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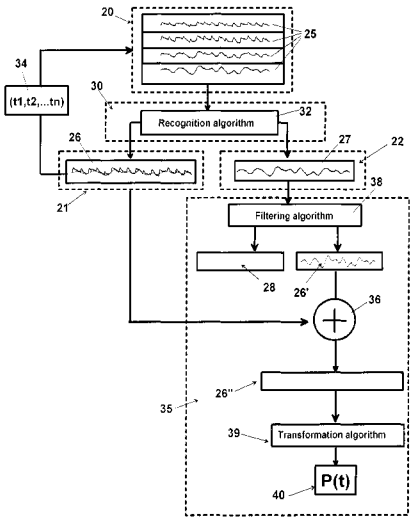

Fig.1B

(57) Abstract: A tonometer structure (100) for permanently monitoring a patient' s arterial pressure during a determined time comprising a support body (10) that can be worn by a patient (50), a detection unit (150) mounted to the wearable support body (10). The support body (10) and the detection unit (150) are configured such that the detection unit, in use, can contact the patient's skin (50) proximate to an artery path (52). The detection unit (150) has a plurality of piezoresistive pressure sensors (20) each of which is configured to measure a pressure variation when the detection unit (150) can contact the patient's skin, and configured to provide a respective measurement signal (25) associated with a respective sphygmic wave of a determined amplitude. Furthermore, a control unit (30) is arranged to receive the measurement signals (25) and to recognize a reference signal (26) associated with a respective reference sensor (21) and at least one boundary signal (27) associated with a respective boundary sensor (22). Furthermore, a means is provided for actuating (34) said recognition means (32) at predetermined instants (t1, t2, t3, tn) for determining a relative reference sensor (21) at each instant (t1, t2, t3, tn), such that also in the case of an accidental movement of the detection unit (150) with respect to said artery path (52) a reference sensor (21) is always recognized.

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A WEARABLE TONOMETER STRUCTURE

DESCRIPTION

Field of the invention

The present invention relates to the medical field, and, in particular, it relates to a tonometer structure that can be worn by a user for a permanent and non invasive monitoring of a patient's artery path, e.g. the radial artery.

Furthermore, the invention relates to a corresponding measurement method that can be carried out by the above tonometer structure.

State of the art

Arterial pressure is one of the most useful parameters to diagnose a cardiovascular disease and to follow-up patients who suffer from these pathologies. The measurement methods are different in nature and type, and it is possible to classify the methods into two main groups, i.e. invasive methods and non-invasive methods. The invasive methods allow permanently, beat-to-beat measuring the sphygmic signal, but they require introducing a needle into the artery, with drawbacks that such a technique of the type entails. The non-invasive methods may essentially be of two main types, i.e. direct measurement methods and derivative measurement methods. Direct measurements comprise using instruments that measure the arterial pressure in a non-permanent way, for instance by oscillometric techniques or by auscultation techniques, via a pneumatic cuff, which is very annoying to wear. The derivative measurements use non invasive instruments configured to obtain permanent parameter signals related to the arterial pressure from non-sphygmic signals. For

instance, instruments are used based on the pulse wave analysis, which exploits the ECG and plethysmographic signals. Since they provide values deriving from non-sphygmic signals, these instruments may introduce errors during the signal transformation.

A tonometer is a non-invasive apparatus for measuring the arterial pressure by pressing an artery path, for example the radial artery path, pressing it against a bone structure laying below. Then, by a dedicated algorithm, the central arterial pressure and the central mean aortic pressure, systolic and diastolic, are derived from it.

Among the earliest prior art tonometers, non-wearable tonometers are known, as disclosed in US5363855, US5605156 and US6290650.

A wearable clock-shaped tonometer is disclosed in IL166200.

This device is comfortable to wear and allows monitoring a patient's pressure even for a long time and even far away from a specialized centre and without the support of a qualified person.

In particular, the device of IL166200 comprises a pressure sensor that is immersed in a chamber containing a transmission fluid, such as a gel, and the chamber can contact the artery and with the transmission fluid, and transmits forces that arise from the deformation of the artery. Opposite to the sensor chamber, a display unit is provided by which the data measured by the sensor can be displayed.

However, this device has a drawback. By using only one pressure sensor, a loss or a reduction of the measurement signal occurs, since the position of the sensor with respect to the artery may change while the device is being worn by the user.

In order to overcome this drawback, devices have been

developed that provide more pressure sensors arranged adjacent with respect to each other, as disclosed in US2009069698. In this case, a dedicated control unit identifies the sensor that provides the best signal, according to the intensity and to the quality of the signals received from each sensor, and performs the measurement through the sensor so identified. This way, the positioning is optimised, since the sensor is selected that is best positioned upon the artery. In this case, optical sensors are used.

It has also been observed that each sensor is affected by systematic errors during the signal measurement, which is due to different factors, for example to the user's movement, to the position of the tonometer on the artery, etc.

However, in the case of a wearable tonometer device that may be displaced and/or may be undergo impacts, the array of sensors may be moved in such a way that the selected sensor may lose the signal and may become a sensor incorrectly positioned with respect to the artery.

In Edward J. Ciaccio and Gary M. Drzewiecki "Tonometric arterial pulse sensor with noise cancellation" IEEE Transactions on Biomedical Engineering, vol. 55, no. 10, October 2008, a device is described for permanently non-invasively monitoring the pressure wave of an artery. In particular, two piezoelectric sensors are provided in order to eliminate artifacts that reduce the quality of the signal, in particular movement artifacts and background noise. A first sensor is located at the radial artery (p) and another sensor is positioned in such a way that to prevent any overlapping with the artery pulsation (n). A step of noise removal is conventionally carried out using a reference input, or reducing the movement and noise artifacts from the acquired artery pulsation tonometric

signal.

Even in this case, the arrangement of the sensor upon the artery must be carried out with precision, so that the received measurement signal is strong enough.

In US2010/204588 an apparatus and a method are described for identifying an ideal blood pressure measurement site. In particular, the apparatus comprises a detection unit for detecting the pressures that are exerted to a blood vessel in a particular region of the body, a calculation unit to calculate the waveform that represents the detected signal, and a decision unit for deciding whether the examined site is the ideal site. The detection unit comprises an oscillometric sensor, i.e. a spot-type pressure sensor to be used together with a pressurization unit, such as a pneumatic cuff.

The step of checking check whether the examined site is the ideal blood pressure measurement site is carried out by analysing the trend of the detected pressures, which are plotted accordingly.

Thus, the solution proposed in US2010/204588 was conceived to identify the ideal site where to measure the arterial pressure, which will take place later by a different and dedicated instrument. Therefore, the solution proposed in US2010/204588 is not well-suited to measure the arterial pressure value, nor can it carry out a permanent monitoring of a patient's arterial pressure, during a determined time. Moreover, the processing of the measured data is complex and cannot provide precise pressure data.

In US6475153 a method is described for obtaining pressure data by means of optical sensors. Once the patient's pressure have been obtained, the linear calibration relationships between the output signal and the blood pressure are determined by a calibration procedure that is carried out for some of the optical sensors of by

the device.

In particular, the solution described in US6475153 comprises using non optical auxiliary sensors for eliminating the artifacts, since the optical sensors cannot detect the so-called "hold-on pressure" artifacts.

Therefore, also the solution of US6475153 necessarily comprises a complex processing of the measured data, in particular, in order to eliminate the artifacts, and cannot provide precise pressure data.

Summary of the invention

It is therefore a feature of the invention to provide a wearable tonometer structure for obtaining precise and reliable measurement signal, regardless of the movement that may be experienced by a measurement sensor optimally positioned with respect to an artery.

It is another feature of the invention to provide a wearable tonometer structure that makes it possible to obtain a more precise and more reliable measurement signal, without errors or background noise.

It is also a feature of the invention to provide a wearable tonometer structure that assists positioning and attaining an optimum position and quickly changing the layout of the sensors and to mount any number of sensors, according to its use.

Is another feature of the invention to provide a wearable tonometer structure that is simple and comfortable to use while allowing a precise and reliable long-lasting measurement.

It is another feature of the invention to provide a method for tonometry measurements carried out by the above wearable tonometer structure.

These and other objects are achieved by a tonometer structure for permanently monitoring a patient's arterial

pressure during a determined time, said tonometer structure comprising:

- a support body that can be worn by a patient;
- a detection unit mounted to said support body, said support body and said detection unit configured such that said detection unit, in use, can contact said patient's skin proximate to an artery path, said detection unit having a plurality of piezoresistive pressure sensors, each sensor of said plurality configured to measure a pressure variation when said detection unit can contact said patient's skin, and configured to provide a respective measurement signal, said measurement signal associated with a respective sphygmic wave of a determined amplitude;
- a control unit associated with said plurality of piezoresistive pressure sensors and arranged to receive said plurality of measurement signals, said control unit equipped with a recognition means which is adapted to process said plurality of measurement signals by a recognition algorithm to:
  - recognize a reference signal among said plurality of measurement signals, wherein said reference signal is associated with a respective reference sensor, wherein said reference signal is the measurement signal of said plurality, wherein said reference signal is associated with the sphygmic wave that has the largest amplitude;
  - recognizing at least one boundary signal in the remainder part of said plurality of measurement signals, said at least one boundary signal associated with a respective boundary sensor, wherein said boundary signal is the measurement signal of said plurality, wherein said reference signal is associated with the

sphygmic wave that has the smallest amplitude;

- an actuation means for actuating said recognition means at predetermined instants (t1,t2,t3,tn), said recognition means configured to measure a reference signal and to identify a respective reference sensor at each of said instants (t1,t2,t3,…,tn), such that also in the case of an accidental movement of the detection unit with respect to the artery path a reference sensor is always recognized;

and wherein the control unit comprises a program means, said program means configured to process the or each boundary signal by a filtering algorithm for extracting as said boundary signal a "useful" component, or "sphygmic", and for extracting a "useful" component, i.e. a sphygmic component from said boundary signal, and for extracting a noise component, or artifact, said program means also configured to:

- combine said reference signal and said "useful" component of said boundary signal, by a merging algorithm, and obtaining an enhanced reference signal, in order to increase the information and the quality of said reference signal;
- subtract said noise component of said boundary signal from said reference signal, or from said enhanced reference signal, by a subtraction algorithm, to obtain a "clean", or correct reference signal, i.e. a reference signal that is depurated from artifacts and background noise;
- a combination thereof;

said program means also adapted to process said improved and/or correct reference signal, by a transformation algorithm, and to provide a real-time value of the

patient's arterial pressure.

In particular, the reference sensor is the sensor of said plurality of sensors that is located most proximate to said artery path.

In particular, said recognition means is configured to process the frequency spectrum of the measurement signals in a predetermined frequency band to which the signal pressure belongs, in particular a cardiac frequency belongs to said frequency band.

Advantageously, said recognition means is also configured to recognize at least one boundary signal with respect to said reference signal in the remainder part of said array, said boundary signal associated with a corresponding boundary sensor.

Advantageously, said recognition means is configured to recognize a plurality of boundary signals with respect to said reference signal in the remainder part of said array, said recognition means computed by said first program means to improve the quality of said reference signal, by a merging algorithm, and in order to determine said artifact signal to be subtracted from said reference signal by a subtraction algorithm.

Advantageously, said control unit comprises a wireless transmission means configured to transmit the data measured by said plurality of sensors to a remote unit.

Advantageously, said detection unit comprises a plurality of housings, each housing of said plurality of housings arranged to house a respective sensor, such that a sensor unit is formed.

In particular, each housing is made of a flexible material, in particular silicone rubber, that is adapted to transmit the external forces to the sensor that is housed within said housing.

For instance, each housing may have a box-like

elongated shape and is adapted to house an elongated sensor. In this case, the sensor units are advantageously arranged adjacent to one another, in order to define said plurality of sensors.

In particular, said elongated sensor comprises:

- a support base;
- a sensitive element connected to said support base.

As an alternative, each housing is made of a stiff material, in particular a ceramic material, and is adapted to be filled with a fluid material, in particular silicone rubber. More in detail, the fluid material is adapted to transmit the external forces to the sensor that is housed within said housing made of a stiff material.

In particular, each stiff housing houses a sensor that is formed by said sensitive element only. In this case, the sensor units are arranged at a predetermined distance from one another, in order to define said plurality of sensors.

In a further exemplary embodiment, the box-like shaped detection unit comprises a single housing that is arranged to house a sensorized sheet at which said plurality of sensors is arranged.

Normally, the plurality of sensor units that form said detection units are arranged on the support body according to a predetermined layout 2xN, wherein 2xN is the number of said sensor elements.

In a possible exemplary embodiment, the support body is a support body made of a flexible material, said support body configured to be arranged about said patient's wrist.

In particular, the sensor units are arranged at an end portion of the flexible support body and with a data feed and transfer connector is provided arranged at a second end opposite to the first end.

In particular, the support body also comprises a display interface, in particular a display unit, which is

arranged at an opposite side with respect to the detection unit.

Advantageously, the wearable support body comprises at least one auxiliary sensor in addition to the pressure sensors, in order to provide further useful data, said or each auxiliary sensor selected from the group consisting of:

- an accelerometer configured to eliminate the artifacts due to the patient's movement;
- a biochemical sensor for measuring electrolytes in the patient's skin, in order to increase the patient's physiological or pathological data;
- a temperature sensor for compensating the intrinsic reading changes of the piezoresistive sensors;
- or a combination thereof.

In particular, the tonometer structure is configured to be removably connected to a base body that allows providing said further sensors.

In particular, the control unit may also comprise a memory unit configured to memorize said plurality of measurement signals.

Advantageously, the tonometer may provide an actuator and a control device of said actuator to assist the positioning and to attain an optimum positioning at said artery path, said actuator arranged to apply to said artery path a flattening pressure that is best suited for detecting the sphygmic wave.

According to another exemplary embodiment, the tonometer device comprises:

- a wearable support body made of a flexible material, said wearable support body having a first side that, in use, can be oriented towards the user's skin and a second side opposite to the first side;
- a plurality of piezoresistive elements arranged to

form rows, each piezoresistive element of said plurality arranged at said first side of said wearable support body;

- a main body made of a stiff material fastened, e.g. glued, to the first side of the wearable support body, said main body having a plurality of openings at each of which, in use, a respective piezoresistive sensitive element is arranged of one of said rows, such that a sensor unit is formed;
- each opening of said plurality arranged to be filled with a predetermined amount of a fluid polymeric material in order to fully cover the respective piezoresistive sensitive element that is housed within said opening, said fluid polymeric material hardened in such a way that a transmission element is provided which is arranged to transmit the external forces to the piezoresistive sensitive element, which protrudes from said main body.

Advantageously, the fluid polymeric material, for example a silicone rubber, is formed to harden by a curing process.

In particular, the flexible material can be a flexible Printed Circuit Board, e.g. a PCB Flex.

Advantageously, each main body may also comprise a third opening, said third opening arranged to house a temperature sensor, in use, said temperature sensor configured to measure the temperature at the measurement site, and to compensate the output values produced by the piezoresistive sensors.

In order to improve the patient's comfort, a further silicone rubber or rubber layer may be provided on the transmission element, or a layer may be provided made of any biocompatible material that is adapted, in use, to be brought into contact of the user's skin.

Besides, the tonometer device may also comprise a stiffening element that is arranged on the second side of the flexible base support. More in detail, a stiffening element may be provided, for example a stiffening element made of a plastic stiff material such as a stiff PCB, that is arranged on the second side of the wearable support body at a respective main body, i.e. at a mirror-like position opposed to said main body, with respect to the wearable support body.

This way, an object is obtained that is highly stiff at the stiffening bodies and at the main bodies, and that is very flexible between two adjacent main bodies, due to the support body made of a flexible material that assists arranging the device about the user's wrist.

Preferably, the stiffening bodies and the main bodies are arranged, in use, along a direction substantially longitudinal of said artery path, such that the tonometer device is highly stiff along the longitudinal direction of the artery and is flexible along a direction transversal to the artery.

Moreover, in a possible exemplary embodiment, an adjustment means is provided for adjusting the distance of said sensor unit from said artificial artery.

Advantageously, the adjustment means is arranged to remove/approach the sensor unit from/to the artery path, to cause the artery path to become flat accordingly.

As well known, in fact, the arterial pressure signal can be detected through a pressure sensor only after slightly flattening the artery. In particular, the flattening is caused between a lower limit artery flattening value below which the pressure wave cannot be detected and an upper limit artery flattening value above which the artery is blocked. The adjustment means to adjust the distance of the sensor unit from the artery path serves

therefore to flatten the artery enough to allow the detection of the pressure signal.

Furthermore, a control means is provided that is configured to read the detected pressure signal and to compare it with a reference value. More in detail, when the detected pressure signal value is higher than the reference value, a display and/or a sound emitter of the tonometer communicates to the patient that the detected signal is strong enough for detecting the arterial pressure, i.e. that the artery is flattened between the above mentioned limit values.

Brief description of the drawings

The invention will now be shown with the following description of its exemplary embodiments, exemplifying but not limitative, with reference to the attached drawings in which:

- Fig. 1 is a perspective view of an arrangement of the tonometer structure, according to the invention, above a wrist radial artery, the tonometer structure comprising a plurality of pressure sensors;
- Fig. 1A is a diagram schematically showing the measurement signals associated with the sphygmic waves detected by the piezoresistive sensors, according to the invention;
- Figs. 1B to 1D are block diagrams schematically showing the logical measurement sequence followed by the tonometer structure of Fig. 1, according to three possible alternative exemplary embodiments of the present invention, in particular the block diagrams point out the recognition sequence, repeated at determined time intervals, of a reference signal that turns out to be correctly positioned above the radial artery, as well as the recognition of boundary signals that are computed in order to improve the

quality of the reference signal and to eliminate any artifacts due to background noise;

- Figs. 2 and 3 show a first exemplary embodiment of the detection unit, in which the detection unit is arranged upon a flexible support body that can be arranged about a user's wrist (Fig.3);
- Fig. 4 shows a perspective view of a further exemplary embodiment of a tonometer structure comprising a plurality of housings for each sensor that forms the sensor array; this figure also shows the introduction of a sensor in its own housing;
- Fig. 5 shows a perspective view of a second exemplary embodiment of a tonometer structure comprising a single housing for sensors arrays that are arranged above a sensorized sheet comprising a single PCB for the whole array;
- Fig. 6 shows a perspective view of the exemplary embodiment of Fig. 5, during the introduction of the sensorized sheet into the housing;
- Fig. 7 shows a diagrammatical view of the electronic architecture that forms the tonometer structure;
- Fig. 7A shows a diagrammatical view of the electronic architecture that forms the tonometer structure of Fig. 7, also comprising a user interface provided with a display unit;
- Fig. 8 shows a diagrammatical view of the electronic architecture that forms the tonometer structure of Fig. 5 also comprising a wireless transmission means, along with a remote unit;
- Figs. 9 to 15 show an exemplary embodiment of the tonometer device of Figs. 2 to 6;
- Figs. 16 to 19 show a further possible exemplary embodiment of the tonometer device, according to the

present invention, equipped in particular with a means for adjusting the distance from the artery path.

Detailed description of the invention

With reference to Fig. 1, a tonometer structure 100, according to the invention, comprises a support body 10 that, in use, is worn by a patient 50. Support body 10 comprises, in particular, a detection unit 150 configured to be arranged, in use, in contact with the skin of patient 50 proximate to an artery path 52, in order to measure the pressure variation which occur in artery path 52, due to the blood flow.

Detection unit 150 comprises a plurality, or an array, of pioezoresistive pressure sensors 20 (see for example Figs. 2,5,11).

More in detail, as diagrammatically shown in the block diagram of Fig. 1B, piezoresistive sensors 20 are arranged to provide a plurality of measurement signals 25 when detection unit 150 detects the pressure change within artery path 52 of patient 50. This circumstance, as described in detail hereinafter, takes place when artery 52 receives a predetermined force suitable for causing a predetermined flattening of the artery.

Tonometer 100 also comprises a control unit 30, as diagrammatically shown, that is associated with the plurality of pressure sensors 20 and is arranged to receive the plurality of measurement signals 25, each of which is associated with a respective sphygmic wave that has a determined amplitude. For example, Fig. 1A relates to the sphygmic waves of four measurement signals 25a-25d for each of which the respective amplitude A1-A4 is indicated.

Control unit 30 comprises a recognition means 32 configured to identify a reference signal 26 associated with a corresponding reference sensor 21 of the array of

sensors 20, among the plurality of detected measurement signals 25, by means of a given recognition algorithm. More in detail, reference signal 26 corresponds to measurement signal 25 of the above-mentioned plurality, where said reference signal is associated with the sphygmic wave that has the largest amplitude.

In particular, reference sensor 21 that is associated with reference signal 26 is the one, among the plurality of sensors 20, which is arranged most proximate to artery path 52, with respect to the remainder part of sensors.

The array of sensors 20 and the detection at different times of reference sensor 21 assists the patient to wear support body 10 and to position respective detection unit 150 approximately upon the artery.

In particular, unlike the tonometric devices of known type, the assistance is not required of medical or paramedical staff, i.e. of a person specialized for correctly positioning a single sensor on artery 52. This allows tonometer 100, according to the present invention, to be used also directly by the end user at home, and therefore without requiring a nurse to position it every time. Furthermore, if wearable support 10, and in particular detection unit 150, can be displaced, for example, due to the rotation of the support about the user's wrist, the recognition procedure of reference sensor 21 is repeated at a plurality of instants $(t_1, t_2, t_3, \ldots, t_n)$. This way, the measure is independent from the movement of detection unit 150, since an optimum reference signal from which reference signal 26 is identified.

More in particular, recognition means 32 is configured to process the frequency spectrum of measurement signals 25 in a predetermined frequency band to which the signal pressure belongs, for example a cardiac frequency belongs to said frequency band.

Moreover, as shown always in Fig. 1B, recognition means 32 is configured to recognize, in the remainder part of the array of sensors 20, at least one boundary signal 27 with respect to reference signal 26. More in detail, boundary signal 27 is associated with a respective boundary sensor 22 and corresponds to measurement signal 25 of the above-mentioned plurality, which is associated with a sphygmic wave that has the smallest amplitude.

Moreover, control unit 30 comprises a means 34 for actuating $(t_1, t_2, t_3, \ldots, t_n)$ the recognition means at predetermined instants, in order to measure $(t_1, t_2, t_3, \ldots, t_n)$ a reference measurement signal 26 and a relative reference sensor 21 at each instant. This way, it is always possible to determine sensor 20 that is arranged most proximate to artery path 52 among all the sensors 20 of the above-mentioned plurality. In particular, the step of identifying sensor 20 is possible even in the case of an accidental movement of detection unit 150 with respect to artery path 52.

Piezoresistive sensors 20 are arranged to recognize both a "useful" reference signal and a noise signal, which comprises the artifact signal caused by the movement, and the "hold-on pressure" signal, i.e. a signal related to the pressure that is required to flatten artery 52. More in detail, the sensor most proximate to the artery detects both the useful signal and the noise signal, whereas the sensor arranged at a longer distance from artery 52 than reference sensor 21 detects the noise signal only. This way, it is possible to precisely identify the useful signal by processing the data measured by reference sensor 21 and by subtracting the data measured by the boundary sensor 22 from it.

Therefore, the use of piezoresistive sensors 20 makes it possible to process more easily the data measured by the

sensor elements, than in the prior art solutions, e.g. in the case of two-dimensional arrays of optical sensors, while obtaining more precise and more reliable results.

Control unit 30 comprises a program means 35 that is configured to process boundary signal 27 by a filtering algorithm 38, in order to extract an additional reference signal 26', i.e. the sphygmic component of boundary signal 27, and/or an artifact signal 28, i.e. the noise component of boundary signal 27.

According to a first exemplary embodiment of the present invention, as diagrammatically shown in Fig. 1B, program means 35 is adapted to combine additional reference signal 26' with reference signal 26 by a merging algorithm 36. This way, an enhanced reference signal 26'' is obtained that has an increased information and quality with respect to reference signal 26. Enhanced reference signal 26'' is then processed by program means 35 by a transformation algorithm 39, to provide a patient's arterial pressure real-time value 40'.

As diagrammatically shown in Fig. 1C, as an alternative to what described with reference to Fig. 1, B, control unit 30 may extract from boundary signal 27 an artifact signal 28.

In this case, program means 35 is adapted to subtract artifact signal 28 from reference signal 26, by a subtraction algorithm 37, thus obtaining a correct reference signal 26''', i.e. without the artifact component 28. Correct reference signal 26''' is then processed by program means 35 by a transformation algorithm 39, to provide a patient's arterial pressure real-time value 40.

In the further exemplary embodiment, as diagrammatically shown in Fig. 1D, once enhanced reference signal 26'' has been obtained, as described in Fig. 1B, program means 35 carries out the subtraction algorithm 37

to subtract artifact 28 from the enhanced signal 26''. In this case, program means 35 uses therefore both the algorithms, i.e. union and differential algorithms.

This way, an improved and correct reference signal 26* is obtained that, besides having an improved information content with respect to reference signal 26, does not contain artifact 28 and is therefore a signal of very high quality. Enhanced and correct reference signal 26* is then processed by transformation algorithm 39 to provide a real-time value of patient's arterial pressure 40*.

While processing the data, besides eliminating artifacts 28, control unit 30 can eliminate possible hold-on pressure variations with respect to the value that has been determined in a preliminary calibration step. The latter may conventionally measure the patient's maximum pressure, minimum pressure and mean pressure, by means of a sleeve, i.e. a cuff, and may associate the measured pressure values to the above defined correct and/or improved signal.

Even if reference has been made above to a boundary signal 27 that is computed by program means 35 to improve the quality of reference measurement signal 26, obtaining an improved and/or correct reference signal, program means 35 can also use all measurement signals 25, apart from reference signal 26, as boundary signals. In this case, all measurement signals 25, and therefore all sensors 20, are used both to improve reference signal 26 and to find out artifact signal 28.

In other words, all measurement signals 25 take part both to the artifact removal step, by the subtraction algorithm, and to the step of the information content improvement signal 26 by the merging algorithm, thanks to the increased available data flow. In other words, all sensors 20 of the array are useful not only to reduce the

noise, but also to increase the quality of the signal.

In particular, two signals are identified, i.e. a signal s(t) and a noise n(t). Each sensor detects, in particular, a linear combination of the two signals. Accordingly, once accepted the two sources model (signal and noise) that can be considered uncorrelated and even independent from each other, it is possible to divide the two sources by blind decomposition methods, such as the Principal Component Analysis (PCA), or the Independent Component Analysis (ICA).

In particular, PCA is based on the signal covariance matrix, and calculates its eigenvalues. In our case, 4 signals = 4 eigenvalues. Still theoretically, the 2 highest eigenvalues should "define" large part of the variance (i.e. of the information content) of the signals. As an alternative, an algorithm can be provided that analyses the spectrum of the combined signal comprising the signal and the noise, and are able to separate the signal from the noise, since some features of the signal of interest are known, such as the frequency band to which the pressure signal belongs (about the cardiac frequency).

From a structural viewpoint, as shown in Fig. 2 or 4, detection unit 150 comprises a plurality of housings 13, each of which is arranged to house a respective sensor 20, in order to form a sensor unit 20a with it.

In particular, in a first exemplary embodiment, each housing is made of a flexible material, in particular it is made of a silicone rubber. This allows transmitting the external forces to the sensor that is contained within the housing.

As an alternative, each housing 13 is made of a stiff material, for example a ceramic material. Then, each housing 13A receives a fluid material, in particular a silicone rubber which, once polymerized, transmits the

external forces to sensor 20 that is contained within stiff housing 13. In particular, each stiff housing 13 houses a sensor that comprises only a sensitive element 20c. As well known, the piezoresistive sensitive element 20c generally comprises a membrane that changes its shape responsive to the pressure variation that is transmitted by artery path 52, with which it comes into contact.

In this case, sensor units 20a are arranged at a predetermined distance, in order to define the array of sensors 20.

In particular, detection unit 150 comprises several sensor elements 20a according to a predetermined layout, for example 2x2,2x4, or normally 2xN, where N represents the number of sensor elements 20a.

Sensor elements 20a are located on support body 10, in particular on a flexible support body that is configured to be arranged about the user's wrist 50, as diagrammatically shown in Fig. 3. In particular, sensor elements 20a are arranged at an end portion 11a of flexible support body 10. At a second end 11b, opposite to first end 11a, support body 10 comprises a feed and output connector 14 of sensors 20. This way, by positioning connector 14 on the side opposite to sensors 20, the operation of the tonometer is assisted, since the sensitive part, in use, is arranged on the wrist. Furthermore, this connector 14 is located in a position that is, in use, at a distance of several cm from the array, so that the bending of the flexible support is not hindered by the presence of the connector itself.

In particular, flexible support body 10 may comprise, for instance, a stiff bracelet ring element 10', that has a recess to provide an access to connector 14 of the support of the sensors, on which it is connected, in order to maintain detection unit 20 oriented towards the artery path of patient 50, and in order to keep its position stable

enough to avoid any nuisance to the patient. Such an embodiment is particularly easy and comfortable to use and to wear. This allows using it like a simple wristwatch that, accordingly, can be worn permanently, to detect measurement signals obtained from pressure sensors 20.

In the exemplary embodiment of Fig. 4, housings 13 have a box-like elongated shape and are adapted to house an elongated sensor 20'. In this case, sensor units 20a are arranged adjacent to one another, in order to define the array of sensors 20.

More in detail, each elongated sensor 20' comprises a support base 20'a on which a sensitive element 20c is arranged and is connected to support base 20'a.

As an alternative, as shown in Figs. 5 and 6, detection unit 150 comprises a single housing 13 that is arranged to house a sensorized sheet 23a on which the plurality of sensors 20 is arranged.

As diagrammatically shown in Fig. 7, the packaging 13 of box-like portion 12 contains the array of piezoresistive sensors 20 and also contains a temperature sensor 135 configured to compensate the temperature drift which, as well known, is likely to take place in piezoresistive sensors 20. Packaging 13 is connected to control unit 30 as described hereinafter. Between sensors 20 and control unit 30 an analog front-end, or AFE, 42 may be provided, and an analog - digital converter 44. Also temperature sensor 135 may be connected to control unit 30, by a respective Analog front-end, or AFE, 42'. Control unit 30 compensates for the temperature drift of sensors 20 on the basis of the measurements made through temperature sensor 135, and analyses the measurement signals 25 detected by sensors 20, as described with reference to Figs. 1A to 1D.

As shown, for instance, in Fig. 7A, a display interface 60 may be provided on wearable support body 10, in

particular a display unit may be provided, which is arranged, in use, opposite to detection unit 150.

As shown in Fig. 8, control unit 30 also comprises a transmission means 65, in particular a wireless means, that is configured to transmit the data measured by the plurality of sensors 20 to a remote unit 70. As an alternative, control unit 30 may comprise a memory unit configured to memorize the plurality of measurement signals 25 and to successively transfer them to remote unit 70.

Besides pressure sensors 20, wearable support body 10 may comprise further sensors in order to improve the available data, for instance, the further sensors are an accelerometer configured to eliminate the artifacts due to the movement of patient 50, a biochemical sensor configured to measure the electrolytes in the skin, to increase physiological or pathological data of patient 50, a temperature sensor 135, to compensate the intrinsic reading changes of the piezoresistive sensors.

Moreover, in order to assist positioning of tonometer 100, an actuator and a control system may be provided to obtain an optimum positioning at artery path 52. In particular, the actuator is adapted to apply a flattening pressure that is most suitable for detecting the sphygmic wave on artery path 52.

In the exemplary embodiment diagrammatically shown in Figs. 9 to 15, tonometer device 100 comprises a wearable support body 10 made of a flexible material, in particular of flexible Printed Circuit Boards, e.g. PCB flex, which has a first side 11 and a second side 12 opposite to first side 11.

A predetermined number of piezoresistive sensor elements 120 is arranged to form rows 121 on first side 11 of wearable support body 10, said elements connected to the first side of the base layer by means of a "wirebond"

technique.

More in detail, in the exemplary embodiment of Figs. 9 to 15, tonometer 100 provides a main body 125 of a stiff material that is connected to first side 11 of wearable support body 10, for example by gluing, and has a first and a second opening 113a and 113b. At each opening 113a and 113b is arranged, in use, a respective piezoresistive sensitive element 120a,120b of a predetermined row of piezoresistive sensor elements, or "die", i.e. the essential part of a piezoresistive sensor.

Each opening 113a and 113b is adapted to be filled with a predetermined amount of fluid silicone rubber in order to fully cover the respective piezoresistive sensitive element 120a,120b that is housed within this opening. Once hardened, the silicone rubber provides a transmission element 160 that protrudes from main body 125 and is adapted to transmit the external forces to piezoresistive sensitive element 120.

In particular, main body 125 serves to protect the couple of sensors from dirt, powder and shocks and to stiffen the overall structure along a determined direction as explained in detail hereinafter. Main body 125 also serves for covering sensitive element 120 with fluid silicone rubber through openings 133.

The group consisting of a main body 125, a force transmission element, and a row of piezoresistive sensor elements 120a,120b, forms a sensor unit 112. Therefore, in the case diagrammatically shown in Figs. 9 to 15, a first sensor unit 112a and a second sensor unit 112b are provided.

According to the invention, each main body 125 may also comprise a third opening 133c, which may be located between two adjacent piezoresistive sensor elements 120a and 120b of the row. A temperature sensor 135 is arranged at opening

133c. As well known, piezoresistive sensors 120 cold be affected by a considerable temperature drift if the temperature changes. Therefore, temperature sensor 135 serve to record possible temperature changes, in order to compensate the above temperature drift. In order to increase the patient's comfort, and to arrange temperature sensor 135 at a same condition as piezoresistive sensors 20, a further silicone rubber or rubber layer may be provided on the transmission element, or a layer made of any biocompatible material.

Besides, tonometer 100 can also provide a stiffening element 140 that is arranged on the second side of the flexible base support. More in detail, a stiffening element 140 may be provided, for example a stiffening element made of a plastic stiff material such as a stiff PCB, which is arranged on the second side at a respective main body 125, i.e. at a mirror-like position opposed to it, with respect to the flexible base support.

This way, an object is obtained that is considerably stiff at stiffening bodies 140 and at main bodies 125, in order to ensure, among other things, the integrity of the welded joints made with the "wire bond" technique, and with a remarkable flexibility, between two adjacent main bodies 125 thanks to support body 10 made of a flexible material that assists arranging device 100 about the user's wrist. More in detail, tonometer device 100 is positioned on user's wrist, in such a way to be very stiff along the longitudinal direction of artery 52 and to be flexible along the transversal direction.

The above described particular technical solution for tonometer device 100, according to the invention, which comprises at least one first and a second sensor units 112a and 112b, each of which is equipped with a respective row 121a,121b of sensor elements 120 comprising at least one

first and at least one second sensitive elements 120a and 120b, has different advantages. Firstly, this layout makes it possible to arrange a row of sensor elements 120 in a position well suited for detecting the arterial pressure, i.e. in the case diagrammatically shown in Fig. 10, at a recess 56 between the radial bone 53 and a tendon 54. Once sensor unit 112 that is arranged in the above correct position has been identified, a search begins among all the sensors of the row of this sensor unit 112, of sensitive element 120a or 120b that can detect the best measurement signal. In this connection, it should be remarked that the quality of the signal changes responsive to the proximal distance from the artery.

In the exemplary embodiment diagrammatically shown in Figs. 16 to 19, a distance adjustment means 210 is also provided for adjusting the distance of sensor unit 112 from the artery path of patient 50 52. More in detail, adjustment means 210 is adapted to remove/approach sensor unit 112 from/to artery path 52, in order to flatten it accordingly. As well known, a pressure sensor signal can detect the arterial pressure only if artery 52 is slightly flattened. More in detail, a lower limit value exists of the flattening of artery 52, below which the pressure wave cannot be measured, as well as an upper limit of the flattening of artery 52, above which the artery itself is blocked. Therefore, the means for adjusting distance 210 of sensor unit 112 from artery path 52 serves for applying a pressure on the patient's wrist that is strong enough to flatten artery 52 and, accordingly, to allow detecting the pressure signal by sensor unit 112, but not so strong to block artery 52 itself. Advantageously, adjustment means 210 may a manual means, to be manually operated by the patient himself.

For example, adjustment means 210 may comprise a worm

screw, not shown in detail in Fig., which has an end portion integral to a knob 215, or to a different interaction element. When positioning sensor unit 112 with respect to artery 52, patient 50 can act manually on knob 215 in order to slide sensor unit 112 towards/away from artery 52. More in detail, if the knob is turned in a first rotation direction, sensor unit 112 is moved towards artery 52, in order to flatten the latter (Fig. 18), whereas if knob 215 is turned in the opposite direction, sensor unit 112 is moved in the direction opposite to the previous direction, i.e. sensor unit 112 is removed from artery 52 (Fig. 19).

Wearable body 10 may also comprise a closure 15 that allows a steady lock about patient 50's wrist and then allows of keeping sensor unit 112 in the correct position with respect to artery 52.

Furthermore, a control means, not shown in the figures, can be provided on board of tonometer structure 100, which is configured to read the pressure signal detected by sensor unit 112, and configured to compare it with a reference value. More in detail, when value of the detected pressure signal is higher than the reference value, a display and/or a sound emitter of the tonometer communicates to the patient that the detected signal is strong enough for detecting the arterial pressure.

The foregoing description exemplary embodiments of the invention will so fully reveal the invention according to the conceptual point of view, so that others, by applying current knowledge, will be able to modify and/or adapt for various applications such embodiment without further research and without parting from the invention, and, accordingly, it is therefore to be understood that such adaptations and modifications will have to be considered as equivalent to the specific embodiments. The means and the

materials to realize the different functions described herein could have a different nature without, for this reason, departing from the field of the invention. It is to be understood that the phraseology or terminology that is employed herein is for the purpose of description and not of limitation.

CLAIMS

1. A tonometer structure (100) for permanently monitoring a patient's arterial pressure during a determined time, said structure (100) **characterized in that** it comprises:

- a support body (10) that can be worn by a patient (50);

- a detection unit (150) mounted to said wearable support body (10), said support body (10) and said detection unit (150) configured such that said detection unit, in use, can contact said patient's skin (50) proximate to an artery path (52), said detection unit (150) having a plurality of piezoresistive pressure sensors (20), each sensor of said plurality configured to measure a pressure variation when said detection unit (150) can contact said patient's skin, and configured to provide a respective measurement signal (25), said measurement signal (25) associated with a respective sphygmic wave of a determined amplitude;

- a control unit (30) associated with said plurality of pressure sensors (20) and arranged to receive said plurality of measurement signals (25), said control unit equipped with a recognition means (32)configured to process said plurality of measurement signals by a recognition algorithm to:

  - recognize a reference signal (26) among said plurality of measurement signals (25), wherein said reference signal is associated with a respective reference sensor (21), wherein said reference signal is the measurement signal of said plurality, wherein said reference signal is associated with the sphygmic wave that has the largest amplitude;

  - recognizing at least one boundary signal (27) in

the remainder part of said plurality of measurement signals (25), said at least one boundary signal associated with a respective boundary sensor (22), wherein said boundary signal (27) is the measurement signal (25) of said plurality, wherein said reference signal is associated with the sphygmic wave that has the smallest amplitude;

- an actuation means for actuating (34) said recognition means (32) at predetermined instants (t1,t2,t3,tn), said recognition means (32) configured to measure a reference measurement signal (26) and to identify a relative reference sensor (21) at each of said instants (t1,t2,t3,tn), such that also in the case of an accidental movement of said detection unit (150) with respect to said artery path (52), a reference sensor (21) is always recognized;

said control unit (30) also comprising a program means (35) configured to process said or each boundary signal (27) by a filtering algorithm for extracting a "useful" component, i.e. a sphygmic component from said boundary signal (27), and for extracting a noise component, or artifact, said program means (35) also configured to:

- combine said reference signal and said "useful" component of said boundary signal, by a merging algorithm, and obtaining an enhanced reference signal, in order to increase the information and the quality of said reference signal itself;
- subtract said noise component of said boundary signal (27) from said reference signal by a subtraction algorithm, to obtain a "clean", or correct reference signal, i.e. a reference signal that is depurated from artifacts and background noise;
- a combination thereof;

said program means also adapted to process said improved and/or correct reference signal by a transformation algorithm, and to provide a real-time value (40,40',40*) of the patient's arterial pressure.

2. A tonometer structure (100) according to claim 1, wherein said recognition means is configured to process the frequency spectrum of said measurement signals (25) in a predetermined frequency band to which the signal pressure belongs.

3. A tonometer structure (100) according to claim 2, wherein said predetermined frequency band belongs to a frequency band comprising said cardiac frequency.

4. A tonometer structure (100) according to claim 1, wherein said recognition means (32) is configured to recognize a plurality of boundary signals (27) with respect to said reference signal (26) in the remainder part of said plurality of sensors (20), said recognition means provided by said program means (35) in order to improve the information of said reference signal (26), by a merging algorithm (36), and in order to determine said artifact signal (28) to be subtracted from said reference signal (26) by a subtraction algorithm (37).

5. A tonometer structure (100) according to claim 1, wherein said detection unit (150) comprises a plurality of housings (13), each housing of said plurality of housings arranged to house a respective sensor (20), such that a sensor unit is formed (20a).

6. A tonometer structure (100) according to claim 5, wherein each housing (13) is made of a flexible material that is adapted to transmit the external forces to the sensor that is housed within said housing (13).

7. A tonometer structure (100) according to claim 5,

wherein each housing (13) has a box-like elongated shape and is adapted to house an elongated sensor, said elongated sensor comprising a support base (20'a) and a sensitive element (20c) connected to said support base (20'a).

8. A tonometer structure (100) according to claim 5, wherein said flexible material is silicone rubber.

9. A tonometer structure (100) according to claim 5, wherein each housing (13) is made of a stiff material and is adapted to be filled with a fluid polymeric material that, once hardened, is adapted to transmit the external forces to the sensor (20) contained in said housing made of a stiff material, each housing (13) made of a stiff material arranged to house a sensor that is formed by said sensitive element (20c) only.

10. A tonometer structure (100) according to claim 9, wherein said stiff material is a ceramic material.

11. A tonometer structure (100) according to claim 9, wherein said fluid polymeric material is silicone rubber.

12. A tonometer structure (100) according to claim 5, wherein said plurality of sensor units (20a) is arranged according to a predetermined layout (2xN), wherein 2xN is the number of said sensor elements (20a), on said support body, said sensor unit (20a) arranged at one end (11a) of said flexible support body (10) and provided with a feed connector (14) arranged at a second end (11b) opposite to said first end (11a).

13. A tonometer structure (100) according to claim 5, wherein said box-like shaped detection unit (150) comprises a single housing (13) arranged to house a sensorized sheet (13a) at which said plurality of sensors (20) is arranged.

14. A tonometer structure (100) according to claim 1, wherein said wearable support body (10) comprises, besides said pressure sensors (20), at least one auxiliary sensor configured to provide further useful data, said or each auxiliary sensor selected from the group consisting of:

- an accelerometer for eliminating the artifacts due to the patient's movement (50);
- a biochemical sensor for measuring electrolytes in the skin, for increasing the patient's (50) physiological or diagnostic data;
- a temperature sensor for compensating the intrinsic reading changes of the piezoresistive sensors;
- an actuator and a control device of said actuator for more easily positioning and attaining an optimum positioning at said artery path (52), said actuator arranged to apply to said artery path (52) an flattening pressure best suited for detecting the sphygmic wave;
- or a combination thereof.

15. A tonometer structure (100) according to claim 14, comprising a base body provided with said or each further sensor, said base body arranged to be removably connected to said tonometer structure in order to allow providing said further sensors.

16. A tonometer structure (100) according to claim 1, comprising:

- a wearable support body (10) made of a flexible material, said wearable support body (10) having a first side (11) that, in use, can be oriented towards the user's skin (50) and a second side (12) opposite to the first side;
- a plurality of piezoresistive elements (120) arranged to form rows (121), each piezoresistive

element (120) of said plurality arranged at said first side (11) of said wearable support body (10);

- a main body made of a stiff material (125) arranged at said first side (11) of said wearable support body (10), said main body (10) having a plurality of openings (113) at each of which, in use, a respective piezoresistive sensitive element (120) is arranged of one of said rows, such that a sensor unit (112) is formed;

- each opening (113) of said plurality arranged to be filled with a predetermined amount of a fluid polymeric material in order to fully cover the respective piezoresistive sensitive element (120) that is housed within said opening, said fluid polymeric material adapted to harden such that a transmission element (160) is provided arranged to transmit the external forces to the piezoresistive sensitive element (120), which protrudes from said main body (125).

17. A tonometer structure (100) according to claim 16, wherein said fluid polymeric material is silicone rubber.

18. A tonometer structure (100) according to claim 16, wherein said flexible material is a flexible Printed Circuit Boards, in particular a PCB flex.

19. A tonometer structure (100) according to claim 16, wherein each main body is also provided with a third opening, said third opening arranged to house a temperature sensor, in use.

20. A tonometer structure (100) according to claim 16, wherein a further silicone rubber or rubber layer is provided on said transmission element, or a layer is provided made in any biocompatible material that is adapted, in use, to be brought into contact of the user's skin, in order to increase the patient's

comfort.

21. A tonometer structure (100) according to claim 16, wherein a stiffening element is also provided, for example a stiffening element made of a plastic stiff material such as a stiff PCB, which is arranged on said second side of said wearable support body at a respective main body, i.e. at a mirror-like position opposed to said main body, with respect to said wearable support body.

22. A tonometer structure (100) according to claim 21, wherein said stiffening bodies and said main bodies are arranged, in use, along an axial direction of said artery path.

23. A tonometer structure (100), according to any of the previous claims, wherein an adjustment means is also provided for adjusting the distance of said sensor unit from said artificial artery, said adjustment means arranged to remove/approach said sensor unit from/to said artery path, to cause said artery path to become flat.

24. A tonometer structure (100) according to claim 23, wherein a control means is provided configured to read said detected pressure signal and to compare it with a reference value such that, when said value of said detected pressure signal is higher than said reference value, a display and/or a sound emitter of said tonometer communicates to the patient that the detected signal is strong enough for detecting the arterial pressure.

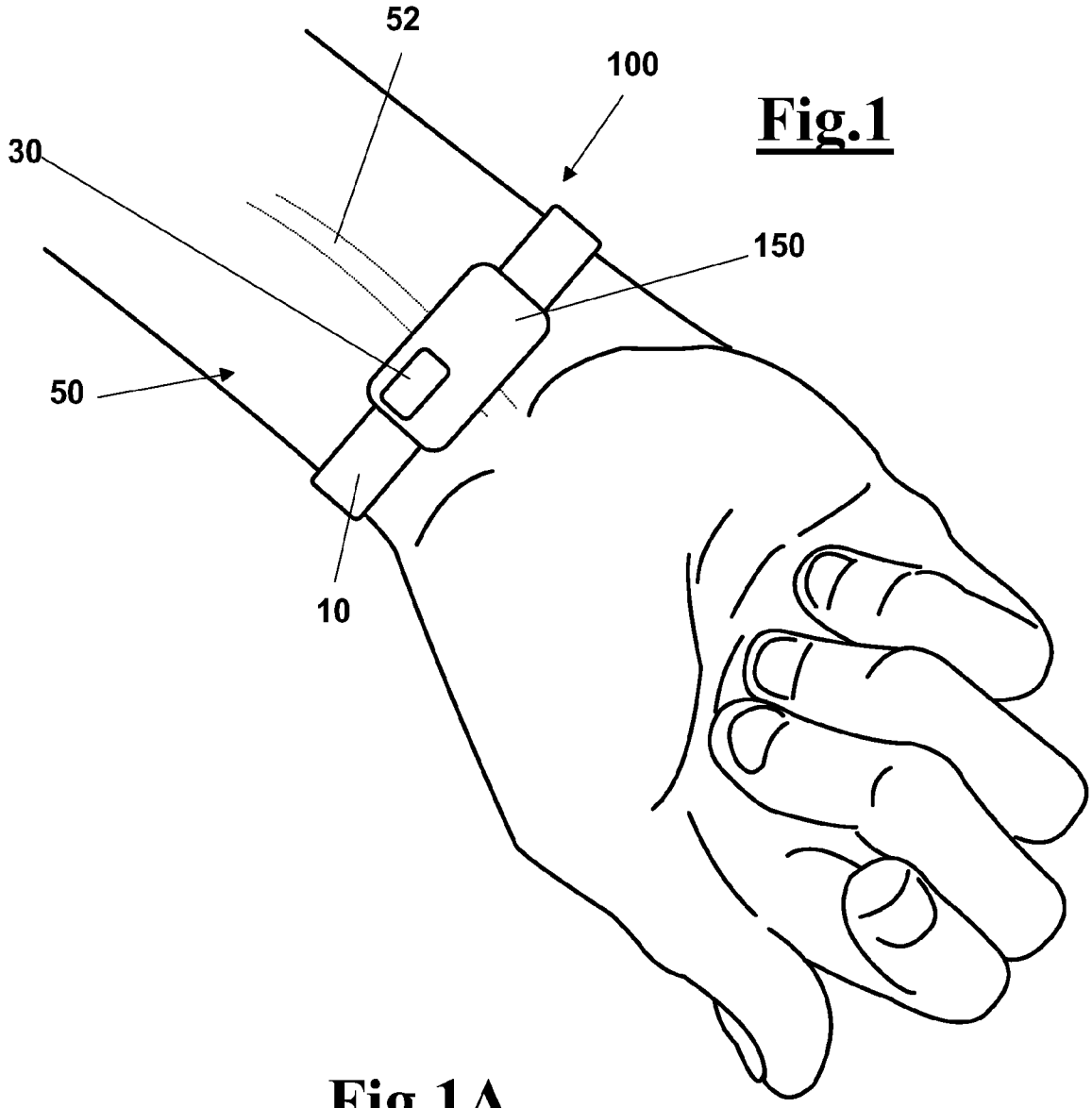


Fig.1

Fig.1A

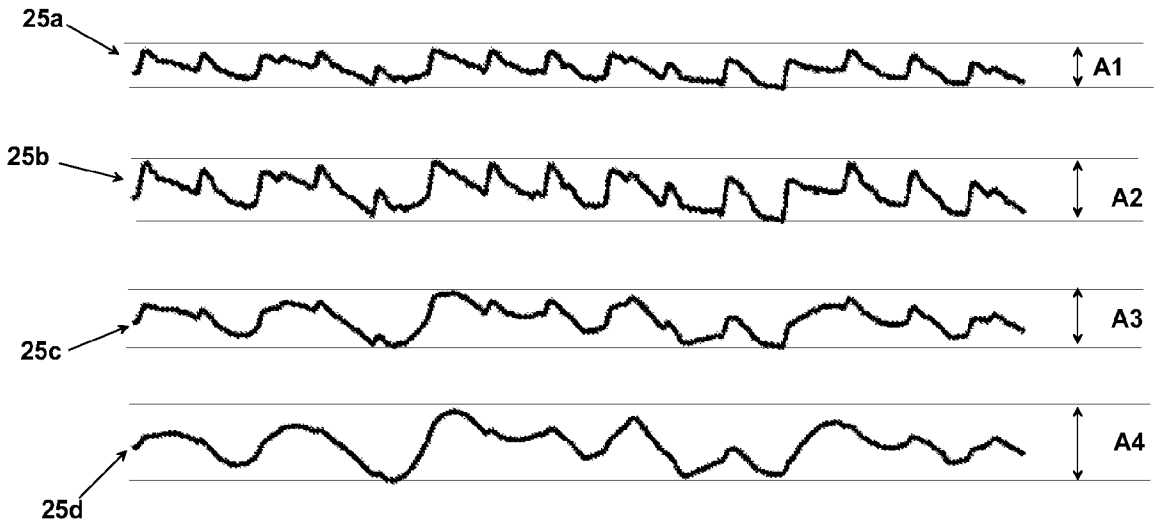


Fig.1B

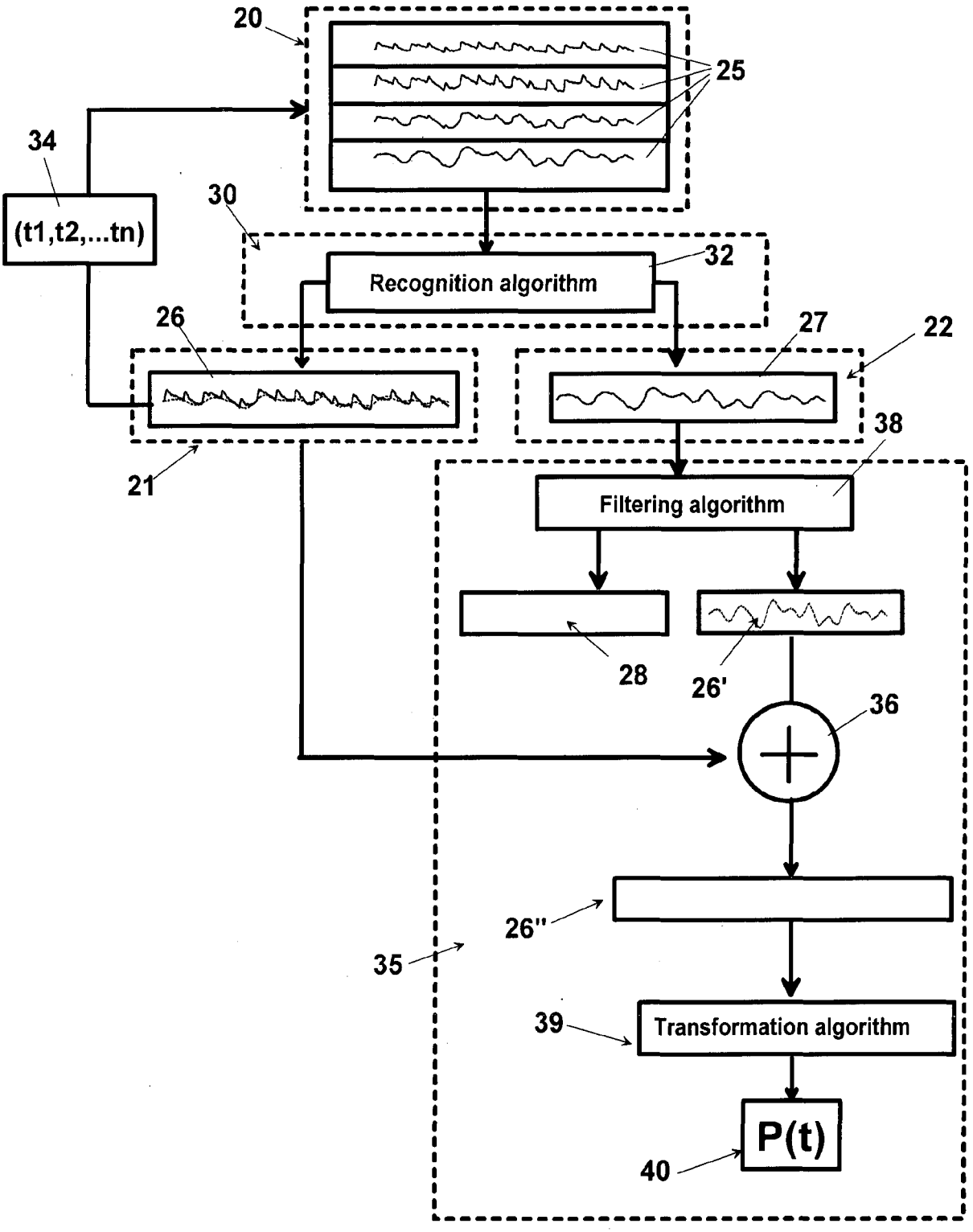
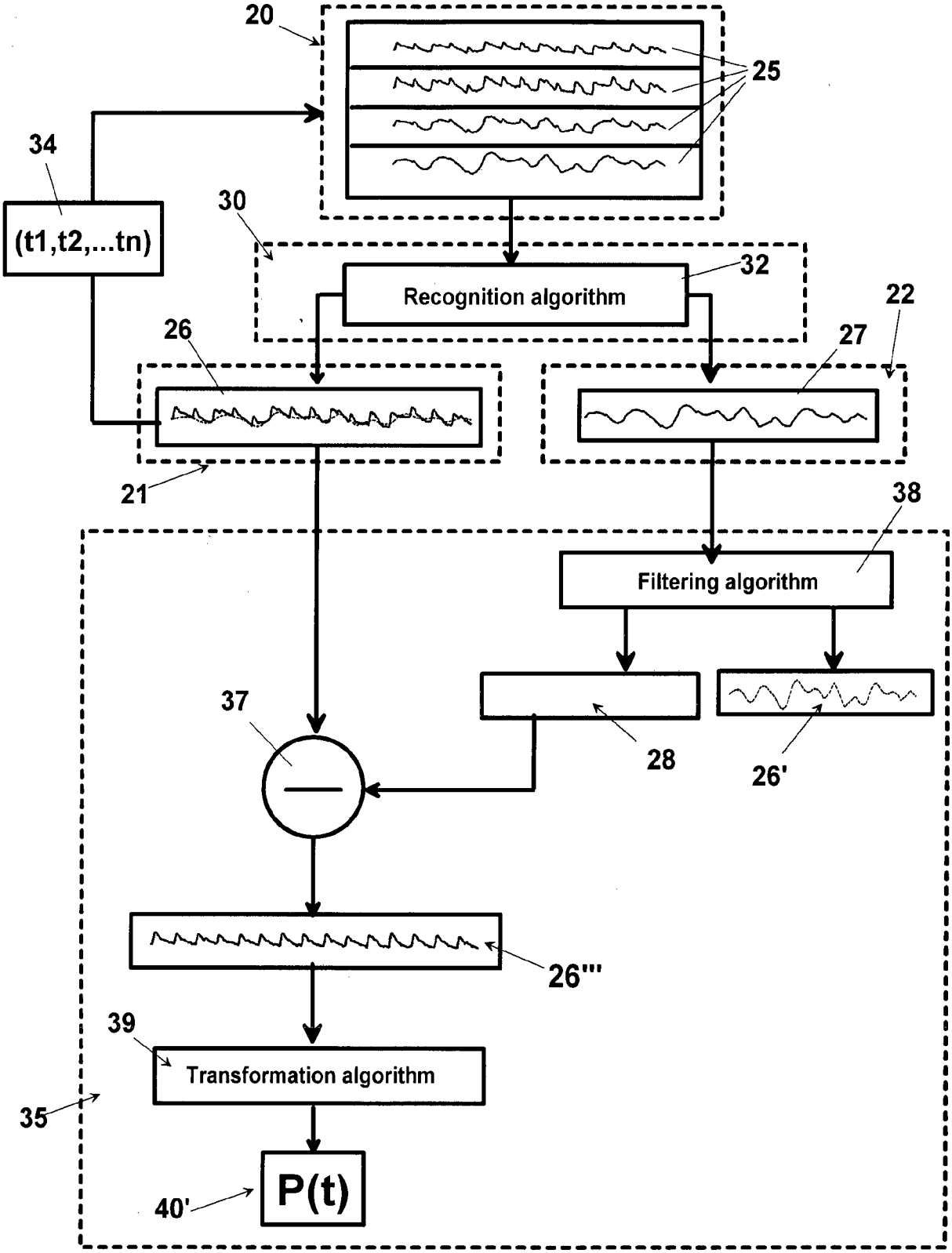

20
25
34
(t1,t2,...tn)
30
Recognition algorithm
32
26
27
22
21
38
Filtering algorithm
28
26'
36
26''
35
39
Transformation algorithm
P(t)
40

Fig.1C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25
34
(t1,t2,...tn)
30
Recognition algorithm
32
22
26
27
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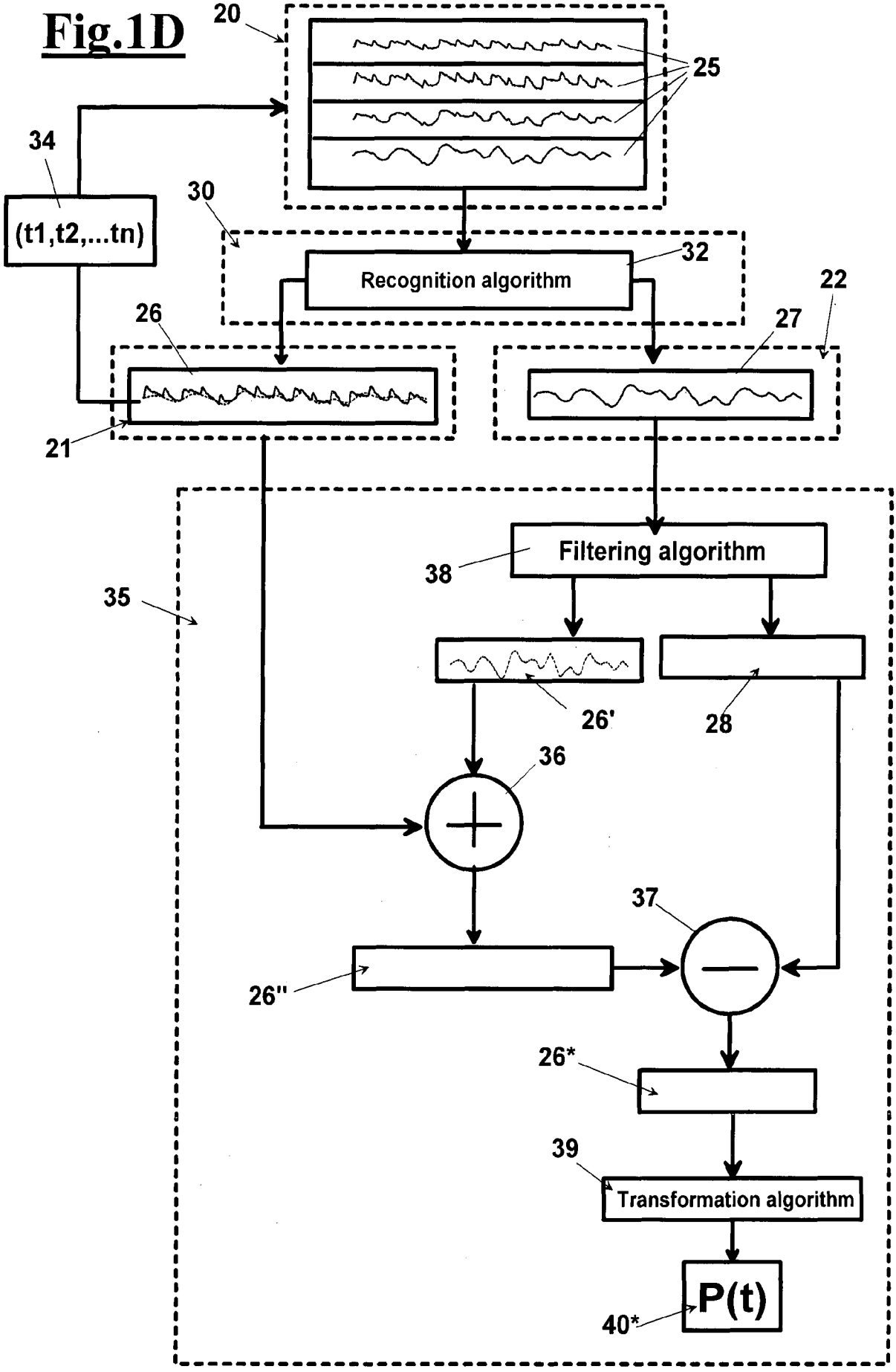
38
Filtering algorithm
37
28
26'
26'''
39
Transformation algorithm
35
40'
P(t)

Fig.1D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25
34
(t1,t2,...tn)
30
Recognition algorithm
32
22
26
27
21
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Filtering algorithm
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26'
28
36
37
26"
26*
39
Transformation algorithm
P(t)
40*

Fig.2

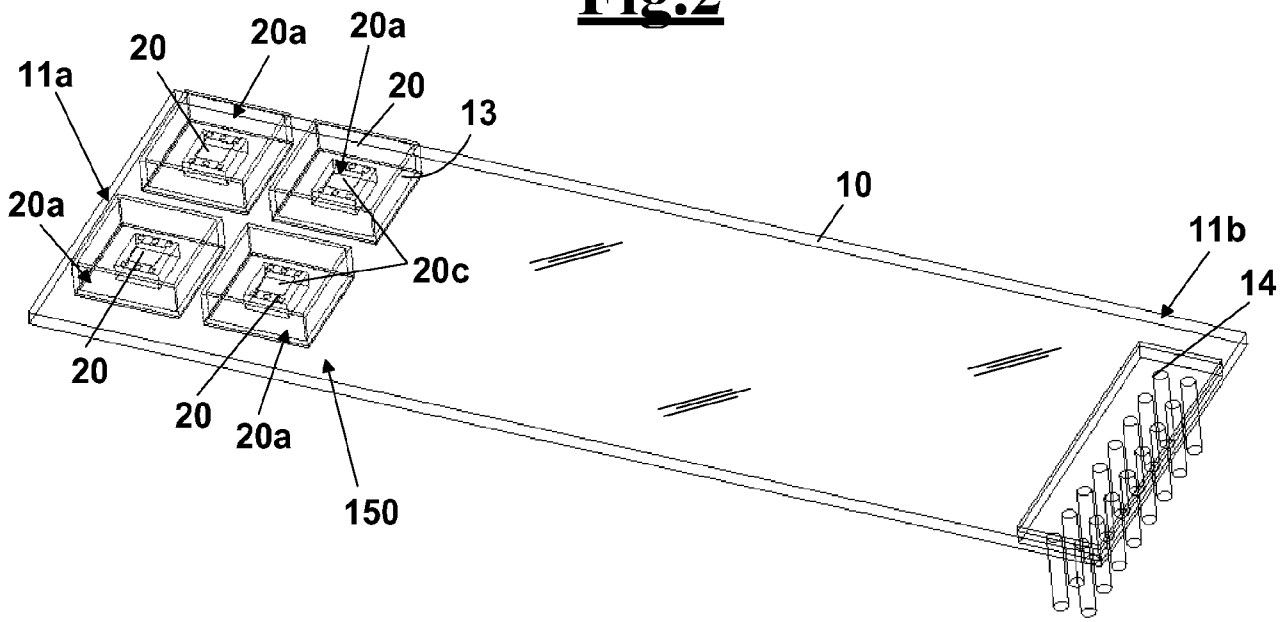


Fig.3

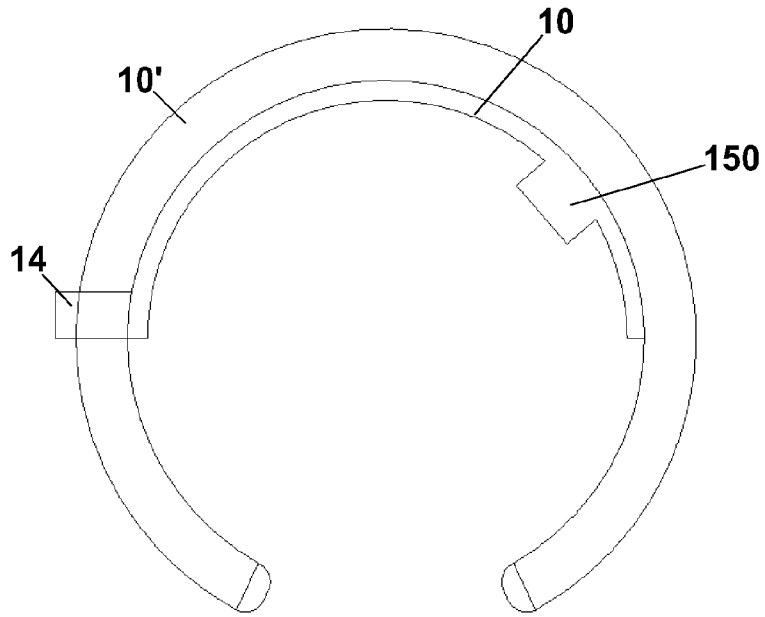


Fig.4

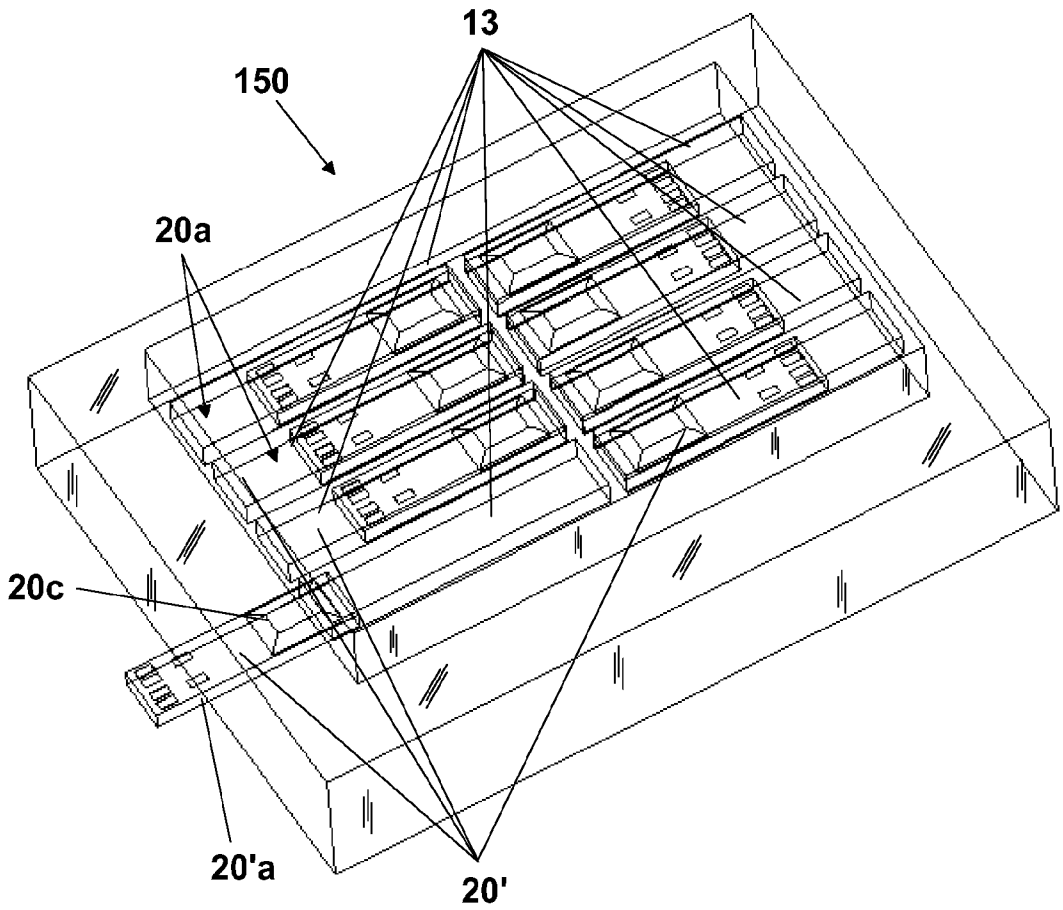


Fig.5

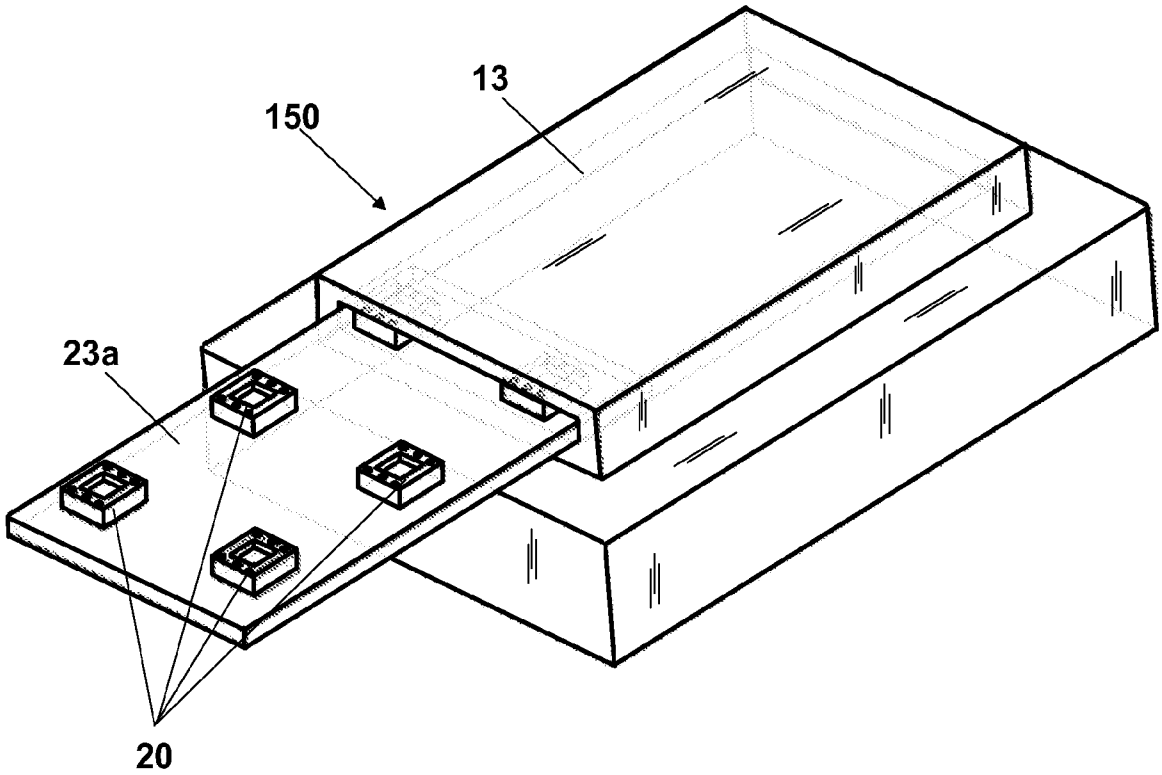


Fig.6

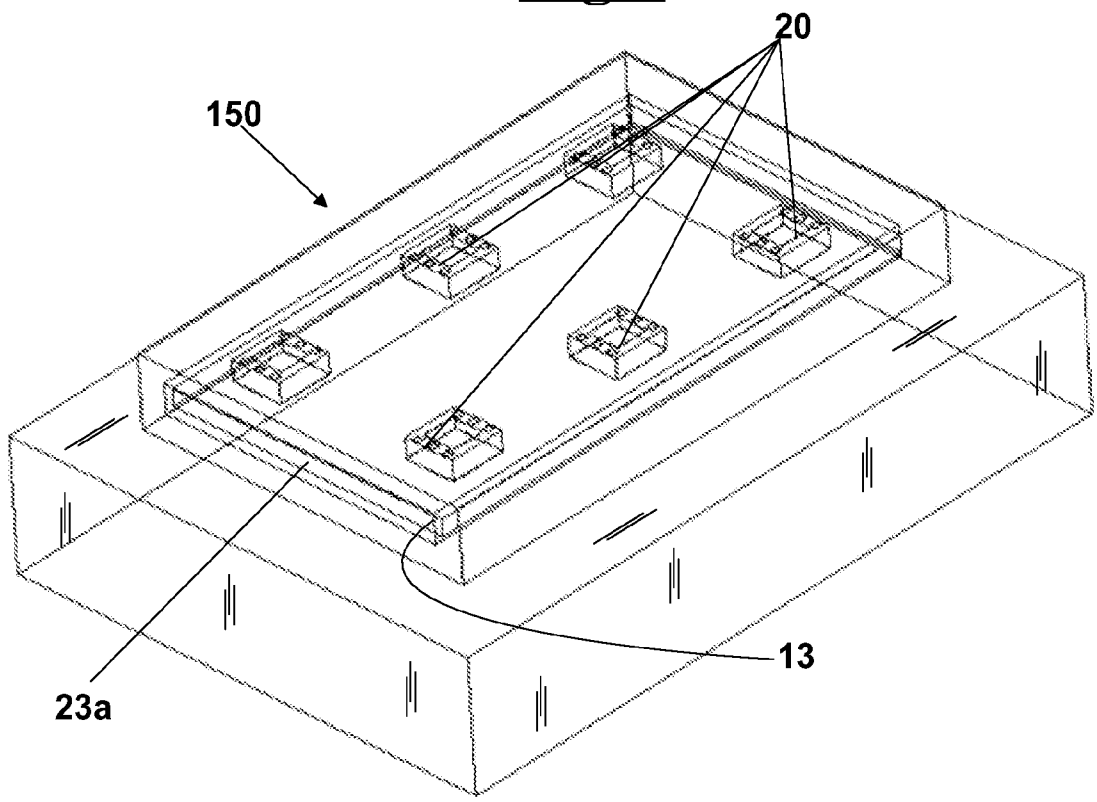


Fig.7

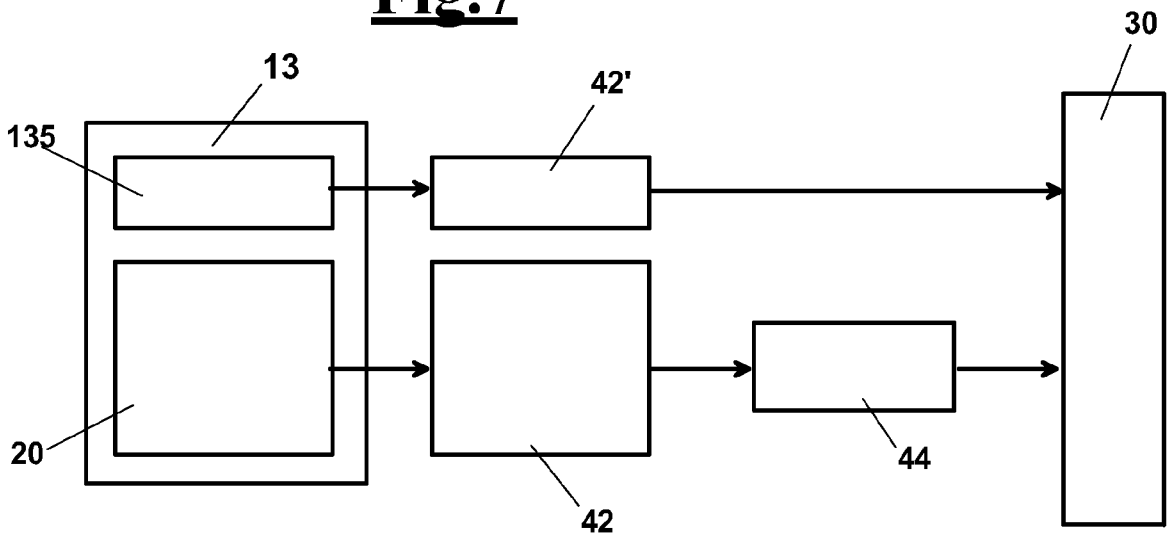
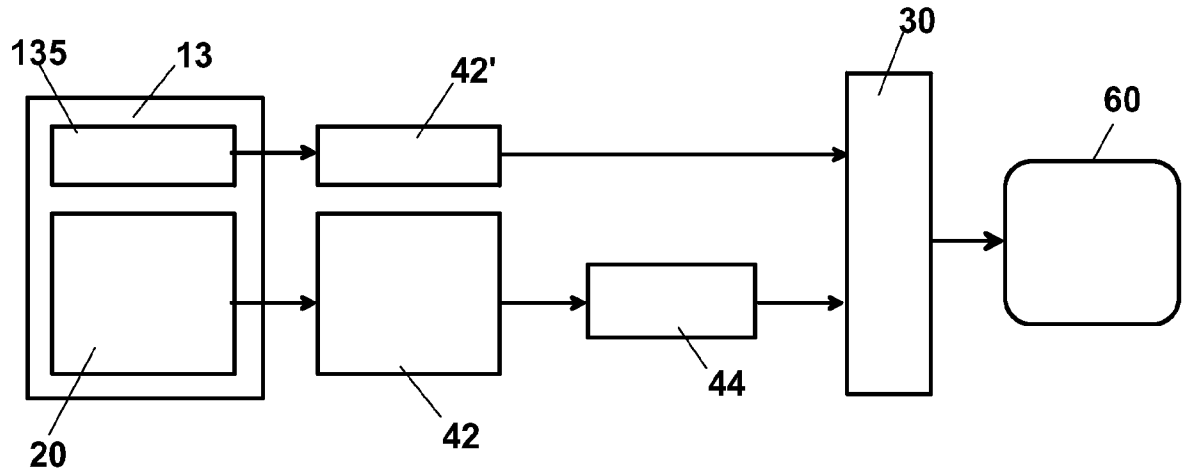


Fig.7A



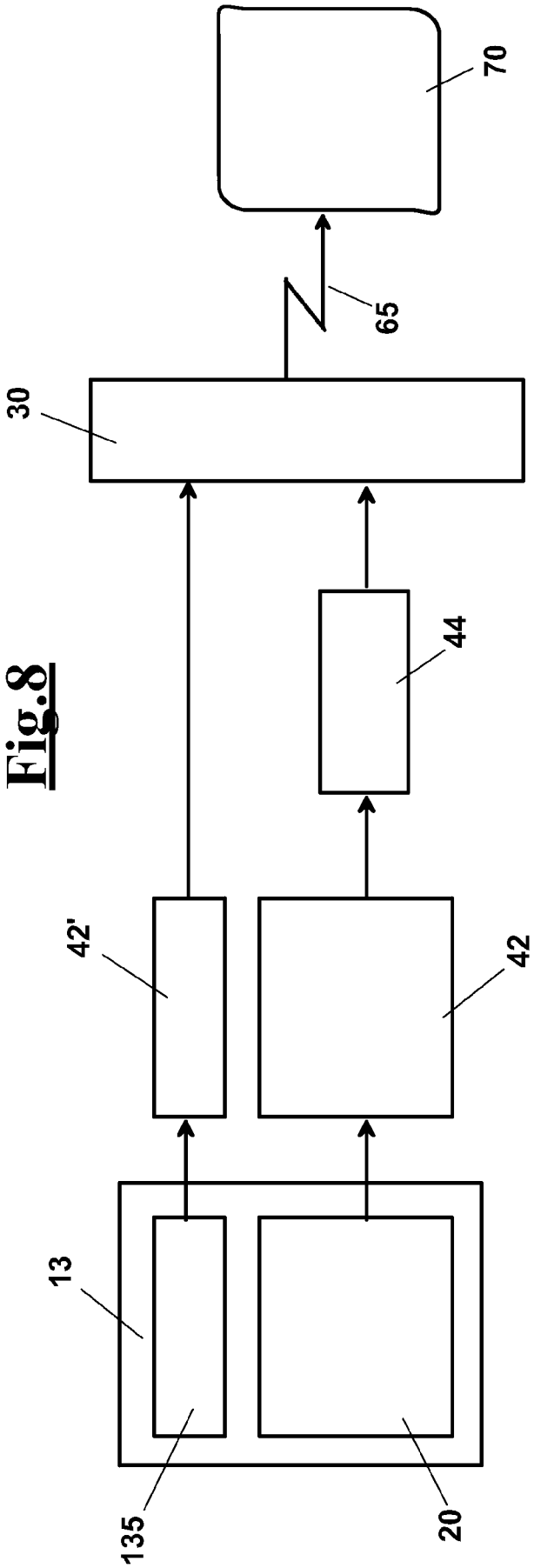


Fig.8

Fig. 9

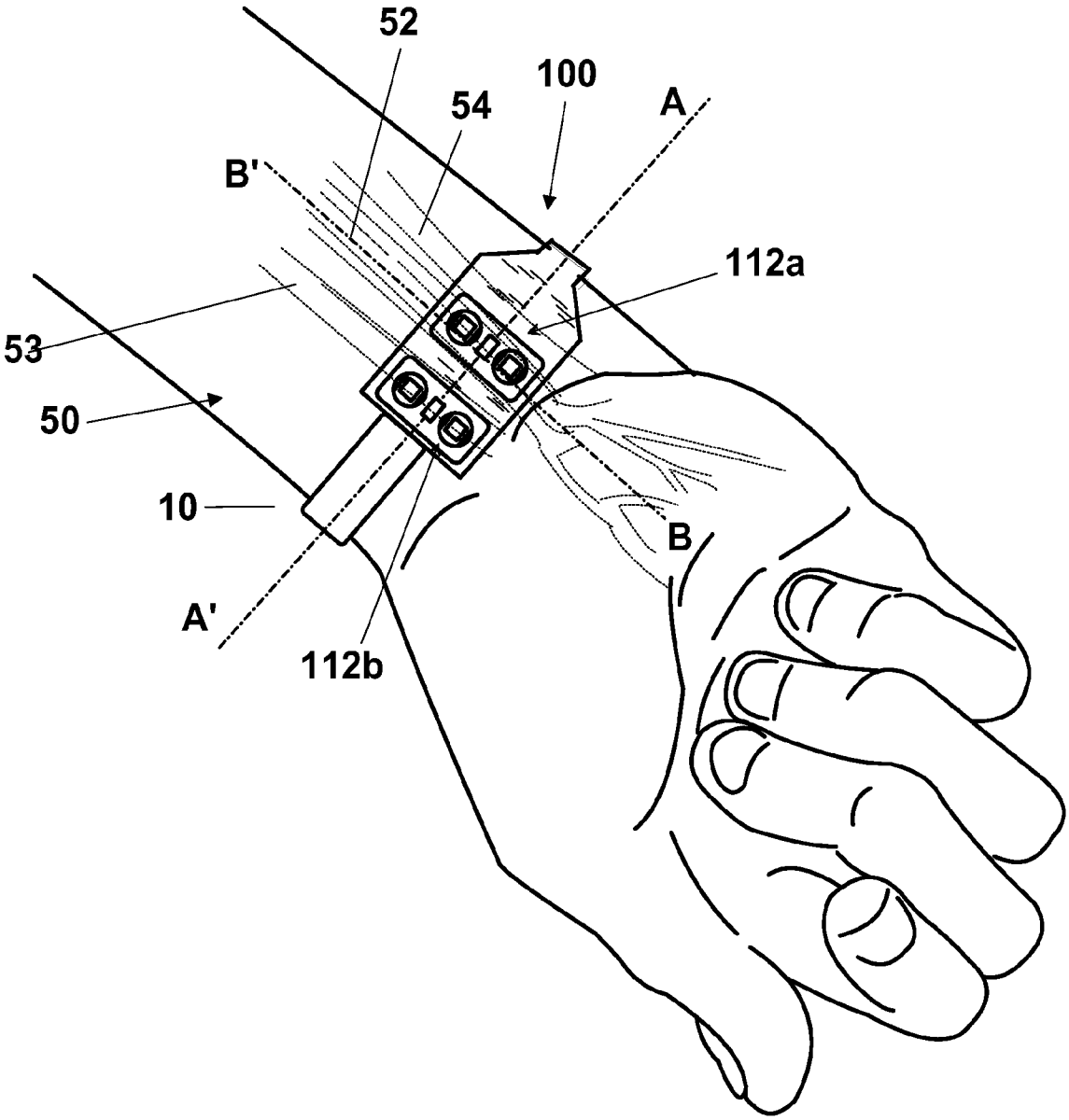


Fig. 10

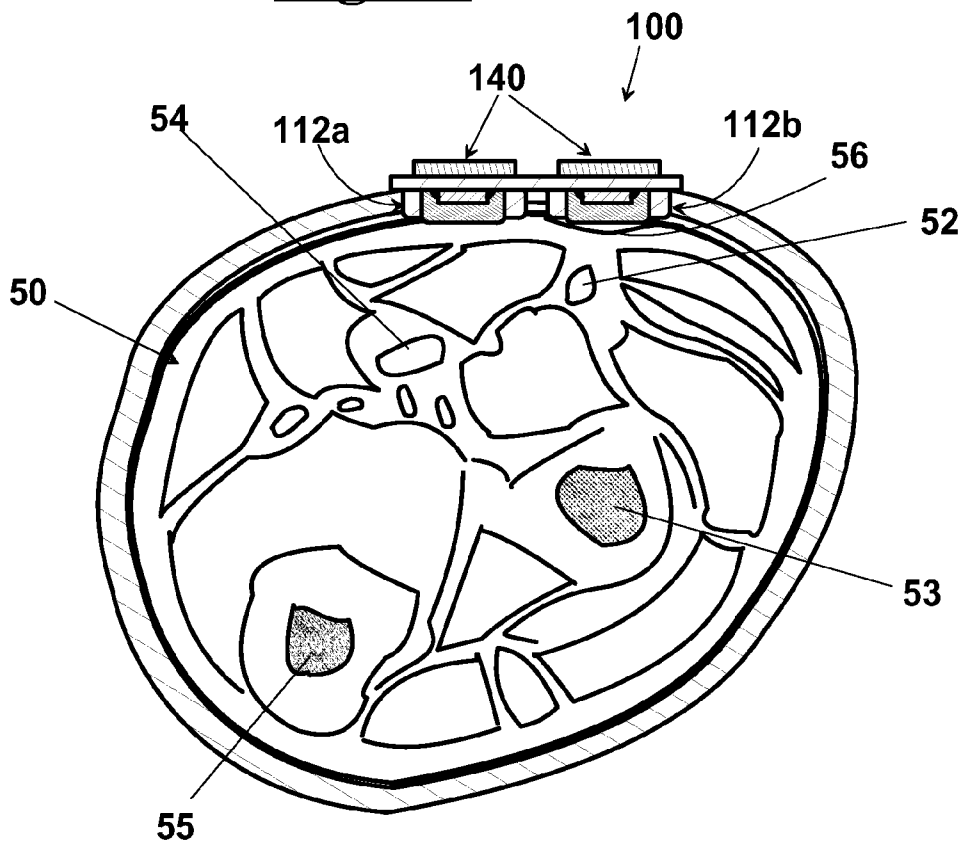

100
140
54
112a
112b
56
52
50
53
55

Fig. 11

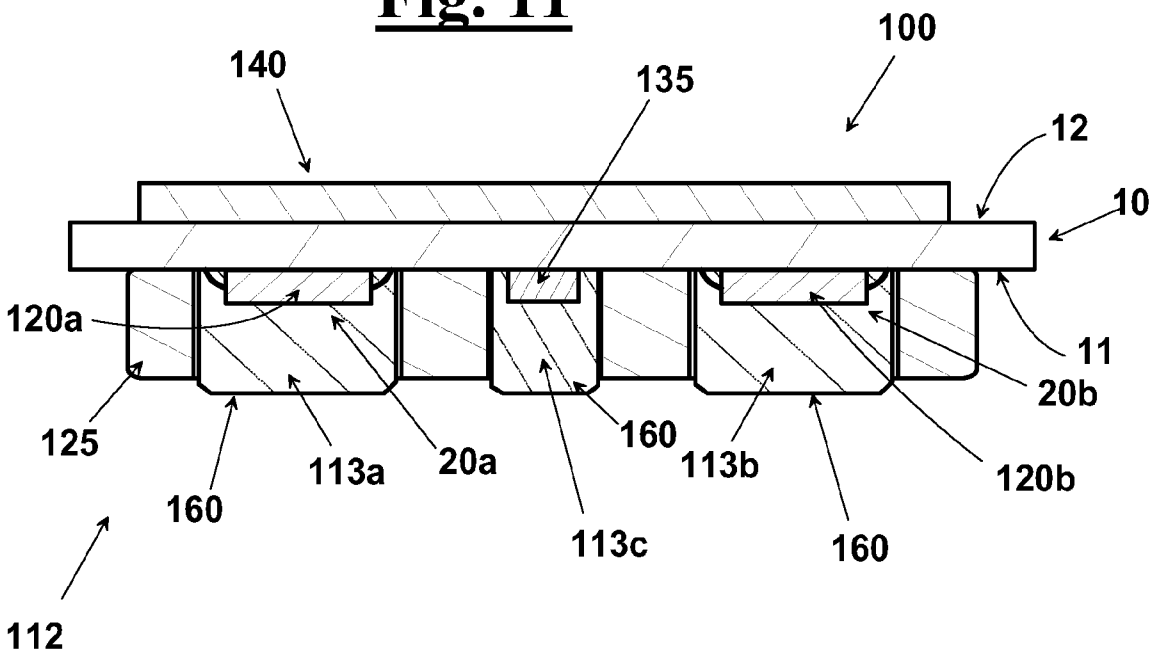

100
140
135
12
10
120a
11
20b
125
160
113a
20a
160
113b
120b
160
113c
160
112

Fig. 12

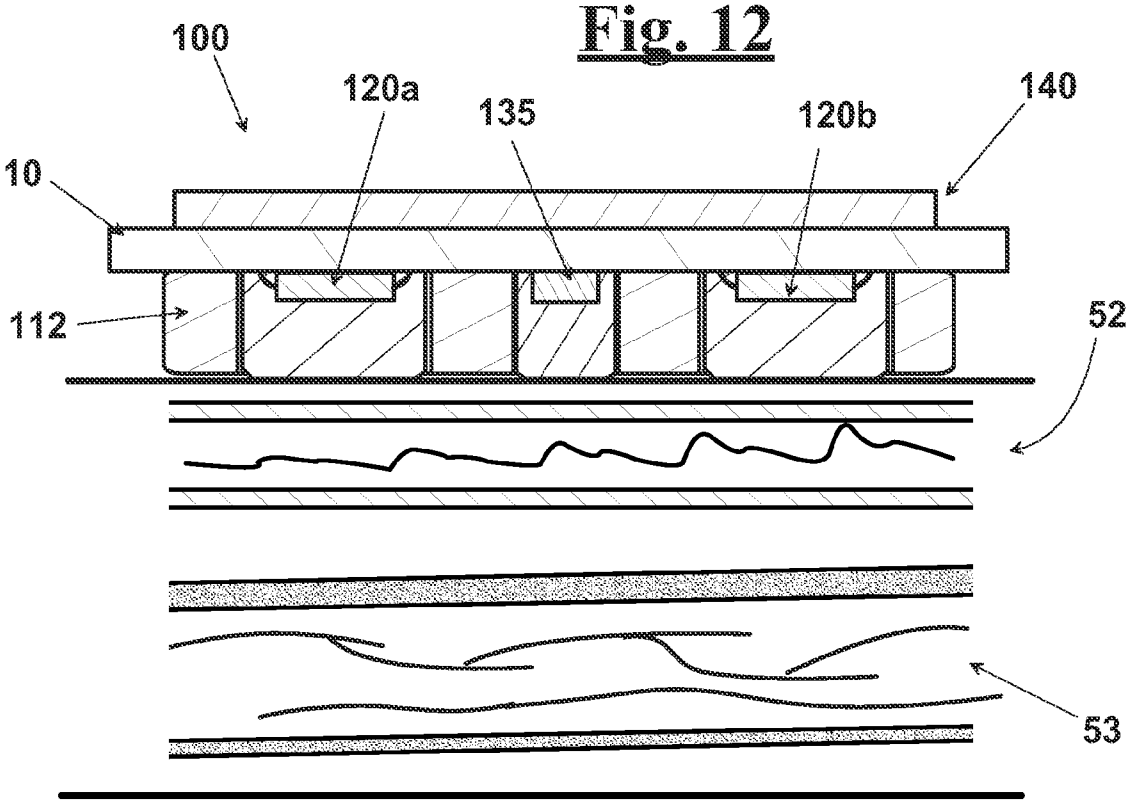

100
120a
135
120b
140
10
112
52
53

Fig. 13

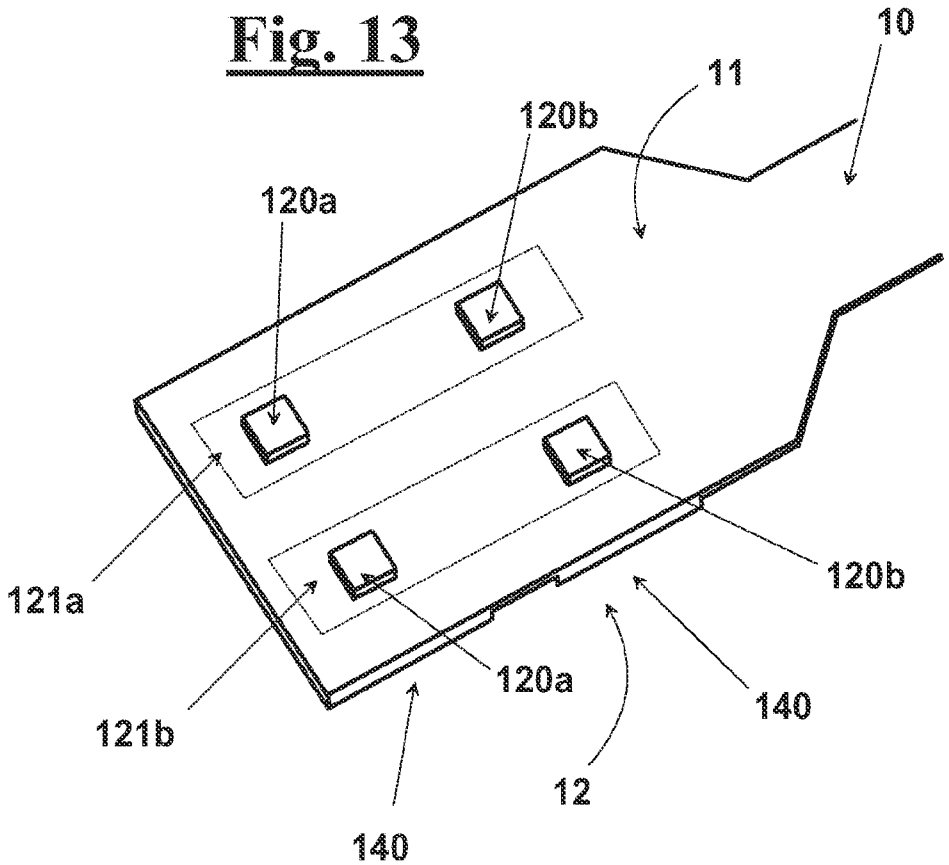

10
11
120b
120a
121a
120b
120a
121b
140
12
140

Fig. 14

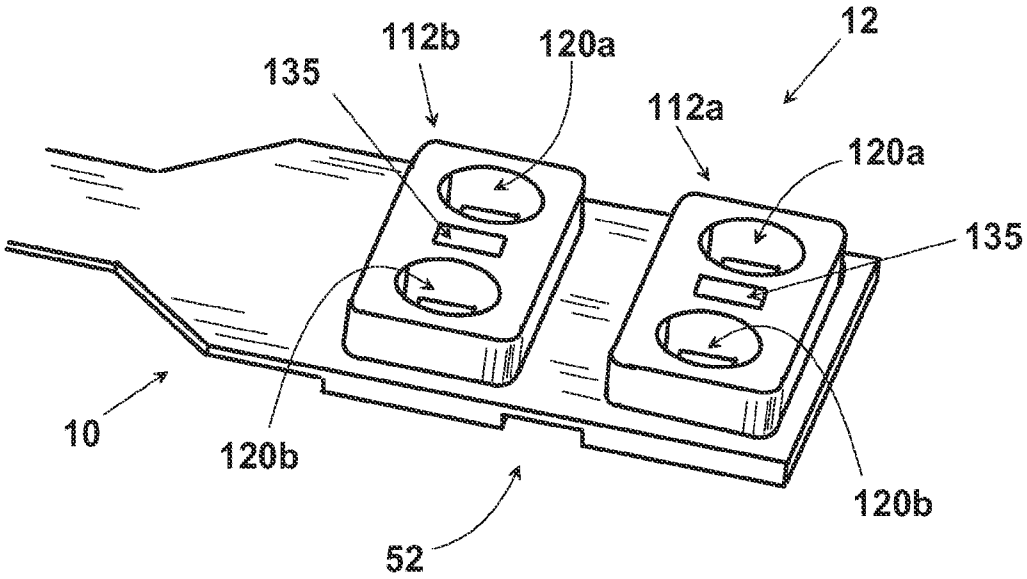

12
112b
120a
135
112a
120a
135
10
120b
120b
52

Fig. 15

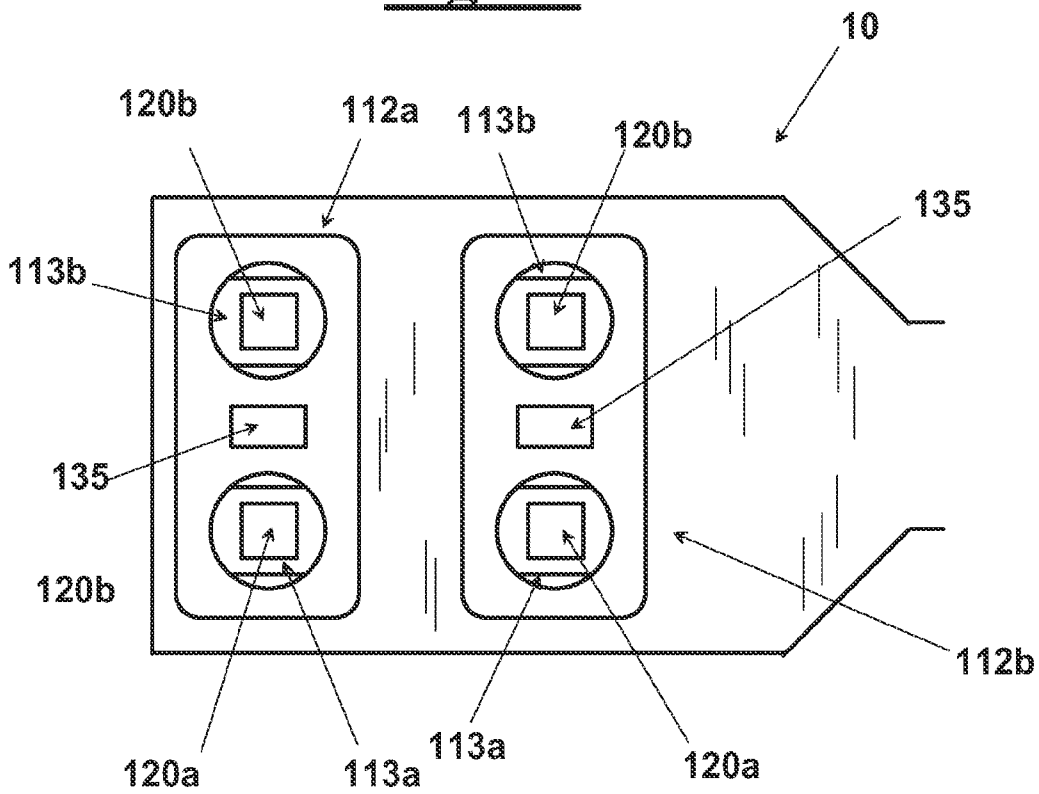

10
120b
112a
113b
120b
135
113b
135
120b
112b
120a
113a
113a
120a

Fig. 16

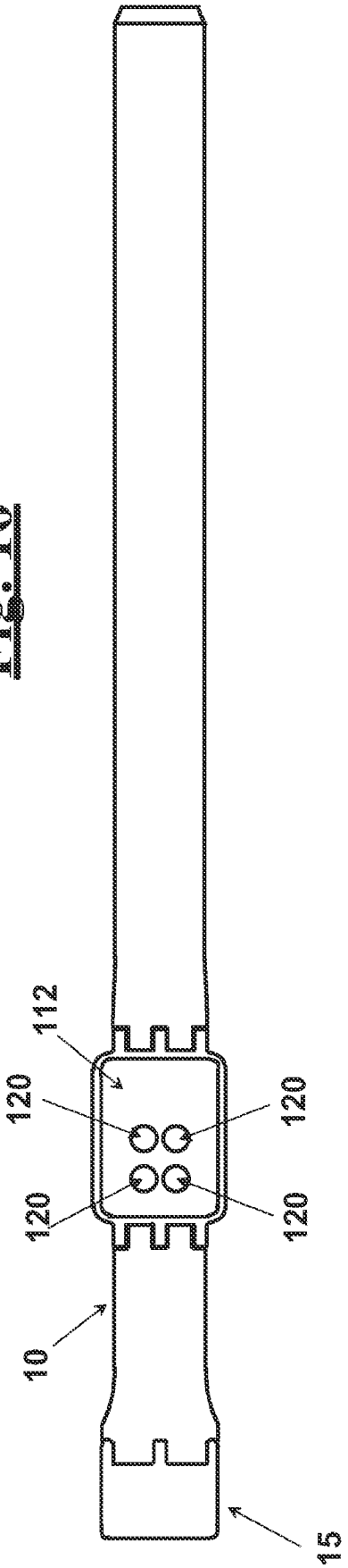


Fig. 17

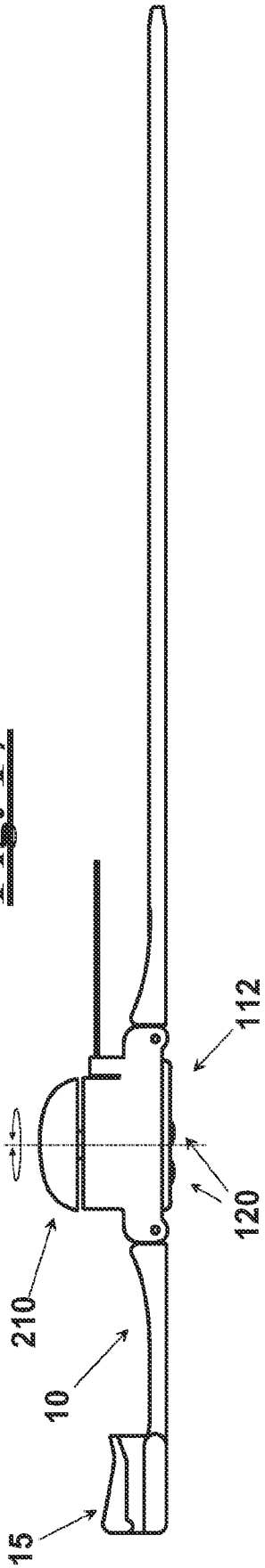


Fig. 18

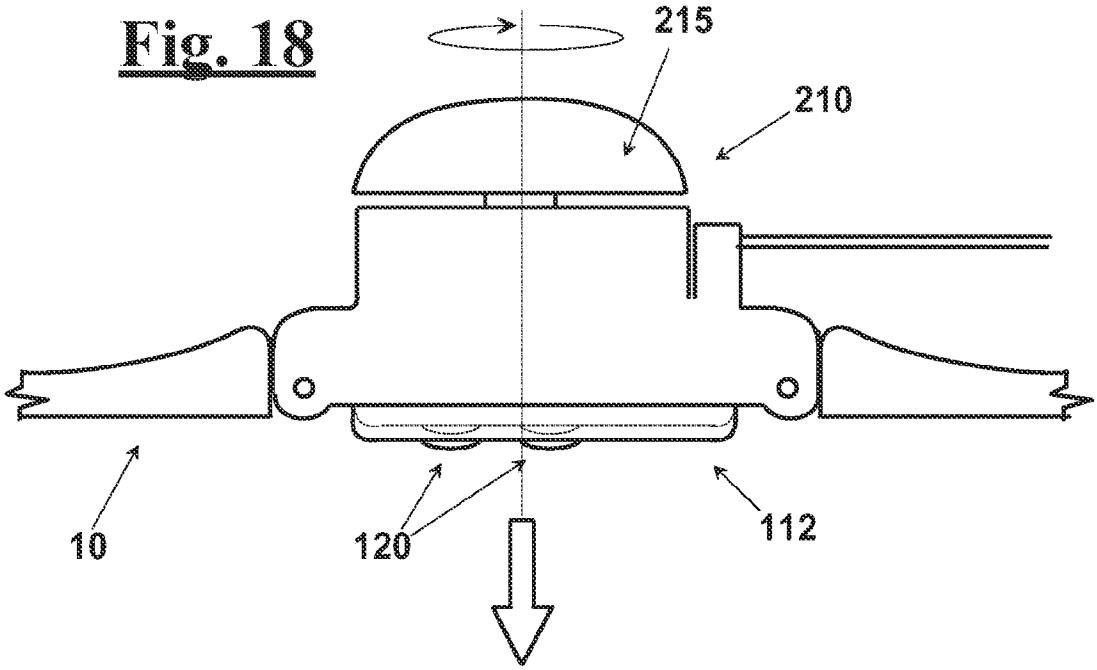
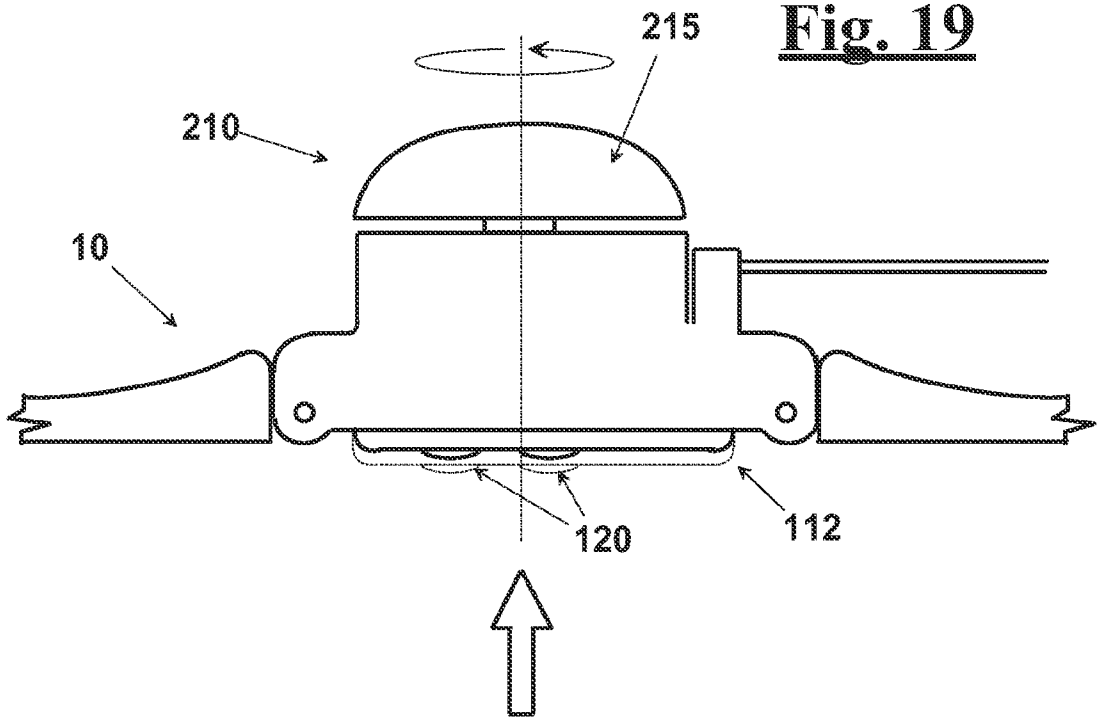


Fig. 19



INTERNATIONAL SEARCH REPORT

International application No
PCT/IB2012/056251

A. CLASSIFICATION OF SUBJECT MATTER
INV. A61B5/022
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
A61B

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

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

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 243 992 A (ECKERLE JOSEPH S [US] ET AL) 14 September 1993 (1993-09-14) column 3, lines 1-4 column 4, line 7 - column 5, line 18 column 5, line 40 - column 13, line 4; claims; figures	1-24
X	US 2011/077537 A1 (EBARA KAZUHIRO [JP] ET AL) 31 March 2011 (2011-03-31) paragraphs [0005] - [0007], [0015], [0024] - [0049]; claims; figures	1-24
X	US 5 494 043 A (O'SULLIVAN MARTIN [US] ET AL) 27 February 1996 (1996-02-27) column 2, lines 15-53 column 4, line 59 - column 8, line 20; claims; figures	1-24

☐ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

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

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"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
22 April 2013	03/05/2013

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

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No
PCT/IB2012/056251

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 5243992 A	14-09-1993	NONE	
US 2011077537 A1	31-03-2011	JP 2011072645 A	14-04-2011
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US 5494043 A	27-02-1996	NONE	