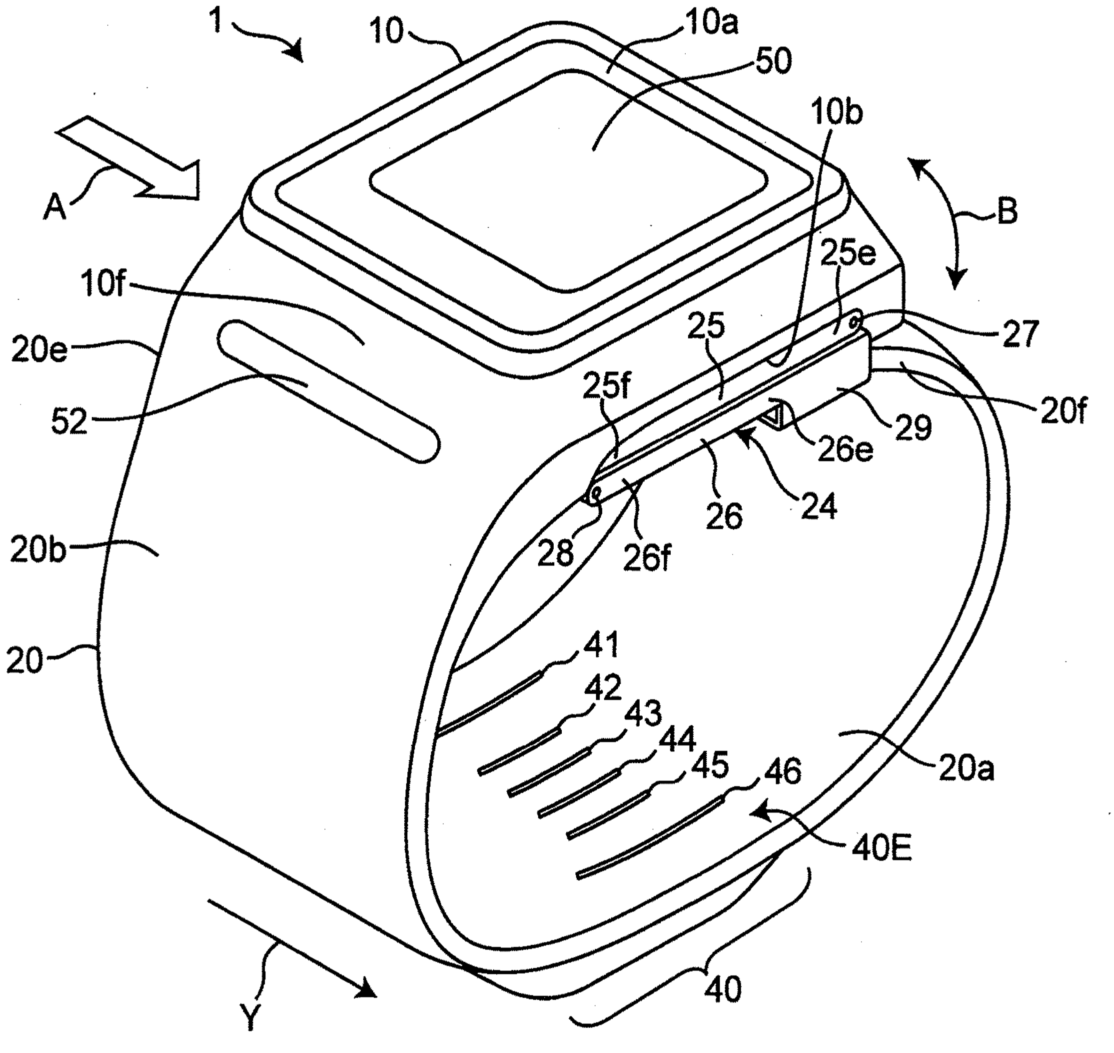

1
10
10a
50
10b
A
B
25e
10f
25
27
20e
25f
20f
52
29
26e
24
26
20b
28
26f
41
20
42
43
44
45
46
20a
40E
Y
40

FIG.2

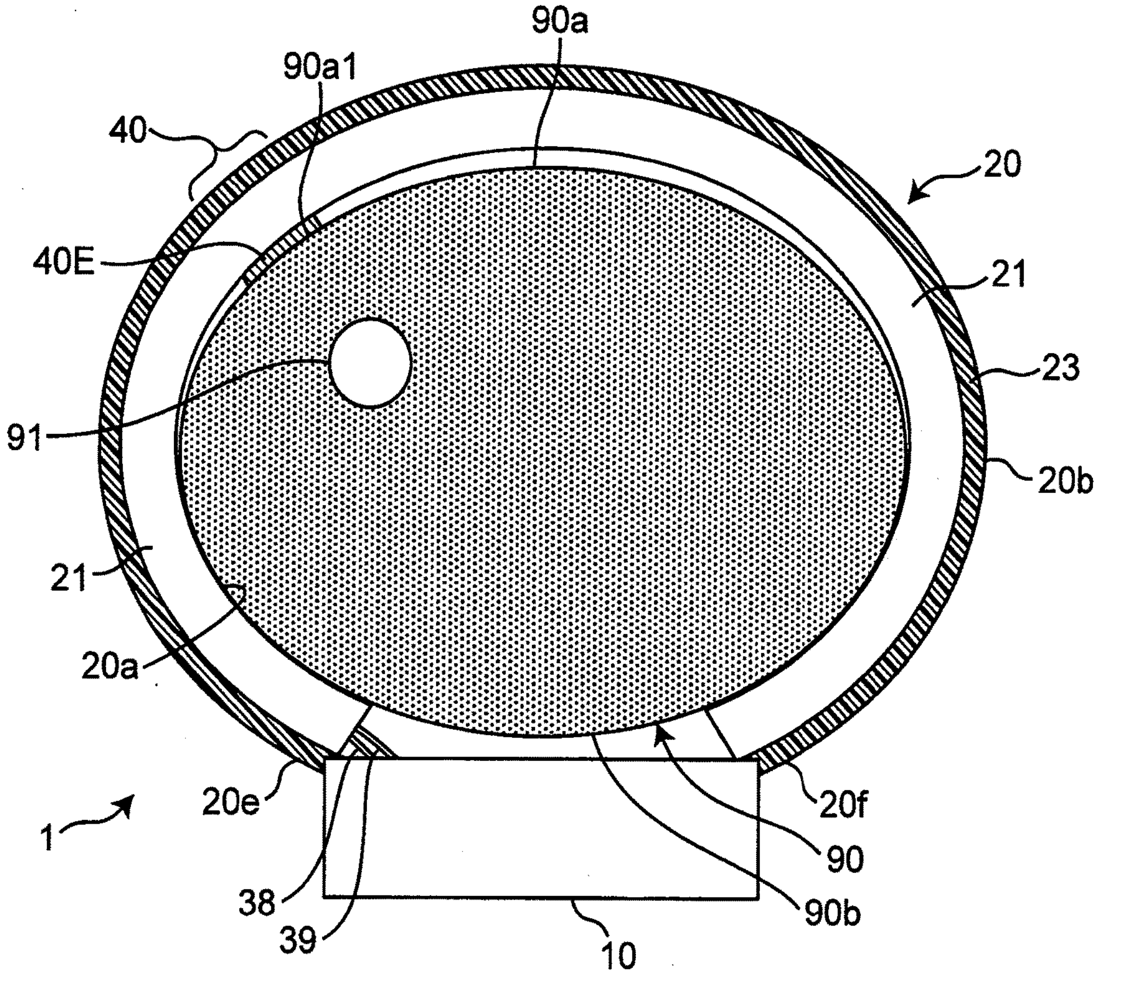


FIG.3

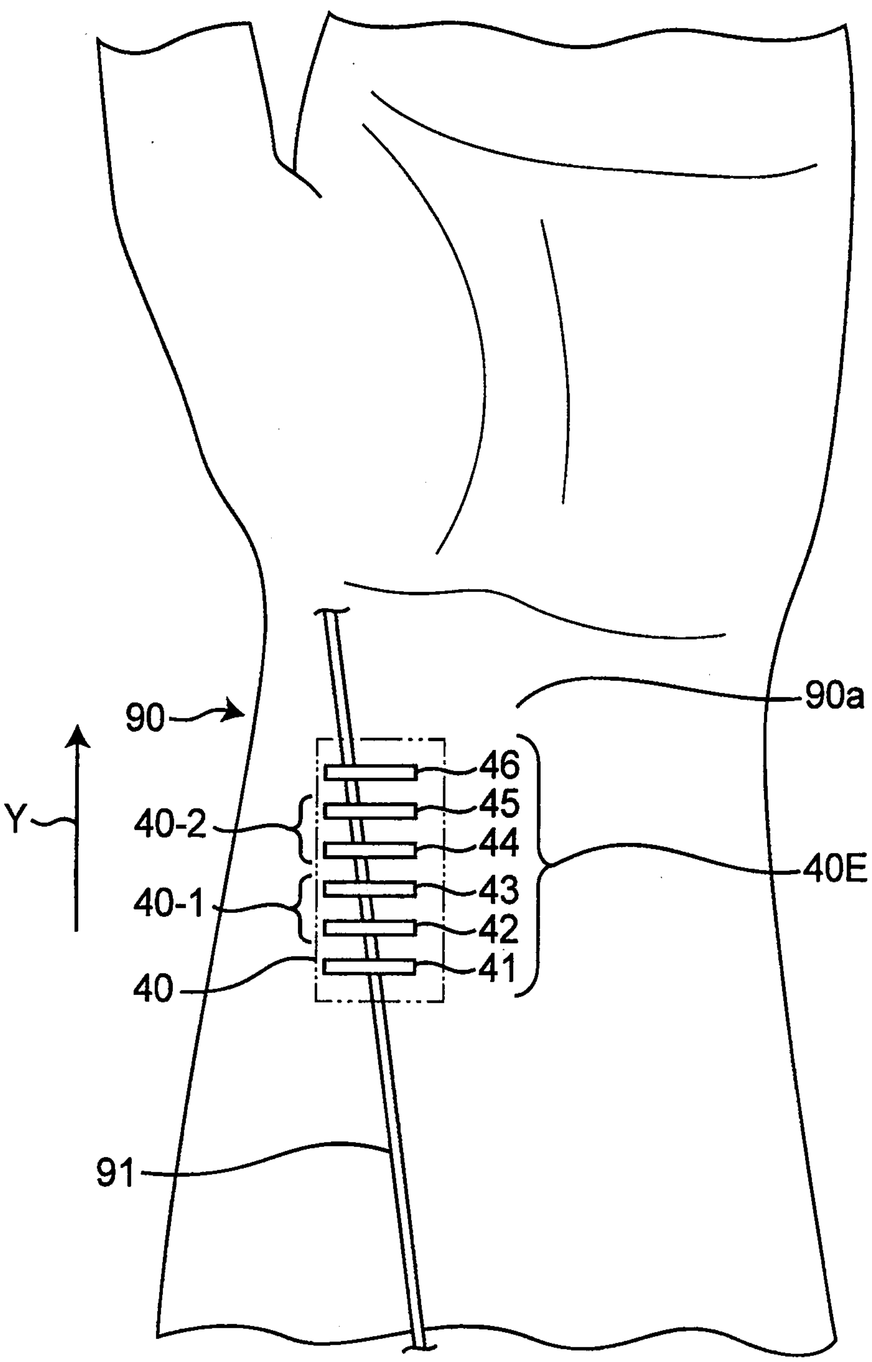
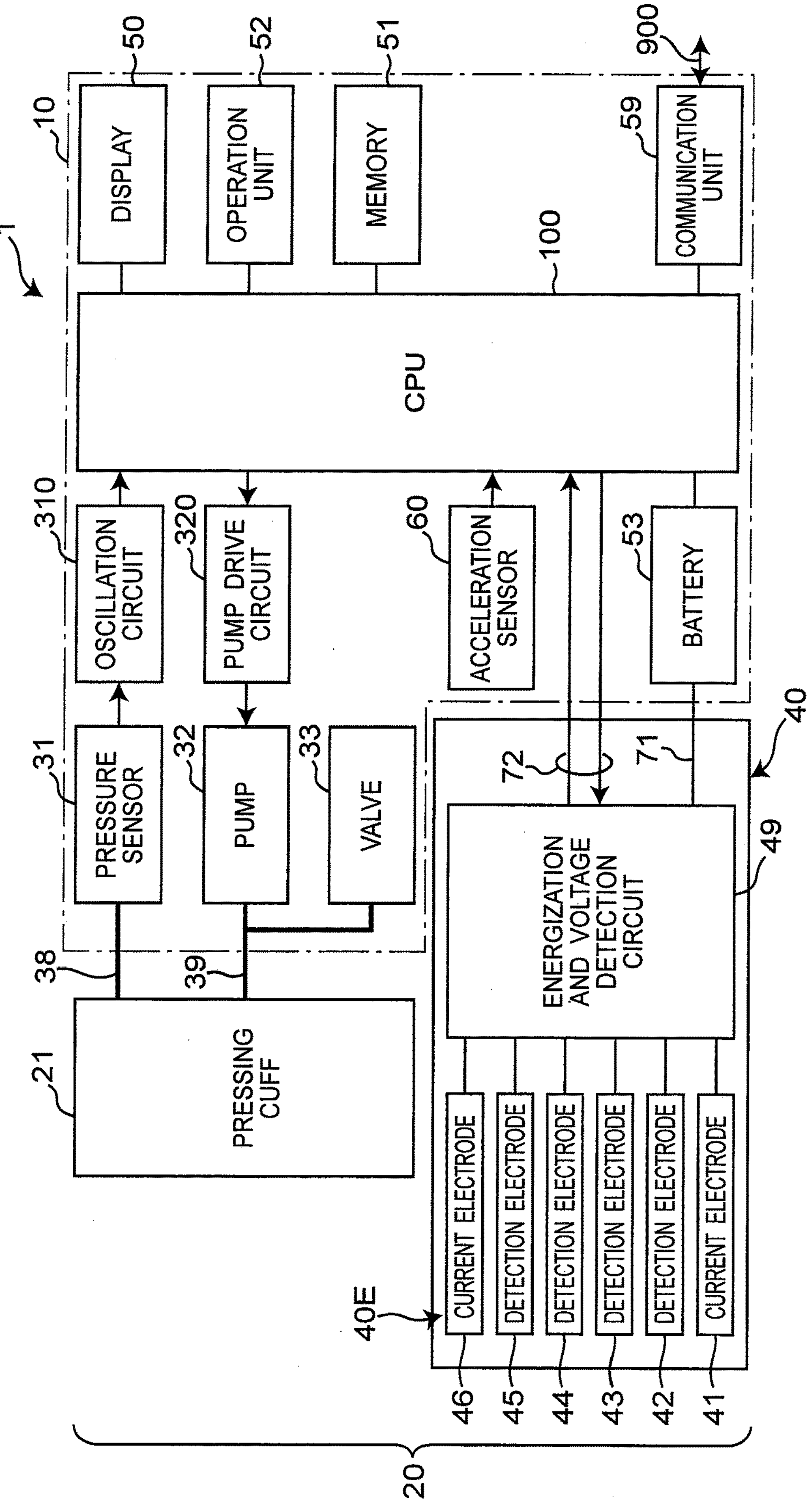


FIG.4



1
10
DISPLAY
50
OPERATION UNIT
52
MEMORY
51
COMMUNICATION UNIT
59
900
CPU
100
OSCILLATION CIRCUIT
310
PUMP DRIVE CIRCUIT
320
ACCELERATION SENSOR
60
BATTERY
53
PRESSURE SENSOR
31
PUMP
32
VALVE
33
38
39
PRESSING CUFF
21
40
72
71
ENERGIZATION AND VOLTAGE DETECTION CIRCUIT
49
CURRENT ELECTRODE
DETECTION ELECTRODE
DETECTION ELECTRODE
DETECTION ELECTRODE
DETECTION ELECTRODE
CURRENT ELECTRODE
40E
46
45
44
43
42
41
20

FIG.5A

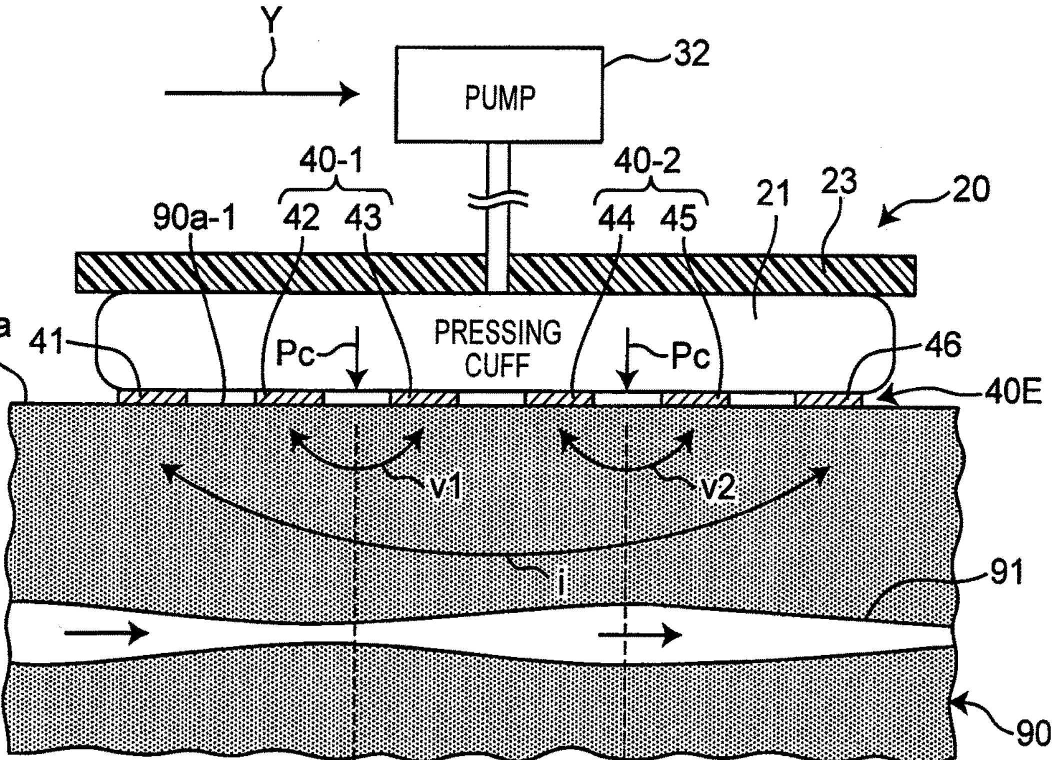

Y
PUMP
32
40-1
40-2
21
23
20
90a-1
42
43
44
45
90a
41
Pc
PRESSING
CUFF
Pc
46
40E
v1
v2
i
91
90

FIG.5B

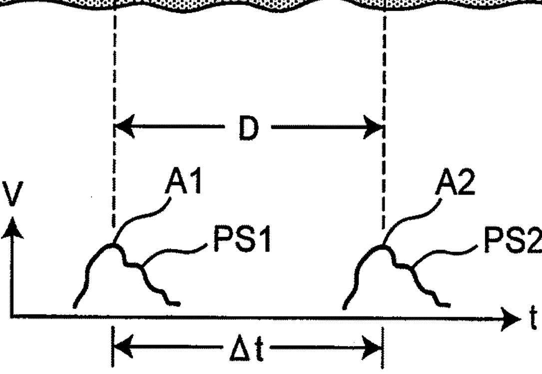

D
V
A1
PS1
A2
PS2
t
Δt

FIG.6

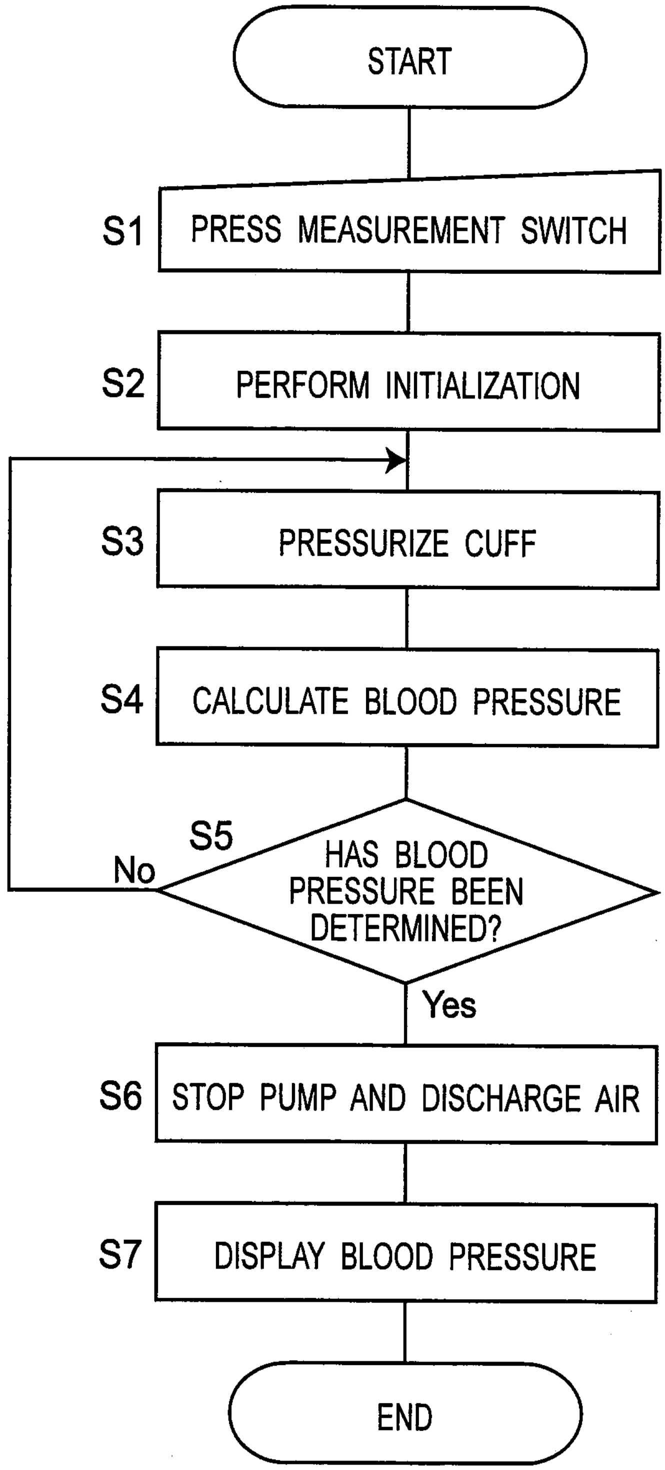

START
S1
PRESS MEASUREMENT SWITCH
S2
PERFORM INITIALIZATION
S3
PRESSURIZE CUFF
S4
CALCULATE BLOOD PRESSURE
S5
HAS BLOOD PRESSURE BEEN DETERMINED?
No
Yes
S6
STOP PUMP AND DISCHARGE AIR
S7
DISPLAY BLOOD PRESSURE
END

FIG.7

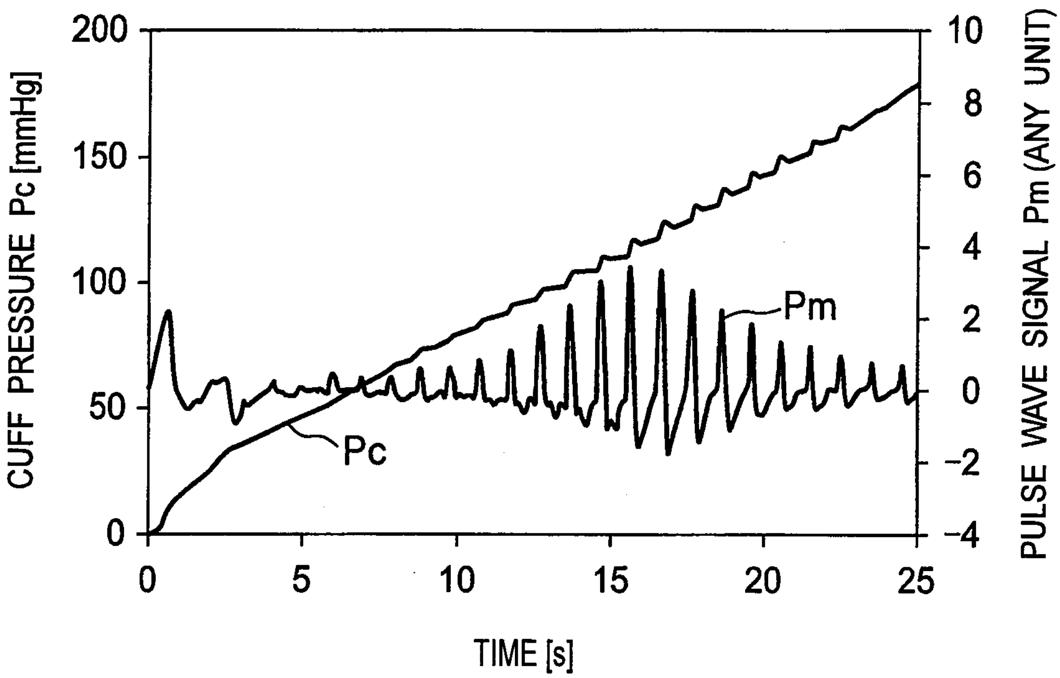
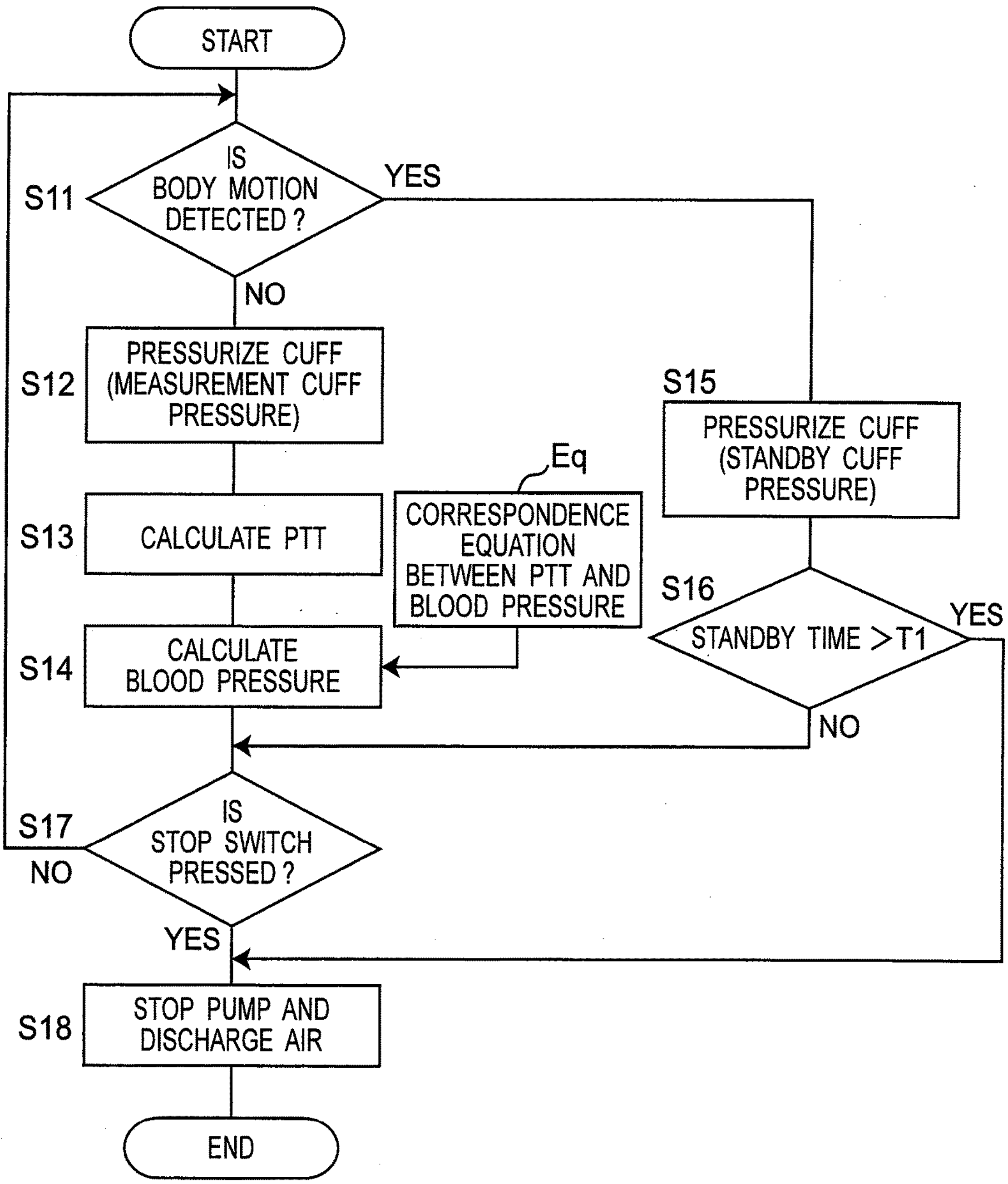

CUFF PRESSURE Pc [mmHg]
200
150
100
50
0
PULSE WAVE SIGNAL Pm (ANY UNIT)
10
8
6
4
2
0
−2
−4
Pm
Pc
0
5
10
15
20
25
TIME [s]

FIG.8


START
S11
IS BODY MOTION DETECTED ?
YES
NO
S12
PRESSURIZE CUFF (MEASUREMENT CUFF PRESSURE)
S13
CALCULATE PTT
Eq
CORRESPONDENCE EQUATION BETWEEN PTT AND BLOOD PRESSURE
S14
CALCULATE BLOOD PRESSURE
S15
PRESSURIZE CUFF (STANDBY CUFF PRESSURE)
S16
STANDBY TIME >T1
YES
NO
S17
IS STOP SWITCH PRESSED ?
NO
YES
S18
STOP PUMP AND DISCHARGE AIR
END

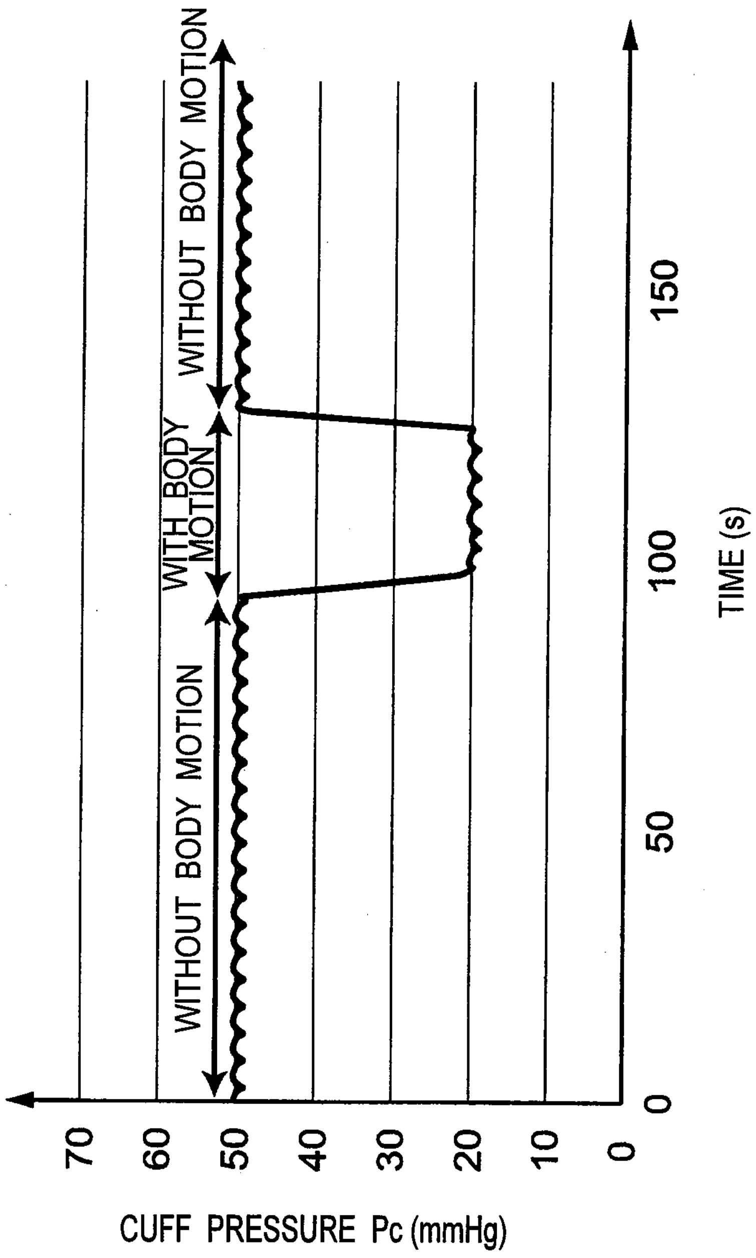

WITHOUT BODY MOTION
WITH BODY MOTION
WITHOUT BODY MOTION
0
10
20
30
40
50
60
70
CUFF PRESSURE Pc (mmHg)
0
50
100
150
TIME (s)

FIG.9

FIG. 10

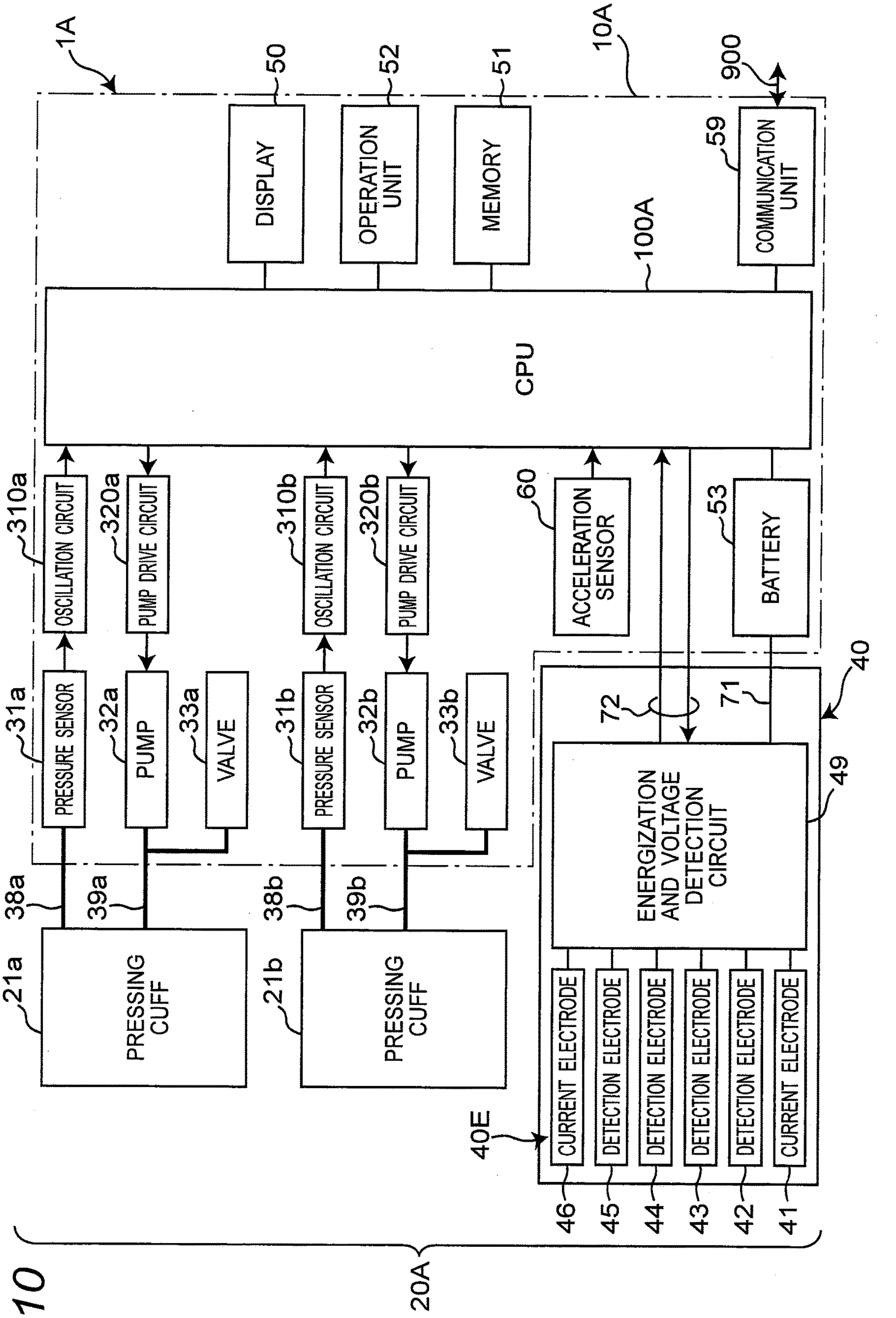

1A
10A
50
DISPLAY
52
OPERATION UNIT
51
MEMORY
900
59
COMMUNICATION UNIT
100A
CPU
310a
OSCILLATION CIRCUIT
320a
PUMP DRIVE CIRCUIT
310b
OSCILLATION CIRCUIT
320b
PUMP DRIVE CIRCUIT
60
ACCELERATION SENSOR
53
BATTERY
31a
PRESSURE SENSOR
32a
PUMP
33a
VALVE
31b
PRESSURE SENSOR
32b
PUMP
33b
VALVE
38a
39a
38b
39b
21a
PRESSING CUFF
21b
PRESSING CUFF
40
72
71
49
ENERGIZATION AND VOLTAGE DETECTION CIRCUIT
40E
CURRENT ELECTRODE
DETECTION ELECTRODE
DETECTION ELECTRODE
DETECTION ELECTRODE
DETECTION ELECTRODE
CURRENT ELECTRODE
46
45
44
43
42
41
20A

FIG. 11

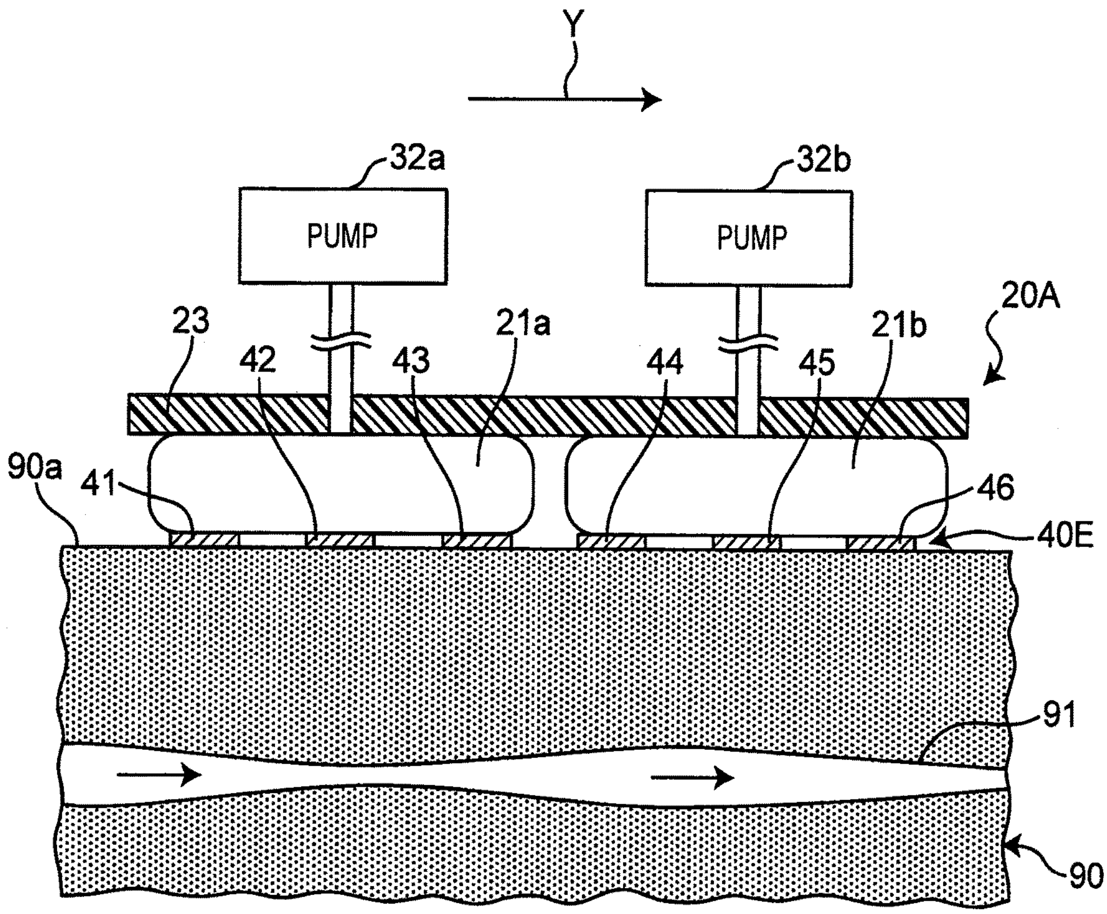


FIG.12

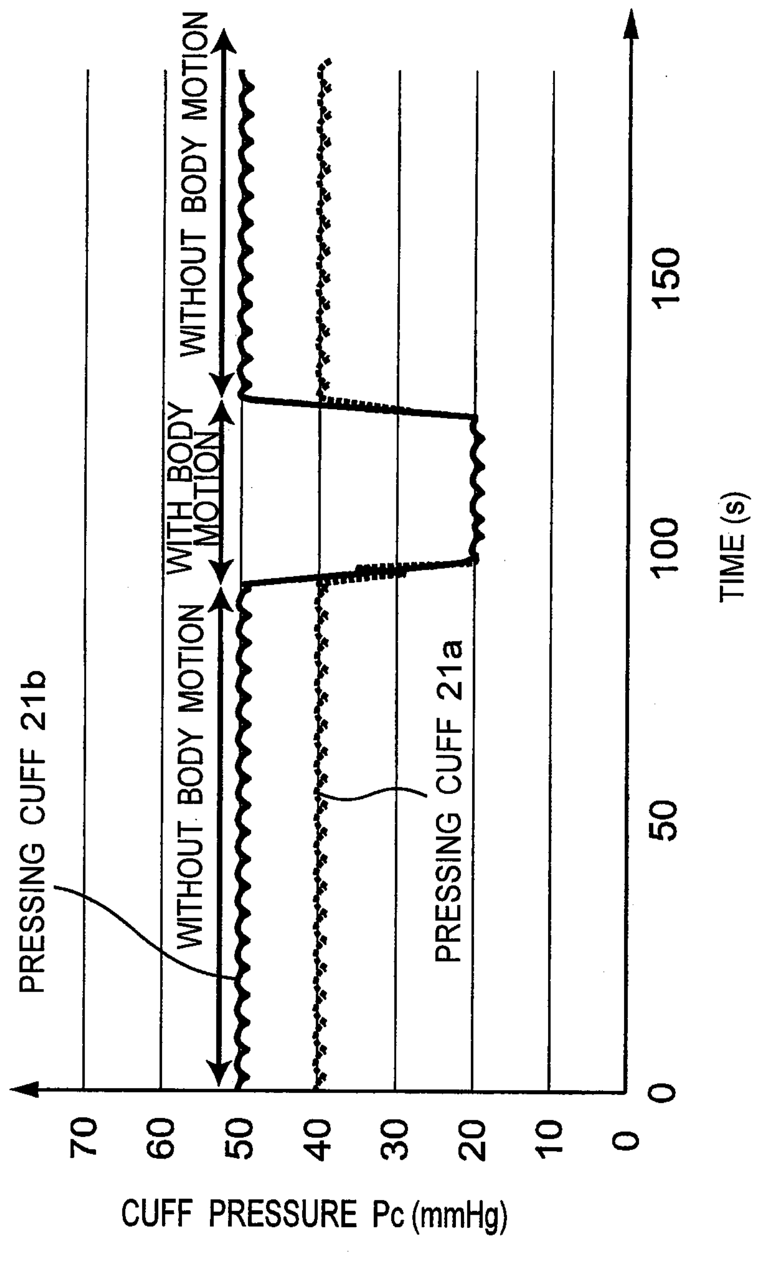

PRESSING CUFF 21b
WITHOUT BODY MOTION
WITH BODY MOTION
WITHOUT BODY MOTION
PRESSING CUFF 21a
CUFF PRESSURE Pc (mmHg)
70
60
50
40
30
20
10
0
0
50
100
150
TIME (s)

FIG. 13

$$EBP = \frac{\alpha}{DT^2} + \beta \quad \cdots (Eq.1)$$

FIG. 14

$$EBP = \frac{\alpha}{DT^2} + \frac{\beta}{DT} + \gamma DT + \delta \quad \cdots (Eq.2)$$

FIG. 15

$$EBP = \frac{\alpha}{DT} + \beta RR + \gamma VR + \delta \quad \cdots (Eq.3)$$

FIG. 16

$$r = \frac{\sum_{i=1}^{n}(x_i - \bar{x})(y_i - \bar{y})}{\left\{\left(\sum_{i=1}^{n}(x_i - \bar{x})^2\right)\left(\sum_{i=1}^{n}(y_i - \bar{y})^2\right)\right\}^{1/2}} \quad \cdots (Eq.4)$$

PULSE WAVE MEASUREMENT DEVICE, PULSE WAVE MEASUREMENT METHOD, AND BLOOD PRESSURE MEASUREMENT DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This is a continuation application of International Application No. PCT/JP2017/038870, with an International filing date of Oct. 27, 2017, which claims priority of Japanese Patent Application No. 2016-254771 filed on Dec. 28, 2016, the entire content of which is hereby incorporated by reference.

TECHNICAL FIELD

[0002] The present invention relates to a pulse wave measurement device and a pulse wave measurement method, and more specifically, relates to a pulse wave measurement device and pulse wave measurement method for non-invasively measuring the transit time of pulse waves propagating in an artery (pulse transit time; PTT).

[0003] In addition, the present invention relates to a blood pressure measurement device that includes this pulse wave measurement device and calculates the blood pressure by using a correspondence equation between pulse transit time and blood pressure.

BACKGROUND ART

[0004] Conventionally, for example, as disclosed in Patent Literature 1 (JP H02-213324 A), there is known a technique for fixedly arranging a small cuff 13 and a middle cuff 12 in a cuff 10 in a state of being separated from each other in the width direction of the cuff 10 (corresponding to the longitudinal direction of the upper arm) to measure a time difference between the respective pulse wave signals detected by the small cuff 13 and the middle cuff 12 (pulse transit time). In the cuff 10, a large cuff 11 for blood pressure measurement by oscillometric method is arranged along the space between the small cuff 13 and the middle cuff 12.

SUMMARY OF INVENTION

[0005] When continuous measurements of pulse wave or blood pressure over a fixed period are to be obtained, since it is necessary to keep pressing the measurement site of the subject, the subject is physically burdened.

[0006] On the other hand, when the subject of the pulse wave is not in a resting state, there may be a case where a component resulting from the body motion of the subject is superimposed on the pulse wave signal, and the pulse transit time cannot be accurately measured. Therefore, when there is a body motion of the subject (when the pulse transit time cannot be measured), for example, it is conceivable to stop the pressing at the measurement site to relieve the physical burden of the subject. Thus, relieving the physical burden as much as possible when the pulse wave or the blood pressure is measured improves the convenience of the subject.

[0007] Thus, an object of the present invention is to provide a pulse wave measurement device and a pulse wave measurement method for controlling pressing force on a measurement site with a novel control method so as to improve the convenience of the subject in consideration of the body motion of the subject.

[0008] In addition, an object of the present invention is to provide a blood pressure measurement device that includes this pulse wave measurement device and calculates the blood pressure by using a correspondence equation between pulse transit time and blood pressure.

[0009] In order to solve the above-mentioned problem, a pulse wave measurement device of the present disclosure comprises:

[0010] a belt to be mounted around a measurement site of a subject;

[0011] at least one pulse wave sensor mounted on the belt, the at least one pulse wave sensor configured to detect a pulse wave of an artery passing through the measurement site;

[0012] a pressing member mounted on the belt, the pressing member configured to vary a pressing force to press the at least one pulse wave sensor against the measurement site;

[0013] a body motion detection unit configured to detect presence or absence of body motion of the subject; and

[0014] a control unit configured to set a pressing force of the pressing member to a first pressing force when there is no body motion of the subject to measure a pulse wave with the at least one pulse wave sensor, the control unit configured to set a pressing force of the pressing member to a second pressing force lower than the first pressing force and higher than zero when there is body motion of the subject and interrupt measurement of a pulse wave.

[0015] In the present specification, "measurement site" refers to a site through which an artery passes. The measurement site may be, for example, an upper limb such as a wrist or an upper arm, or a lower limb such as an ankle or a thigh.

[0016] In addition, "belt" refers to a band-shaped member mounted around a measurement site regardless of the name. For example, instead of the belt, the name may be "band", "cuff", or the like.

[0017] In addition, the "width direction" of the belt corresponds to the longitudinal direction of the measurement site.

[0018] In addition, the "body motion" refers to the motion of the subject's body which brings significant variation in the pulse wave signal detected by at least one pulse wave sensor.

[0019] In addition, the "first pressing force" is the force of strength that can appropriately measure the pulse wave with at least one pulse wave sensor.

[0020] In addition, the "second pressing force" is the force of strength to the extent that an unnecessary physical load is not placed on the subject and to the extent that the position of at least one pulse wave sensor does not deviate from the measurement site as long as the body motion of the subject is not excessively violent.

[0021] In another aspect, a pulse wave measurement method of the present disclosure is a pulse wave measurement method includes:

[0022] using

[0023] a belt to be mounted around a measurement site of a subject,

[0024] at least one pulse wave sensor mounted on the belt, the at least one pulse wave sensor configured to detect a pulse wave of an artery passing through the measurement site,

[0025] a pressing member mounted on the belt, the pressing member configured to vary a pressing force to press the at least one pulse wave sensor against the measurement site, and

[0026] a body motion detection unit configured to detect presence or absence of body motion of the subject,

[0027] to measure a pulse wave of the measurement site, the pulse wave measurement method comprising:

[0028] setting a pressing force of the pressing member to a first pressing force when there is no body motion of the subject to measure a pulse wave with the at least one pulse wave sensor; and

[0029] setting a pressing force of the pressing member to a second pressing force lower than the first pressing force and higher than zero when there is body motion of the subject and interrupting measurement of a pulse wave.

BRIEF DESCRIPTION OF DRAWINGS

[0030] The present invention will become more fully understood from the detailed description given hereinbelow and the accompanying drawings which are given by way of illustration only, and thus are not limitative of the present invention, and wherein:

[0031] FIG. **1** is a perspective view illustrating an appearance of a sphygmomanometer being a blood pressure measurement device including a pulse wave measurement device according to a first embodiment of the present invention.

[0032] FIG. **2** is a diagram schematically illustrating a cross section perpendicular to a longitudinal direction of a wrist in a state where the sphygmomanometer in FIG. **1** is mounted on the left wrist of the subject.

[0033] FIG. **3** is a planar layout diagram of impedance measurement electrodes constituting first and second pulse wave sensors in a state where the sphygmomanometer in FIG. **1** is mounted on the left wrist of the subject.

[0034] FIG. **4** is a diagram illustrating a block configuration of a control system of the sphygmomanometer in FIG. **1**.

[0035] FIG. **5**A is a diagram schematically illustrating a cross section along the longitudinal direction of the wrist in a state where the sphygmomanometer in FIG. **1** is mounted on the left wrist of the subject.

[0036] FIG. **5**B is a diagram illustrating waveforms of first and second pulse wave signals respectively output from the first and second pulse wave sensors.

[0037] FIG. **6** is a diagram illustrating an operation flow when the sphygmomanometer in FIG. **1** performs blood pressure measurement by oscillometric method.

[0038] FIG. **7** is a diagram illustrating changes in a cuff pressure and a pulse wave signal according to the operation flow in FIG. **6**.

[0039] FIG. **8** illustrates an operation flow when the sphygmomanometer executes a pulse wave measurement method of one embodiment to acquire pulse transit time (PTT) and to perform blood pressure measurement (estimation) based on the pulse transit time.

[0040] FIG. **9** is a graph illustrating a cuff pressure Pc set according to the presence or absence of body motion in the sphygmomanometer in FIG. **1**.

[0041] FIG. **10** is a diagram illustrating a block configuration of the control system of a sphygmomanometer being a blood pressure measurement device including a pulse wave measurement device according to a second embodiment of the present invention.

[0042] FIG. **11** is a diagram schematically illustrating a cross section along the longitudinal direction of the wrist in a state where the sphygmomanometer in FIG. **10** is mounted on the left wrist of the subject.

[0043] FIG. **12** is a graph illustrating a cuff pressure Pc set according to the presence or absence of body motion in the sphygmomanometer in FIG. **10**.

[0044] FIG. **13** is a diagram illustrating an example of a predetermined correspondence equation between pulse transit time and blood pressure.

[0045] FIG. **14** is a diagram illustrating another example of a predetermined correspondence equation between pulse transit time and blood pressure.

[0046] FIG. **15** is a diagram illustrating still another example of a predetermined correspondence equation between pulse transit time and blood pressure.

[0047] FIG. **16** is a diagram illustrating an equation representing a cross-correlation coefficient r between a data sequence $\{x_i\}$ and a data sequence $\{y_i\}$.

DESCRIPTION OF EMBODIMENTS

[0048] Hereinafter, embodiments of the present invention will be described in detail with reference to the drawings.

First Embodiment

[0049] Hereinafter, a blood pressure measurement device including a pulse wave measurement device according to a first embodiment of the present invention will be described.

(Configuration of Sphygmomanometer)

[0050] FIG. **1** illustrates an appearance of a wrist-type sphygmomanometer (the whole is denoted by reference numeral **1**) being a blood pressure measurement device including a pulse wave measurement device according to the first embodiment of the present invention as viewed from an oblique direction. In addition, FIG. **2** schematically illustrates a cross section perpendicular to the longitudinal direction of the left wrist **90** in a state where the sphygmomanometer **1** is mounted on the left wrist **90** as a measurement site (hereinafter referred to as "mounted state").

[0051] As illustrated in these drawings, the sphygmomanometer **1** roughly includes a belt **20** to be worn around a user's left wrist **90** and a main body **10** integrally attached to the belt **20**.

[0052] As well understood from FIG. **1**, the belt **20** has an elongated belt shape to surround the left wrist **90** along the circumferential direction, an inner peripheral surface **20***a* to be in contact with the left wrist **90**, and an outer peripheral surface **20***b* on the opposite side of the inner peripheral surface **20***a*. The dimension (width dimension) in the width direction Y of the belt **20** is set to about 30 mm in this example.

[0053] The main body **10** is integrally provided at one end portion **20***e* of the belt **20** in the circumferential direction by integral molding in this example. It should be noted that the belt **20** and the main body **10** may be separately formed, and the main body **10** may be integrally attached to the belt **20** via an engaging member (for example, a hinge or the like). In this example, the site where the main body **10** is disposed is intended to correspond to the back side surface of the left wrist **90** (the surface on the back side of the hand) **90***b* in the mounted state (see FIG. **2**). In FIG. **2**, a radial artery **91** passing near the palmar surface (the surface on the palmar side) **90***a* in the left wrist **90** is illustrated.

[0054] As well understood from FIG. **1**, the main body **10** has a three-dimensional shape having a thickness in a direction perpendicular to the outer peripheral surface **20***b* of the belt **20**. The main body **10** is formed small and thin so as not to interfere with the daily activities of the user. In this example, the main body **10** has a truncated quadrangular pyramid-shaped contour projecting outward from the belt **20**.

[0055] A display **50** serving as a display screen is provided on the top surface of the main body **10** (the surface on a side farthest from the measurement site) **10***a*. In addition, an operation unit **52** for inputting instructions from the user is provided along the side surface **10***f* of the main body **10** (side surface on the left front side in FIG. **1**).

[0056] An impedance measurement unit **40** constituting at least one pulse wave sensor is provided in a site between one end **20***e* and the other end **20***f* in the circumferential direction of the belt **20**. In the present embodiment, the case where the impedance measurement unit **40** constitutes first and second pulse wave sensors will be described. Of the belt **20**, on the inner peripheral surface **20***a* of the site where the impedance measurement unit **40** is disposed, six plate-shaped (or sheet-shaped) electrodes **41** to **46** (all of which are referred to as "electrode group" and denoted by reference numeral **40**E) are arranged in a state of being separated from each other in the width direction Y of the belt **20** (described in detail below). In this example, the site where the electrode group **40**E is disposed is intended to correspond to the radial artery **91** of the left wrist **90** in the mounted state (see FIG. **2**).

[0057] As illustrated in FIG. **1**, the bottom surface of the main body **10** (the surface on the side closest to the measurement site) **10***b* and the end portion **20***f* of the belt **20** are connected by a threefold buckle **24**. The buckle **24** includes a first plate-shaped member **25** disposed on the outer peripheral side and a second plate-shaped member **26** disposed on the inner peripheral side. One end portion **25***e* of the first plate-shaped member **25** is rotatably attached to the main body **10** via a coupling rod **27** extending along the width direction Y. The other end portion **25***f* of the first plate-shaped member **25** is rotatably attached to one end portion **26***e* of the second plate-shaped member **26** via a coupling rod **28** extending along the width direction Y. The other end portion **26***f* of the second plate-shaped member **26** is fixed near the end portion **20***f* of the belt **20** by the fixing portion **29**. It should be noted that the attaching position of the fixing portion **29** in the circumferential direction of the belt **20** is variably set in advance in accordance with the circumferential length of the left wrist **90** of the user. Thus, the sphygmomanometer **1** (belt **20**) is formed in a substantially annular shape as a whole, and the bottom surface **10***b* of the main body **10** and the end portion **20***f* of the belt **20** can be opened and closed in the arrow B direction by the buckle **24**.

[0058] When mounting the sphygmomanometer **1** on the left wrist **90**, the user inserts the left hand into the belt **20** in the direction indicated by the arrow A in FIG. **1** with the buckle **24** open and the diameter of the ring of the belt **20** increased. Then, as illustrated in FIG. **2**, the user adjusts the angular position of the belt **20** around the left wrist **90** to position the impedance measurement unit **40** of the belt **20** on the radial artery **91** passing through the left wrist **90**. Thus, the electrode group **40**E of the impedance measurement unit **40** abuts on a portion **90***a***1** corresponding to the radial artery **91** on the palmar surface **90***a* of the left wrist **90**. In this state, the user closes and fixes the buckle **24**. Thus, the user wears the sphygmomanometer **1** (belt **20**) on the left wrist **90**.

[0059] As illustrated in FIG. **2**, in this example, the belt **20** includes a strip **23** forming the outer peripheral surface **20***b* and a pressing cuff **21** as a pressing member attached along the inner peripheral surface of the strip **23**. The strip **23** is, in this example, made of a plastic material that is flexible in the thickness direction and substantially non-stretchable in the circumferential direction (longitudinal direction). In this example, the pressing cuff **21** is configured as a fluid bag by facing two stretchable polyurethane sheets in the thickness direction and welding their peripheral portions. The electrode group **40**E of the impedance measurement unit **40** is disposed at a site corresponding to the radial artery **91** of the left wrist **90** on the inner peripheral surface **20***a* of the pressing cuff **21** (belt **20**) as described above.

[0060] As illustrated in FIG. **3**, in the mounted state, the electrode group **40**E of the impedance measurement unit **40** is aligned along the longitudinal direction of the wrist (corresponding to the width direction Y of the belt **20**) according to the radial artery **91** of the left wrist **90**. The electrode group **40**E includes a current electrode pair **41** and **46** for energization disposed on both sides in the width direction Y, a first detection electrode pair **42** and **43** forming a first pulse wave sensor **40-1** for voltage detection disposed between the current electrode pair **41** and **46**, and a second detection electrode pair **44** and **45** forming a second pulse wave sensor **40-2**. With respect to the first detection electrode pair **42** and **43**, the second detection electrode pair **44** and **45** is disposed according to the portion on the more downstream side of the blood flow of the radial artery **91**. In the width direction Y, the distance D between the center of the first detection electrode pair **42** and **43** and the center of the second detection electrode pair **44** and **45** (see FIG. **5**A) is set to 20 mm in this example. This distance D corresponds to a substantial space between the first pulse wave sensor **40-1** and the second pulse wave sensor **40-2**. In addition, in the width direction Y, the space between the first detection electrode pair **42** and **43** and the space between the second detection electrode pair **44** and **45** are both set to 2 mm in this example.

[0061] This electrode group **40**E can be configured to be flat. Therefore, in the sphygmomanometer **1**, the belt **20** can be configured to be thin as a whole.

[0062] FIG. **4** illustrates a block configuration of a control system of the sphygmomanometer **1**. In addition to the display **50** and the operation unit **52** described above, the main body **10** of the sphygmomanometer **1** mounts a central processing unit (CPU) **100** as a control unit, a memory **51** as a storage unit, a communication unit **59**, a pressure sensor **31**, a pump **32**, a valve **33**, an oscillation circuit **310** for converting the output from the pressure sensor **31** into a frequency, a pump drive circuit **320** for driving the pump **32**, and an acceleration sensor **60** for measuring acceleration applied to the sphygmomanometer **1**. Furthermore, in addition to the electrode group **40**E described above, the impedance measurement unit **40** mounts an energization and voltage detection circuit **49**.

[0063] The display **50** includes an organic electro luminescence (EL) display in this example, and displays information related to blood pressure measurement such as blood pressure measurement results and other information in accordance with a control signal from the CPU **100**. It should be noted that the display **50** is not limited to the organic EL display, and may include another type of display such as a liquid crystal display (LCD).

[0064] The operation unit **52** includes a push switch in this example, and inputs an operation signal corresponding to the user's instructions to start or stop blood pressure measurement into the CPU **100**. It should be noted that the operation unit **52** is not limited to the push switch, and may be, for example, a pressure-sensitive (resistive) or proximity (capacitive) touch panel switch. In addition, the operation unit **52** may include a microphone (not shown) to input a blood pressure measurement start instructions in response to the user's voice.

[0065] The memory **51** non-transitorily stores data of a program for controlling the sphygmomanometer **1**, data used for controlling the sphygmomanometer **1**, setting data for setting various functions of the sphygmomanometer **1**, data of measurement results of blood pressure values, and the like. In addition, the memory **51** is used as a work memory or the like when a program is executed.

[0066] The CPU **100** executes various functions as a control unit in accordance with a program for controlling the sphygmomanometer **1** stored in the memory **51**. For example, when blood pressure measurement is performed by oscillometric method, the CPU **100** drives the pump **32** (and the valve **33**) based on a signal from the pressure sensor **31** in response to instructions to start blood pressure measurement from the operation unit **52**. In addition, the CPU **100** calculates the blood pressure value based on the signal from the pressure sensor **31** in this example.

[0067] The communication unit **59** is controlled by the CPU **100** to transmit predetermined information to an external device via the network **900**, receives information from an external device via the network **900**, and delivers the information to the CPU **100**. The communication via the network **900** may be wireless or wired. In this embodiment, the network **900** is the Internet, but is not limited thereto, and may be another type of network such as a hospital local area network (LAN), or may be one-to-one communication using a USB cable or the like. The communication unit **59** may include a micro USB connector.

[0068] The pump **32** and the valve **33** are connected to the pressing cuff **21** via the air pipe **39**, and the pressure sensor **31** is connected to the pressing cuff **21** via the air pipe **38**. It should be noted that the air pipes **39** and **38** may be one common pipe. The pressure sensor **31** detects the pressure in the pressing cuff **21** via the air pipe **38**. The pump **32** includes a piezoelectric pump in this example and supplies air as a fluid for pressurization to the pressing cuff **21** through the air pipe **39** in order to raise the pressure in the pressing cuff **21** (cuff pressure). The valve **33** is mounted on the pump **32**, and is configured to be controlled in opening/closing as the pump **32** is turned on/off. That is, when the pump **32** is turned on, the valve **33** closes and air is filled into the pressing cuff **21**, while when the pump **32** is turned off, the valve **33** opens and the air in the pressing cuff **21** is discharged into the atmosphere through the air pipe **39**. It should be noted that the valve **33** has a function of a check valve so that the discharged air does not flow back. The pump drive circuit **320** drives the pump **32** based on a control signal supplied from the CPU **100**.

[0069] The pressure sensor **31** is a piezoresistive pressure sensor in this example, and detects the pressure of the belt **20** (pressing cuff **21**), a pressure with the atmospheric pressure as a reference (zero) in this example, through the air pipe **38** to output the detected result as a time-series signal. The oscillation circuit **310** oscillates based on an electrical signal value based on a change in electrical resistance due to the piezoresistive effect from the pressure sensor **31**, and outputs a frequency signal having a frequency corresponding to the electrical signal value of the pressure sensor **31** to the CPU **100**. In this example, the output of pressure sensor **31** is used for controlling the pressure of the pressing cuff **21**, and for calculating the blood pressure value (including systolic blood pressure (SBP) and diastolic blood pressure (DBP)) by oscillometric method.

[0070] The acceleration sensor **60** measures the acceleration applied to the sphygmomanometer **1** to work as a body motion detection unit for detecting the presence or absence of body motion of the subject.

[0071] The battery **53** supplies power to elements mounted on the main body **10**, in this example, to each element of the CPU **100**, the pressure sensor **31**, the pump **32**, the valve **33**, the display **50**, the memory **51**, the communication unit **59**, the oscillation circuit **310**, the pump drive circuit **320**, and the acceleration sensor **60**. In addition, the battery **53** also supplies power to the energization and voltage detection circuit **49** of the impedance measurement unit **40** through the wiring line **71**. This wiring line **71** is provided to extend between the main body **10** and the impedance measurement unit **40** along the circumferential direction of the belt **20** in a state of being sandwiched between the strip **23** of the belt **20** and the pressing cuff **21** together with the signal wiring line **72**.

[0072] The energization and voltage detection circuit **49** of the impedance measurement unit **40** is controlled by the CPU **100**, and supplies a high frequency constant current i having a frequency of 50 kHz and a current value of 1 mA, in this example, between the current electrode pair **41** and **46** disposed on both sides in the longitudinal direction of the wrist (corresponding to the width direction Y of the belt **20**) during the operation, as illustrated in FIG. **5**A. In this state, the energization and voltage detection circuit **49** detects a voltage signal v**1** between the first detection electrode pair **42** and **43** forming the first pulse wave sensor **40-1** and a voltage signal v**2** between the second detection electrode pair **44** and **45** forming the second pulse wave sensor **40-2**. These voltage signals v**1** and v**2** respectively represent the change in the electrical impedance due to the pulse wave of the blood flow of the radial artery **91** in the portions where the first pulse wave sensor **40-1** and the second pulse wave sensor **40-2** face on the palmar surface **90***a* of the left wrist **90** (impedance system). The energization and voltage detection circuit **49** rectifies, amplifies, and filters these voltage signals v**1** and v**2** to output a first pulse wave signal PS**1** and a second pulse wave signal PS**2** having mountain-shaped waveforms in time series as illustrated in FIG. **5**B. In this example, the voltage signals v**1** and v**2** are approximately 1 mV. In addition, the respective peaks A**1** and A**2** of the first pulse wave signal PS**1** and the second pulse wave signal PS**2** are approximately 1 volt in this example.

[0073] It should be noted that assuming that the pulse wave velocity (PWV) of the blood flow of the radial artery **91** is in the range of 1000 cm/s to 2000 cm/s, since the substantial space D between the first pulse wave sensor **40-1**

and the second pulse wave sensor **40-2** is 20 mm, the time difference Δt between the first pulse wave signal PS**1** and the second pulse wave signal PS**2** is in the range of 1.0 ms to 2.0 ms.

(Operation of Blood Pressure Measurement by Oscillometric Method)

[0074] FIG. **6** illustrates an operation flow when the sphygmomanometer **1** performs blood pressure measurement by oscillometric method.

[0075] When the user gives an instruction to measure blood pressure by oscillometric method with the push switch of the operation unit **52** provided in the main body **10** (step S1), the CPU **100** starts operation to initialize the processing memory area (step S**2**). In addition, the CPU **100** turns off the pump **32** via the pump drive circuit **320**, opens the valve **33**, and discharges the air in the pressing cuff **21**. Subsequently, the current output value of the pressure sensor **31** is set as a value corresponding to the atmospheric pressure (0 mmHg adjustment).

[0076] Subsequently, the CPU **100** works as a pressure control unit and drives the pump **32** via the pump drive circuit **320** to send air to the pressing cuff **21**, which closes the valve **33** to inflate the pressing cuff **21**, gradually pressurizing the cuff pressure Pc (see FIG. **7**) (step S3 in FIG. **6**).

[0077] In this pressurization process, the CPU **100** monitors the cuff pressure Pc with the pressure sensor **31** in order to calculate the blood pressure value, and acquires, as a pulse wave signal Pm as illustrated in FIG. **7**, the fluctuation component of the arterial volume generated in the radial artery **91** of the left wrist **90** as the measurement site.

[0078] Next, in step S**4** in FIG. **6**, the CPU **100** acts as a second blood pressure calculation unit, and applies a known algorithm by oscillometric method based on the pulse wave signal Pm acquired at this time to attempt the calculation of blood pressure values (systolic blood pressure SBP and diastolic blood pressure DBP).

[0079] At this time, if the blood pressure value cannot be calculated yet because of insufficient data (NO in step S**5**), unless the cuff pressure Pc reaches the upper limit pressure (for safety, for example, 300 mmHg is predetermined), the processing of steps S**3** to S**5** is repeated.

[0080] If the blood pressure value can be calculated in this manner (YES in step S**5**), the CPU **100** stops the pump **32**, opens the valve **33**, and discharges the air in the pressing cuff **21** (step S**6**). Then, lastly, the measurement result of the blood pressure value is displayed on the display **50** and recorded in the memory **51** (step S**7**).

[0081] It should be noted that the calculation of the blood pressure value may be performed not only in the pressurization process, but also in the depressurization process.

(Operation of Blood Pressure Measurement Based on Pulse Transit Time)

[0082] FIG. **8** illustrates an operation flow when the sphygmomanometer **1** executes a pulse wave measurement method of one embodiment to acquire pulse transit time (PTT) and to perform blood pressure measurement (estimation) based on the pulse transit time.

[0083] When the user gives an instruction to perform the PTT-based blood pressure measurement with a push switch of the operation unit **52** provided on the main body **10**, the CPU **100** starts operation. First, the CPU **100** detects the presence or absence of body motion of the subject by using the acceleration sensor **60** (step S**11** in FIG. **8**).

[0084] When there is no body motion of the subject (NO in step S**11** in FIG. **8**), the CPU **100** sets the pressing force of the pressing cuff **21** to a predetermined measurement cuff pressure (first pressing force) (step S**12** in FIG. **8**). The method for determining the measurement cuff pressure (first pressing force) will be described below. The CPU **100** drives the pump **32** via the pump drive circuit **320** to send air to the pressing cuff **21**, which closes the valve **33** to inflate the pressing cuff **21**, pressurizing the cuff pressure Pc (see FIG. **5**A) to the measurement cuff pressure.

[0085] Next, the CPU **100** measures the first and second pulse wave signals PS**1** and PS**2** with the first pulse wave sensor **40-1** and the second pulse wave sensor **40-2**, and acquires a time difference Δt between the first and second pulse wave signals PS**1** and PS**2** (see FIG. **5**B) as pulse transit time (PTT) (step S**13** in FIG. **8**). More specifically, in this example, a time difference Δt between the peak A**1** of the first pulse wave signal PS**1** and the peak A**2** of the second pulse wave signal PS**2** is acquired as pulse transit time (PTT).

[0086] Next, the CPU **100** works as a first blood pressure calculation unit, and calculates (estimates) the blood pressure based on the pulse transit time (PTT) acquired in step S**13** by using the predetermined correspondence equation Eq between pulse transit time and blood pressure (step S**14** in FIG. **8**). Here, when pulse transit time is represented as DT and blood pressure is represented as EBP, the predetermined correspondence equation Eq between pulse transit time and blood pressure is provided as a known fractional function including the term of $1/DT^2$, for example, as shown in the equation (Eq. 1) in FIG. **13** (see, for example, JP H10-201724 A). In the equation (Eq. 1), each of α and β represents a known coefficient or constant.

[0087] The measurement result of the blood pressure value is displayed on the display **50** and recorded in the memory **51**.

[0088] On the other hand, when there is body motion of the subject (YES in step S**11** in FIG. **8**), the CPU **100** sets the pressing force of the pressing cuff **21** to a standby cuff pressure (a second pressing force lower than the first pressing force and higher than zero), and interrupts the measurement of the pulse wave (step S**15** in FIG. **8**). When interrupting the measurement of the pulse wave immediately after the start of the operation flow in FIG. **1**, the CPU **100** drives the pump **32** via the pump drive circuit **320** to send air to the pressing cuff **21**, which closes the valve **33** to inflate the pressing cuff **21**, pressurizing the cuff pressure to the standby cuff pressure. On the other hand, if the pressing force of the pressing cuff **21** is once set to the measurement cuff pressure, and then the pulse wave measurement is interrupted, the CPU **100** stops the pump **32** via the pump drive circuit **320**, thereby opening the valve **33** to reduce the cuff pressure Pc to the standby cuff pressure. Then, when the cuff pressure Pc reaches the standby cuff pressure, the CPU **100** temporarily operates the pump **32** again via the pump drive circuit **320**, thereby closing the valve **33**. The CPU **100** may display on the display **50** that the measurement of the pulse wave is interrupted due to detecting the body motion of the subject.

[0089] Next, the CPU **100** determines whether the standby time after interrupting the measurement of the pulse wave (that is, the standby time after setting the standby cuff pressure (second pressing force)) exceeds a threshold value T1 having a predetermined length (step **S16** in FIG. **8**). If NO in step **S16** in FIG. **8**, the CPU **100** proceeds to step **S17**, and as long as body motion of the subject is detected in step **S11** (YES in step **S11** in FIG. **8**), the CPU **100** repeats the loop of steps **S11**, **15**, **S16**, and **S17**. If the state of YES is continued in step **S11** in FIG. **8** (that is, if the loop of steps **S11**, **15**, **S16**, and **S17** is repeated), the standby time after interrupting pulse wave measurement is the total value thereof. When the standby time after interrupting the measurement of the pulse wave exceeds the threshold value T1 (YES in step **S16** in FIG. **8**), the CPU **100** stops the pump **32**, opens the valve **33** to discharge the air in the pressing cuff **21**, and sets the pressing force of the pressing cuff **21** to zero (step **S18** in FIG. **8**).

[0090] In this example, if measurement stop is not instructed by the push switch of the operation unit **52** in step **S17** in FIG. **8** (NO in step **S17** in FIG. **8**), the CPU **100** returns to step **S11** to repeat any one of steps **S12** to **S14** for setting the measurement cuff pressure and steps **S15** to **S16** for setting the standby cuff pressure according to the presence or absence of body motion of the subject. FIG. **9** is a graph illustrating a cuff pressure Pc set according to the presence or absence of body motion in the sphygmomanometer in FIG. **1**. When there is no body motion of the subject, the cuff pressure Pc is set to, for example, 50 mmHg, and when there is body motion of the subject, the cuff pressure Pc is set to, for example, 20 mmHg. After interrupting the measurement of the pulse wave (YES in step **S11** in FIG. **8**), and when a state where there is body motion of the subject is transitioned to a state where there is no body motion of the subject (NO in step **S11** in FIG. **8**), the CPU **100** returns the pressing force of the pressing cuff **21** from the second pressing force to the first pressing force to resume measurement of the pulse wave. Every time executing steps **S12** to **S14**, the CPU **100** updates and displays the measurement result of the blood pressure value on the display **50** and accumulates and records the measurement result of the blood pressure value in the memory **51**.

[0091] If the user gives an instruction to stop measurement with the push switch of the operation unit **52** provided on the main body **10** (YES in step **S17** in FIG. **8**), the CPU **100** stops the pump **32**, opens the valve **33**, discharges the air in the pressing cuff **21**, and ends the measurement operation (step **S18**).

[0092] According to the sphygmomanometer **1**, it is possible to control the pressing force on the measurement site by a novel control method in consideration of the body motion of the subject, and to improve the convenience of the subject. According to the sphygmomanometer **1**, when there is body motion of the subject, reducing the pressing force of the pressing cuff allows the physical burden on the subject to be relieved. In addition, according to the sphygmomanometer **1**, when the pressing force of the pressing cuff is reduced, setting the pressing force higher than zero allows the positional deviation of the pulse wave sensors **40-1** and **40-2** to be reduced and the pressurization time when measurement is resumed to be shortened.

[0093] According to the sphygmomanometer **1**, the blood pressure measurement based on the pulse transit time (PTT) allows blood pressure to be measured continuously over a long period of time with a reduced physical burden on the user.

[0094] In addition, according to the sphygmomanometer **1**, the blood pressure measurement (estimation) based on pulse transit time and the blood pressure measurement by oscillometric method can be performed by an integrated device. Therefore, the convenience of the user can be enhanced.

(Determination of First Pressing Force)

[0095] The measurement cuff pressure (first pressing force) set in step **S12** in FIG. **8** is determined, for example, as follows.

[0096] According to experiments by the inventor, it has been found that when the pressing force of the first pulse wave sensor **40-1** (including the first detection electrode pair **42** and **43**) and the second pulse wave sensor **40-2** (including the second detection electrode pair **44** and **45**) on the left wrist **90** as the measurement site (equal to the cuff pressure Pc by the pressing cuff **21**) gradually increases from zero, the cross-correlation coefficient r between the waveforms of the first and second pulse wave signals PS1 and PS2 gradually increases along with that, indicates the maximum value rmax, and then gradually decreases. This operation flow is based on the idea that a range in which the cross-correlation coefficient r exceeds a predetermined threshold value Th (in this example, Th=0.99) is an appropriate range of the pressing force (this is referred to as an "appropriate pressing range").

[0097] In order to determine the first pressing force, first, the CPU **100** drives the pump **32** via the pump drive circuit **320** to send air to the pressing cuff **21**, which closes the valve **33** to inflate the pressing cuff **21**, gradually pressurizing the cuff pressure Pc (see FIG. **5**A). In this example, the cuff pressure Pc is continuously increased at a constant rate (=5 mmHg/s). It should be noted that the cuff pressure Pc may be increased stepwise so that the time for calculating the cross-correlation coefficient r described next is easily secured.

[0098] In this pressurization process, the CPU **100** acquires first and second pulse wave signals PS1 and PS2 respectively output in time series by the first pulse wave sensor **40-1** and the second pulse wave sensor **40-2**, and calculates the cross-correlation coefficient r between the waveforms of the first and second pulse wave signals PS1 and PS2 in real time.

[0099] Along with that, the CPU **100** determines whether the calculated cross-correlation coefficient r exceeds a predetermined threshold value Th (=0.99). Here, if the cross-correlation coefficient r is not more than the threshold value Th, the CPU **100** repeats the pressurization of the cuff pressure Pc and the calculation of the cross-correlation coefficient r until the cross-correlation coefficient r exceeds the threshold value Th. Then, if the cross-correlation coefficient r exceeds the threshold value Th, the CPU **100** stops the pump **32** and sets the cuff pressure Pc to a value at that time, that is, a value when the cross-correlation coefficient r exceeds the threshold value Th.

[0100] Using the measurement cuff pressure (first pressing force) determined in this manner allows the measurement accuracy of the pulse transit time to be enhanced. In addition, since the cuff pressure Pc is set to a value when the cross-correlation coefficient r exceeds the threshold value Th, the pulse transit time can be acquired without unnecessarily increasing the cuff pressure Pc. Thus, the physical burden on the user can be reduced.

Second Embodiment

[0101] Hereinafter, a blood pressure measurement device including a pulse wave measurement device according to a second embodiment of the present invention will be described.

[0102] FIG. **10** is a diagram illustrating a block configuration of the control system of a sphygmomanometer **1**A being a blood pressure measurement device including a pulse wave measurement device according to a second embodiment of the present invention. FIG. **11** is a diagram schematically illustrating a cross section along the longitudinal direction of the wrist in a state where the sphygmomanometer in FIG. **10** is mounted on the left wrist of the subject.

[0103] The sphygmomanometer **1**A includes a main body **10**A and a belt **20**A.

[0104] Instead of one system of the pressure sensor **31**, the pump **32**, the valve **33**, the oscillation circuit **310**, the pump drive circuit **320**, and the CPU **100** for controlling them included in the main body **10** in FIG. **4**, the main body **10**A in FIG. **10** includes two systems of pressure sensors **31***a* and **31***b*, pumps **32***a* and **32***b*, valves **33***a* and **33***b*, oscillation circuits **310***a* and **310***b*, pump drive circuits **320***a* and **320***b*, and a CPU **100**A for controlling them. The pressure sensors **31***a* and **31***b*, the pumps **32***a* and **32***b*, the valves **33***a* and **33***b*, the oscillation circuits **310***a* and **310***b*, and the pump drive circuits **320***a* and **320***b* in FIG. **10** are respectively configured in the same manner as the pressure sensor **31**, the pump **32**, the valve **33**, the oscillation circuit **310**, and the pump drive circuit **320** in FIG. **4**.

[0105] The belt **20**A in FIG. **10** includes two pressing cuffs **21***a* and **21***b* instead of one pressing cuff **21** of the belt **20** in FIG. **4**. Each of the pressing cuffs **21***a* and **21***b* in FIG. **10** is configured in the same manner as the pressing cuff **21** in FIG. **4**. The pressing cuff **21***a* is connected to the pressure sensor **31***a* and the pump **32***a* via the air pipes **38***a* and **39***a*. The pressing cuff **21***b* is connected to the pressure sensor **31***b* and the pump **32***b* via the air pipes **38***b* and **39***b*.

[0106] The other components of the sphygmomanometer **1**A in FIG. **10** are configured in the same manner as the corresponding components of the sphygmomanometer **1** in FIG. **4**.

[0107] The sphygmomanometer **1**A in FIG. **10** includes two systems of pumps **32***a* and **32***b*, thereby allowing the first pulse wave sensor (detection electrodes **42** and **43**) and the second pulse wave sensor (detection electrodes **44** and **45**) to be pressed with individual pressing forces (cuff pressure). The CPU **100** sets the first pressing force (cuff pressure) of the pressing cuffs **21***a* and **21***b* to individual values with respect to the first pulse wave sensor and the second pulse wave sensor. FIG. **12** is a graph illustrating a cuff pressure Pc set according to the presence or absence of body motion in the sphygmomanometer in FIG. **10**. When there is no body motion of the subject, the cuff pressure Pc of the pressing cuff **21***a* is set to, for example, 40 mmHg, and when there is body motion of the subject, the cuff pressure Pc of the pressing cuff **21***a* is set to, for example, 20 mmHg. When there is no body motion of the subject, the cuff pressure Pc of the pressing cuff **21***b* is set to, for example, 50 mmHg, and when there is body motion of the subject, the cuff pressure Pc of the pressing cuff **21***b* is set to, for example, 20 mmHg.

[0108] The cuff pressure Pc of the pressing cuffs **21***a* and **21***b* as the first pressing force is, for example, set to a value at which the cross-correlation coefficient of the first and second pulse wave signals respectively output in time series by the first and second pulse wave sensors exceeds a predetermined threshold value. Setting the first pressing force (cuff pressure) of the pressing cuffs **21***a* and **21***b* to individual values easily brings the cross-correlation coefficient close to 1, and therefore, easily improves the measurement accuracy of the pulse wave and the blood pressure.

[0109] The cuff pressures Pc of the pressing cuffs **21***a* and **21***b* when there is body motion of the subject may be the same value or different values.

(Modification)

[0110] In the above example, the acceleration sensor **60** is used to detect the presence or absence of body motion of the subject, but instead, for example, the pressure sensor **31** may be used to detect a change in cuff pressure caused by body motion of the subject. Both acceleration and a change in cuff pressure may be used to detect the presence or absence of body motion of the subject.

[0111] In the above example, the presence or absence of body motion of the subject is determined only in step S**11** in FIG. **8**, but instead, during the execution of steps S**12** to S**14**, the presence or absence of body motion of the subject may always be determined, and when there is body motion of the subject, steps S**12** to S**14** may be interrupted and the process may proceed to step S**15**.

[0112] In addition, in the above example, in step S**14** in FIG. **8**, the equation (Eq. 1) in FIG. **13** is used as the correspondence equation Eq between pulse transit time and blood pressure so that the blood pressure is calculated (estimated) based on the pulse transit time (PTT). However, the present invention is not limited thereto. As a correspondence equation Eq between pulse transit time and blood pressure, where the pulse transit time is denoted by DT and the blood pressure is denoted by EBP, for example, as illustrated in the equation (Eq. 2) in FIG. **14**, in addition to the term of $1/DT^2$, an equation including the term of 1/DT and the term of DT may be used. In the equation (Eq. 2), each of α, β, γ, and δ represents a known coefficient or a constant.

[0113] Furthermore, for example, as illustrated in the equation (Eq. 3) in FIG. **15**, an equation including the term of 1/DT, the term of the cardiac cycle RR, and the term of the plethysmogram area ratio VR may be used (see, for example, JP 2000-33078 A). In the equation (Eq. 3), each of α, γ, and δ represents a known coefficient or a constant. It should be noted that, in this case, the CPU **100** calculates the cardiac cycle RR and the plethysmogram area ratio VR based on the pulse wave signals PS**1** and PS**2**.

[0114] The blood pressure can be measured in the same manner as in the case of using equation (Eq. 1) also in the case of using these equations (Eq. 2) and (Eq. 3) as the correspondence equation Eq between pulse transit time and blood pressure. Naturally, correspondence equations other than these equations (Eq. 1), (Eq. 2), and (Eq. 3) may be used.

[0115] In the above embodiment, the first pulse wave sensor **40-1** and the second pulse wave sensor **40-2** detect the pulse wave of the artery (radial artery **91**) passing through the measurement site (left wrist **90**) as a change in impedance (impedance system). However, the present invention is not limited thereto. Each of the first and second pulse wave sensors may include a light emitting element for applying light toward an artery passing through a corresponding portion of the measurement site and a light receiving element for receiving the reflected light (or transmitted light) of the light, and may detect a pulse wave of the artery as a change in volume (photoelectric system). Alternatively, each of the first and second pulse wave sensors may include a piezoelectric sensor abutted on the measurement site, and may detect the strain due to the pressure of the artery passing through the corresponding portion of the measurement site as a change in electrical resistance (piezoelectric system). Furthermore, each of the first and second pulse wave sensors may include a transmission element for transmitting a radio wave (transmission wave) toward an artery passing through a corresponding portion of the measurement site and a reception element for receiving the reflected wave of the radio wave, and may detect a change in the distance between the artery and the sensor due to the pulse wave of the artery as a phase shift between the transmission wave and the reflected wave (radio wave irradiation system).

[0116] Although the above embodiments describe the case where the sphygmomanometer in FIG. **1** performs blood pressure measurement (estimation) based on pulse transit time, the processing of controlling the pressing force on the measurement site in consideration of the body motion of the subject is applicable to any case of detecting a pulse wave by using at least one pulse wave sensor.

[0117] In addition, in the above embodiment, the sphygmomanometer **1** is intended to be mounted on the left wrist **90** as a measurement site. However, the present invention is not limited thereto. The measurement site has only to be a site where an artery passes through, may be an upper limb such as an upper arm other than the wrist, and may be a lower limb such as an ankle or thigh.

[0118] In addition, in the above embodiments, the CPU **100** mounted on the sphygmomanometer **1** is assumed to work as a body motion detection unit, a control unit, and first and second blood pressure calculation units to perform blood pressure measurement by oscillometric method (operation flow in FIG. **6**) and blood pressure measurement (estimation) based on pulse wave measurement and PTT (operation flow in FIG. **8**). However, the present invention is not limited thereto. For example, a substantial computer device such as a smartphone provided outside the sphygmomanometer **1** may work as a body motion detection unit, a control unit, and first and second blood pressure calculation units to cause, via the network **900**, the sphygmomanometer **1** to perform blood pressure measurement by oscillometric method (operation flow in FIG. **6**) and blood pressure measurement (estimation) based on pulse wave measurement and PTT (operation flow in FIG. **8**).

[0119] As described above, a pulse wave measurement device of the present disclosure comprises:

[0120] a belt to be mounted around a measurement site of a subject;

[0121] at least one pulse wave sensor mounted on the belt, the at least one pulse wave sensor configured to detect a pulse wave of an artery passing through the measurement site;

[0122] a pressing member mounted on the belt, the pressing member configured to vary a pressing force to press the at least one pulse wave sensor against the measurement site;

[0123] a body motion detection unit configured to detect presence or absence of body motion of the subject; and

[0124] a control unit configured to set a pressing force of the pressing member to a first pressing force when there is no body motion of the subject to measure a pulse wave with the at least one pulse wave sensor, the control unit configured to set a pressing force of the pressing member to a second pressing force lower than the first pressing force and higher than zero when there is body motion of the subject and interrupt measurement of a pulse wave.

[0125] In the present specification, "measurement site" refers to a site through which an artery passes. The measurement site may be, for example, an upper limb such as a wrist or an upper arm, or a lower limb such as an ankle or a thigh.

[0126] In addition, "belt" refers to a band-shaped member mounted around a measurement site regardless of the name. For example, instead of the belt, the name may be "band", "cuff", or the like.

[0127] In addition, the "width direction" of the belt corresponds to the longitudinal direction of the measurement site.

[0128] In addition, the "body motion" refers to the motion of the subject's body which brings significant variation in the pulse wave signal detected by at least one pulse wave sensor.

[0129] In addition, the "first pressing force" is the force of strength that can appropriately measure the pulse wave with at least one pulse wave sensor.

[0130] In addition, the "second pressing force" is the force of strength to the extent that an unnecessary physical load is not placed on the subject and to the extent that the position of at least one pulse wave sensor does not deviate from the measurement site as long as the body motion of the subject is not excessively violent.

[0131] In a pulse wave measurement device of one embodiment, at least one pulse wave sensor is mounted on the belt. In a state in which the belt is mounted around the measurement site, the pressing member presses the at least one pulse wave sensor against the measurement site, for example, with a certain pressing force. In this state, each of the at least one pulse wave sensor detects a pulse wave in a facing portion of an artery passing through the measurement site. The body motion detection unit detects the presence or absence of body motion of the subject. When there is no body motion of the subject, the control unit sets a pressing force of the pressing member to a first pressing force to measure a pulse wave with the at least one pulse wave sensor. When there is body motion of the subject, the control unit sets a pressing force of the pressing member to a second pressing force lower than the first pressing force and higher than zero and interrupts measurement of a pulse wave. Thus, when there is body motion of the subject, it is possible to set a pressing force of the pressing member to the second pressing force to alleviate the physical burden on the subject. In addition, since the second pressing force is higher than zero, the position of at least one pulse wave sensor can be less likely to be deviated from the measurement site. As described above, controlling the pressing force on the measurement site by a novel control method in consideration of the body motion of the subject allows the convenience of the subject to be improved.

[0132] In the pulse wave measurement device of one embodiment, when measurement of a pulse wave is interrupted and then a state where there is body motion of the subject is transitioned to a state where there is no body motion of the subject, the control unit returns the pressing force of the pressing member to the first pressing force to resume measurement of a pulse wave.

[0133] In the pulse wave measurement device of the one embodiment, since the pressing force of the pressing member is set to a second pressing force higher than zero when the measurement of the pulse wave is interrupted, when pulse wave measurement is resumed, the pressing force of the pressing member can be returned to the first pressing force more quickly than when the pressing force of the pressing member is set to zero. Thus, the convenience of the subject can be improved.

[0134] In the pulse wave measurement device of one embodiment, when measurement of a pulse wave is interrupted and then a standby time having a predetermined length elapses, the control unit sets a pressing force of the pressing member to zero.

[0135] In the pulse wave measurement device of this one embodiment, it is possible to avoid useless pressing at the measurement site.

[0136] In the pulse wave measurement device of one embodiment, the pulse wave measurement device comprises a first pulse wave sensor and a second pulse wave sensor mounted on the belt in a state of being separated from each other in a width direction of the belt, each of the first pulse wave sensor and the second pulse wave sensor configured to detect a pulse wave in a facing portion of an artery passing through the measurement site.

[0137] In the pulse wave measurement device according to this embodiment, the first pressing force is, for example, set to a value at which the cross-correlation coefficient of the first and second pulse wave signals respectively output in time series by the first and second pulse wave sensors exceeds a predetermined threshold value. Here, the "cross-correlation coefficient" means the sample correlation coefficient (also referred to as Pearson's product-moment correlation coefficient). For example, when a data sequence $\{x_i\}$ and a data sequence $\{y_i\}$ including two sets of numerical values (where i=1, 2, . . . , n) are given, the cross-correlation coefficient r between the data sequence $\{x_i\}$ and the data sequence $\{y_i\}$ is defined by the equation (Eq. 4) illustrated in FIG. **16**. In the equation (Eq. 4), x and y with overline respectively represent average values of x and y.

[0138] In the pulse wave measurement device of one embodiment, the first and second pulse wave sensors are mounted on the belt in a state of being separated from each other in the width direction of the belt. In a state in which the belt is mounted around the measurement site, the pressing member presses the first and second pulse wave sensors against the measurement site, for example, with a certain pressing force. In this state, each of the first and second pulse wave sensors detects a pulse wave in a facing portion of an artery passing through the measurement site. The body motion detection unit detects the presence or absence of body motion of the subject. When there is no body motion of the subject, the control unit sets a pressing force of the pressing member to a first pressing force to measure a pulse wave with the first and second pulse wave sensors. When there is no body motion of the subject, the control unit sets a pressing force of the pressing member to a first pressing force to measure a pulse wave with the first and second pulse wave sensors. Thus, when there is body motion of the subject, it is possible to set a pressing force of the pressing member to the second pressing force to alleviate the physical burden on the subject. In addition, since the second pressing force is higher than zero, the position of the first and second pulse wave sensors can be less likely to be deviated from the measurement site. As described above, controlling the pressing force on the measurement site by a novel control method in consideration of the body motion of the subject allows the convenience of the subject to be improved.

[0139] In the pulse wave measurement device of one embodiment, the pressing member includes an element configured to press the first pulse wave sensor and the second pulse wave sensor with an individual pressing force, and the control unit sets the first pressing force of the pressing member to individual values with respect to the first pulse wave sensor and the second pulse wave sensor.

[0140] In the pulse wave measurement device of this one embodiment, setting the first pressing force of the pressing member to individual values with respect to the first and second pulse wave sensors allows measurement accuracy of a pulse wave and blood pressure to be improved.

[0141] In another aspect, a blood pressure measurement device of the present disclosure comprises:

[0142] the pulse wave measurement device; and

[0143] a first blood pressure calculation unit configured to calculate blood pressure by using a predetermined correspondence equation between pulse transit time and blood pressure based on pulse transit time being a time difference between a first pulse wave signal and a second pulse wave signal respectively output in time series by the first pulse wave sensor and the second pulse wave sensor.

[0144] In the blood pressure measurement device of this one embodiment, the pulse wave measurement device acquires pulse transit time. The first blood pressure calculation unit calculates (estimates) the blood pressure based on the pulse transit time by using a predetermined correspondence equation between pulse transit time and blood pressure. Therefore, when the blood pressure of the subject is measured, controlling the pressing force on the measurement site by a novel control method in consideration of the body motion of the subject as described above allows the convenience of the subject to be improved.

[0145] In the blood pressure measurement device of one embodiment,

[0146] the pressing member is a fluid bag provided along the belt,

[0147] the blood pressure measurement device further comprises a main body provided integrally with the belt, and

[0148] wherein on the main body, the body motion detection unit, the control unit, and the first blood pressure calculation unit are mounted, and a pressure control unit configured to supply air to the fluid bag to control pressure, and a second blood pressure calculation unit configured to calculate blood pressure based on pressure in the fluid bag are mounted for blood pressure measurement by oscillometric method.

[0149] Herein, the main body being "integrally provided" with respect to the belt may mean that the belt and the main body are, for example, integrally molded, or instead of this, may mean that the belt and the main body may be separately formed, and the main body may be integrally attached to the belt via an engaging member (for example, a hinge or the like).

[0150] In the pulse wave measurement device of this one embodiment, the blood pressure measurement (estimation) based on pulse transit time and the blood pressure measurement by oscillometric method can be performed by an integrated device. Therefore, the convenience of the user is enhanced.

[0151] In another aspect, a pulse wave measurement method of the present disclosure is a pulse wave measurement method includes:

[0152] using

[0153] a belt to be mounted around a measurement site of a subject,

[0154] at least one pulse wave sensor mounted on the belt, the at least one pulse wave sensor configured to detect a pulse wave of an artery passing through the measurement site,

[0155] a pressing member mounted on the belt, the pressing member configured to vary a pressing force to press the at least one pulse wave sensor against the measurement site, and

[0156] a body motion detection unit configured to detect presence or absence of body motion of the subject,

[0157] to measure a pulse wave of the measurement site, the pulse wave measurement method comprising:

[0158] setting a pressing force of the pressing member to a first pressing force when there is no body motion of the subject to measure a pulse wave with the at least one pulse wave sensor; and

[0159] setting a pressing force of the pressing member to a second pressing force lower than the first pressing force and higher than zero when there is body motion of the subject and interrupting measurement of a pulse wave.

[0160] In the pulse wave measurement method of this one embodiment, it is possible to avoid useless pressing at the measurement site.

[0161] The above embodiments are illustrative, and various modifications can be made without departing from the scope of the present invention. It is to be noted that the various embodiments described above can be appreciated individually within each embodiment, but the embodiments can be combined together. It is also to be noted that the various features in different embodiments can be appreciated individually by its own, but the features in different embodiments can be combined.

1. A pulse wave measurement device comprising:

a belt to be mounted around a measurement site of a subject;

at least one pulse wave sensor mounted on the belt, the at least one pulse wave sensor configured to detect a pulse wave of an artery passing through the measurement site;

a pressing member mounted on the belt, the pressing member configured to vary a pressing force to press the at least one pulse wave sensor against the measurement site;

a body motion detection unit configured to detect presence or absence of body motion of the subject; and

a control unit configured to set a pressing force of the pressing member to a first pressing force when there is no body motion of the subject to measure a pulse wave with the at least one pulse wave sensor, the control unit configured to set a pressing force of the pressing member to a second pressing force lower than the first pressing force and higher than zero when there is body motion of the subject and interrupt measurement of a pulse wave.

2. The pulse wave measurement device according to claim **1**, wherein when measurement of a pulse wave is interrupted and then a state where there is body motion of the subject is transitioned to a state where there is no body motion of the subject, the control unit returns the pressing force of the pressing member to the first pressing force to resume measurement of a pulse wave.

3. The pulse wave measurement device according to claim **1**, wherein when measurement of a pulse wave is interrupted and then a standby time having a predetermined length elapses, the control unit sets a pressing force of the pressing member to zero.

4. The pulse wave measurement device according to any one of claim **1**, further comprising a first pulse wave sensor and a second pulse wave sensor mounted on the belt in a state of being separated from each other in a width direction of the belt, each of the first pulse wave sensor and the second pulse wave sensor configured to detect a pulse wave in a facing portion of an artery passing through the measurement site.

5. The pulse wave measurement device according to claim **4**, wherein

the pressing member includes an element configured to press the first pulse wave sensor and the second pulse wave sensor with an individual pressing force, and

the control unit sets the first pressing force of the pressing member to individual values with respect to the first pulse wave sensor and the second pulse wave sensor.

6. A blood pressure measurement device comprising:

the pulse wave measurement device according to claim **4**; and

a first blood pressure calculation unit configured to calculate blood pressure by using a predetermined correspondence equation between pulse transit time and blood pressure based on pulse transit time being a time difference between a first pulse wave signal and a second pulse wave signal respectively output in time series by the first pulse wave sensor and the second pulse wave sensor.

7. The blood pressure measurement device according to claim **6**,

wherein the pressing member is a fluid bag provided along the belt,

the blood pressure measurement device further comprising a main body provided integrally with the belt, and

wherein on the main body, the body motion detection unit, the control unit, and the first blood pressure calculation unit are mounted, and a pressure control unit configured to supply air to the fluid bag to control pressure, and a second blood pressure calculation unit configured to calculate blood pressure based on pressure in the fluid bag are mounted for blood pressure measurement by oscillometric method.

8. A pulse wave measurement method including:

using

a belt to be mounted around a measurement site of a subject,

at least one pulse wave sensor mounted on the belt, the at least one pulse wave sensor configured to detect a pulse wave of an artery passing through the measurement site, a pressing member mounted on the belt, the pressing member configured to vary a pressing force to press the at least one pulse wave sensor against the measurement site, and

a body motion detection unit configured to detect presence or absence of body motion of the subject,

to measure a pulse wave of the measurement site, the pulse wave measurement method comprising:

setting a pressing force of the pressing member to a first pressing force when there is no body motion of the subject to measure a pulse wave with the at least one pulse wave sensor; and

setting a pressing force of the pressing member to a second pressing force lower than the first pressing force and higher than zero when there is body motion of the subject and interrupting measurement of a pulse wave.

* * * * *

专利名称(译)	脉搏波测定装置，脉搏波测定方法以及血压测定装置		
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摘要(译)

第一和第二脉搏波传感器以在宽度方向上彼此分离的状态安装在带上。皮带安装在测量部位周围，该构件以预定的压力将第一和第二脉搏波传感器压向测量部位。每个脉搏波传感器检测在穿过测量部位的动脉的相对部分中的脉搏波。身体运动检测单元检测身体运动的存在或不存在。当没有身体运动时，控制单元将按压构件的力设置为按压力，以利用传感器测量脉搏波。当存在身体运动时，控制单元将按压构件的力设置为小于第一力且大于零的第二力，并中断脉搏波的测量。