(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property Organization
International Bureau

(43) International Publication Date
19 April 2018 (19.04.2018)

WIPO | PCT

(10) International Publication Number
WO 2018/069571 A1

(51) International Patent Classification:
A61B 5/024 (2006.01) *A61B 5/1455* (2006.01)
A61B 5/00 (2006.01)

(21) International Application Number:
PCT/FI2017/050702

(22) International Filing Date:
06 October 2017 (06.10.2017)

(25) Filing Language: English

(26) Publication Language: English

(30) Priority Data:
16193376.7 11 October 2016 (11.10.2016) EP

(71) Applicant: **NOKIA TECHNOLOGIES OY** [FI/FI]; Karaportti 3, 02610 Espoo (FI).

(72) Inventors: **MYYRYLÄINEN, Lea**; Soukansyrjä 15, 02360 Espoo (FI). **POHJONEN, Helena**; Kartanonkuja 3 B, 02360 Espoo (FI).

(74) Agent: **NOKIA TECHNOLOGIES OY** et al.; Ari Aarnio, IPR Department, Karakaari 7, 02610 Espoo (FI).

(81) Designated States *(unless otherwise indicated, for every kind of national protection available)*: AE, AG, AL, AM, AO, AT, AU, AZ, BA, BB, BG, BH, BN, BR, BW, BY, BZ, CA, CH, CL, CN, CO, CR, CU, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JO, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, MW, MX, MY, MZ, NA, NG, NI, NO, NZ, OM, PA, PE, PG, PH, PL, PT, QA, RO, RS, RU, RW, SA, SC, SD, SE, SG, SK, SL, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States *(unless otherwise indicated, for every kind of regional protection available)*: ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM,

WO 2018/069571 A1

(54) Title: SKIN LIFTING FOR PHOTOPLETHYSMOGRAPHY

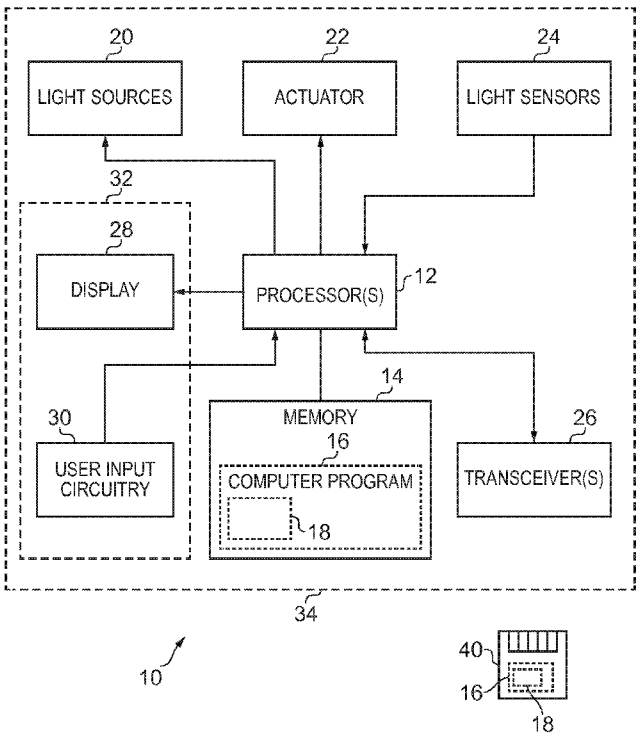


FIG. 1

(57) Abstract: An apparatus, method and computer program are provided. The apparatus (10) comprises: a photoplethysmography light source (20); a photoplethysmography light sensor (24) configured to sense light signals emitted by the photoplethysmography light source (20); and an actuator (22) configured to lift a surface of skin tissue in order to create an optical path through the skin tissue from the photoplethysmography light source (20) to the photoplethysmography light sensor (24), for transmissive photoplethysmography.

[Continued on next page]

TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

— *with international search report (Art. 21(3))*

SKIN LIFTING FOR PHOTOPLETHYSMOGRAPHY

TECHNOLOGICAL FIELD

Embodiments of the present invention relate to photoplethysmography. In particular, they relate to measurement of one or more physiological parameters such as heart rate (HR), heart rate variability (HRV) and/or peripheral capillary oxygen saturation (SpO_2) using photoplethysmography.

BACKGROUND

Photoplethysmography relates to performing volumetric measurement of an organ using optics. Pulse oximetry is a photoplethysmographic method of measuring oxygen saturation in blood.

A person's heart rate, heart rate variability and peripheral capillary oxygen saturation may be determined using such a method. In transmissive photoplethysmography, light signals are sensed by the light sensor after they have been emitted through tissue by the light source. In reflective photoplethysmography, light signals are sensed by the light sensor after being reflected by the tissue.

BRIEF SUMMARY

According to various, but not necessarily all, embodiments of the invention there is provided an apparatus, comprising: a photoplethysmography light source; a photoplethysmography light sensor configured to sense light signals emitted by the photoplethysmography light source; and an actuator configured to lift a surface of skin tissue in order to create an optical path through the skin tissue from the photoplethysmography light source to the photoplethysmography light sensor, for transmissive photoplethysmography.

According to various, but not necessarily all, embodiments of the invention there is provided a method, comprising: controlling, by at least one processor, lifting of a surface of skin tissue in order to create an optical path through the skin tissue from a

photoplethysmography light source to a photoplethysmography light sensor, for transmissive photoplethysmography.

According to various, but not necessarily all, embodiments of the invention there is provided an apparatus, comprising: means for emitting light; means for sensing light; emitted by the means for emitting light; and means for lifting a surface of skin tissue in order to create an optical path through the skin tissue from the means for emitting light to the means for sensing light, for transmissive photoplethysmography.

According to various, but not necessarily all, embodiments of the invention there is provided an apparatus, comprising: at least one processor; and at least one memory storing computer program instructions that, when performed by the at least one processor, cause at least the following to be performed: controlling, by the at least one processor, lifting of a surface of skin tissue in order to create an optical path through the skin tissue from a photoplethysmography light source to a photoplethysmography light sensor, for transmissive photoplethysmography.

According to various, but not necessarily all, embodiments of the invention there is provided a computer program comprising computer program instructions that, when performed by the at least one processor, cause: controlling lifting of a surface of skin tissue in order to create an optical path through the skin tissue from a photoplethysmography light source to a photoplethysmography light sensor, for transmissive photoplethysmography.

According to various, but not necessarily all, embodiments of the invention there is provided examples as claimed in the appended claims.

BRIEF DESCRIPTION

For a better understanding of various examples that are useful for understanding the detailed description, reference will now be made by way of example only to the accompanying drawings in which:

fig. 1 illustrates a schematic of an apparatus;

fig. 2 illustrates a schematic of the apparatus being worn by a person;

fig. 3 illustrates a first flow chart of a method;

fig. 4 illustrates a schematic of the apparatus being worn by a person when the actuator has lifted a surface of skin tissue; and
fig. 5 illustrates a second flow chart of a method.

DETAILED DESCRIPTION

Embodiments of the invention relate to relate to photoplethysmography, and, in particular, measurement of one or more physiological parameters such as heart rate (HR), heart rate variability (HRV) and/or peripheral capillary oxygen saturation (SpO_2) using photoplethysmography.

A technical effect of embodiment of the invention is the provision of transmissive photoplethysmography without a need to position a photoplethysmography light source and a photoplethysmography light sensor on opposing faces of tissue. This technical effect is provided by actuator which lifts a surface of skin tissue in order to create an optical path through the skin from the photoplethysmography light source to the photoplethysmography light sensor, for transmissive photoplethysmography.

Fig. 1 illustrates a schematic of an apparatus 10. The apparatus comprises one or more processors 12, at least one memory 14, at least one photoplethysmography light source 20, at least one actuator 22, at least one photoplethysmography light sensor 24, at least one transceiver 26, at least one display 28 and user input circuitry 30.

The photoplethysmography light source(s) 20 may, for example, be one or more light emitting diodes (LEDs). The light source(s) 20 may, for example, be configured to emit visible and/or infrared light signals. The visible light signals may have a wavelength in the range 500-600 nanometers (green light) and/or a wavelength in the range 600-700 nanometers (red light). The processor 12 is configured to control the emission of light signals by the light source(s) 20.

The photoplethysmography light sensor(s) 24 may, for example, include one or more photodetectors and/or one or more image sensors, such as one or more charge-coupled devices (CCDs) and/or one or more complementary metal-oxide-semiconductor (CMOS) sensors. Each of the light sensors 24 is sensitive to light emitted by the light source(s) 20. The processor 12 is configured to receive inputs from the light sensor(s) 24 representing sensed light signals.

The processor 12 is configured to control the actuation of the actuator 22. An analogue to digital converter may be present between the processor 12 and the actuator 22 to convert digital control signals provided by the processor 12 into analogue electrical signals that are output to the actuator 22.

The actuator 22 is configured to lift a surface of skin tissue when the apparatus 10 is worn by a person and the actuator 22 is placed adjacent the surface of the skin tissue. The actuator 22 may sealingly attach to the surface of the skin tissue and lift the surface of the skin tissue by a suction effect. The actuator 22 may, for example, include an electro-active material, such as an electro-active polymer, which changes its shape and/or configuration in response to the application of an electrical signal to the electro-active material. In some implementations, the actuator 22 is an electro-active polymer pump.

The one or more transceivers 26 are configured to establish a communication link between the apparatus 10 and one or more other entities, such as a local device (for example, a mobile telephone or a computer) or a remote device (such as a remote server). The communication link might, for example, be a wired communication link such as a Universal Serial Bus (USB) link or a wireless communication link such as a Bluetooth link, an IEEE 802.11 link or a cellular link. The processor 12 is configured to provide outputs to and receive inputs from the transceiver(s) 26.

The one or more transceivers 28 provide the apparatus 10 with the ability to communicate with the other devices, enabling it to potentially form part of a system of devices that communicate together and/or part of a cloud-based health platform/service.

The display 28 is configured to display information to a wearer/user of the apparatus 10. The display 28 may, for example, be a liquid crystal display (LCD), an organic light emitting diode (OLED) display or a quantum dot (QD) display. The processor 12 is configured to control the display 28.

The user input circuitry 30 is configured to receive inputs from a user and provide corresponding inputs to the processor 12. The user input circuitry 30 may, for example, include mechanical input devices such as one or more keys or dials. At least part of

the user input circuitry 30 might be combined with the display 28 in the form of a touch sensitive display 32.

The processor(s) 12 is/are described as a single item for ease of explanation in this document, but in practice multiple processors may be provided. The processor 12 may be a single core or multi-core processor.

The processor 12 is configured to read from and write to the memory 14. The processor 12 may also comprise an output interface via which data and/or commands are output by the processor 12 and an input interface via which data and/or commands are input to the processor 12.

The memory 14 stores a computer program 16 comprising computer program instructions (computer program code) 18 that controls the operation of the apparatus 10 when loaded into the processor 12. The computer program instructions 18, of the computer program 16, provide the logic and routines that enables the apparatus to perform at least some aspects of the methods illustrated in figs 3 and 5. The processor 12 by reading the memory 14 is able to load and execute the computer program 16.

As illustrated in fig. 1, the computer program 16 may arrive at the apparatus 12 via any suitable delivery mechanism 40. The delivery mechanism 40 may be, for example, a non-transitory computer-readable storage medium, a computer program product, a memory device, a record medium such as a compact disc read-only memory (CD-ROM) or digital versatile disc (DVD), an article of manufacture that tangibly embodies the computer program 16. The delivery mechanism may be a signal configured to reliably transfer the computer program 16. The apparatus 10 may propagate or transmit the computer program 16 as a computer data signal.

Although the memory 14 is illustrated as a single component/circuitry it may be implemented as one or more separate components/circuitry some or all of which may be integrated/removable and/or may provide permanent/semi-permanent/ dynamic/cached storage.

The elements 12, 14, 20, 22, 24, 26, 28 and 30 are operationally coupled and any number or combination of intervening elements can exist (including no intervening

elements). In the illustrated example, each of the elements 12, 14, 20, 22, 24, 26, 28 and 30 is housed at least partially within a housing 34.

Fig. 2 illustrates a schematic of the apparatus 10 being worn by a person. The apparatus 10 has been positioned adjacent to a surface 71 of skin tissue 70. In some examples, the apparatus 10 may include a band which holds the apparatus 10 in place against the surface 71 of the skin tissue 70. In other examples, the apparatus 10 might, for instance, be adhered in place on the surface 71 of the skin tissue 70.

In the fig. 2 example, the display 28 is positioned on an outer surface of the apparatus 10 of the wearer, such that it can be viewed in use. A battery 29 is also present, which is positioned between the processor 12 and the display 28 in this example. Other electronics, such as an analogue to digital converter, may be positioned adjacent the processor 12.

The actuator 22 can be seen in fig. 2 positioned adjacent to, and in contact with, the surface 71 of the skin tissue 70. In this example, the actuator 22 is an electro-active polymer pump which comprises a membrane 63, electrodes 61 and at least one resilient member/spring 65. The membrane 63 is formed from an electro-active polymer. The spring 65 is configured to urge the membrane 63 away from the surface 71 of the skin tissue 70.

In this example, the spring 65 is located in a central position on one surface/face of the membrane 63 and the electrodes 61 may be ring-shaped electrodes which surround the spring 65 on that surface. Electrodes 63 are also positioned on the other surface/face of the membrane 63.

The apparatus 10 is configured to sealingly attach to the surface 71 of the skin tissue 70, around a perimeter which surrounds the membrane 63. Fig. 2 illustrates a situation in which the processor 12 is not causing an electric signal to be applied to the electrodes 61 (that is, the actuator 22 is in its non-actuated state).

As explained above in relation to Fig. 1, the elements 12, 14, 20, 22, 24, 26, 28 and 30 are housed at least partially within a housing 34. The housing 34 defines an internal cavity 35 which enables the membrane 63 to move within the housing 34 when the actuator 22 is actuated. This is explained in further detail below.

The apparatus 10 illustrated in Fig. 2 includes at least one light source 20 and at least one light sensor 24 located in a first position 55 (on the membrane 63) and at least one light source 20 and at least one light sensor 24 located in a second position 56 (on the membrane 63). The first and second positions 55, 56 are different. In fig. 2, each of the light sources 20 and light sensors 24 is located on the same surface of the membrane 63, adjacent to the electrodes 63. The electrodes 63 and at least some or all of the light sources 20 and light sensors 24 may be formed in the same integrated circuit.

Fig. 3 illustrates a flow chart according to a method according to embodiments of the invention. Initially, the apparatus 10 is applied to the surface 71 of the skin tissue 70 as illustrated in fig. 2. Subsequently, at block 301 in fig. 3, the processor 12 controls the actuator 22 to lift the surface 71 of the skin tissue 70 in order to create an optical path through the skin tissue 70 from a light source 20 to a light sensor 24, for transmissive photoplethysmography. That is, the processor 12 causes actuation of the actuator 22 which in turn causes the lifting of the surface 71 of the skin tissue 70.

Fig. 4 illustrates the actuator 22 in its actuated state. In actuating the actuator 22, the processor 12 causes an electrical signal to be applied to the electrodes 61 which creates an electrostatic force between the electrodes 61 on opposing faces of the membrane 63, bringing them closer together and squeezing the membrane 63. This causes the membrane 63 to expand in dimensions that are perpendicular to the applied electric field and weakens the membrane 63. The membrane 63 then deforms under the force applied by the spring 65. The internal cavity 35 in the housing 34 provides a volume into which the membrane 63 can move, as illustrated in fig. 4.

The apparatus 10 is sealingly attached to the surface 71 of the skin tissue 70, around a perimeter which surrounds the membrane 63. Movement of the membrane 63 provides a suction effect, in which pressure/a force is applied to the surface 71 of the skin tissue 70 that causes the surface 71 of the skin tissue 70 to lift, as illustrated schematically in Fig. 4. The magnitude of the contact pressure/force applied to the surface 71 of the skin tissue 70 depends upon the extent to which the membrane 63 is deformed, which in turn depends upon the electrical signal applied to the electrodes 61. The processor 12 is therefore able to adjust the magnitude of the applied contact pressure by appropriately controlling the electrical signal that is applied to the

electrodes 61. The electrical signal that is applied to the electrodes 61 at an instance in time determines the position (the extent of deformation) of the membrane 63. If the processor 12 causes the application of an electrical signal to the electrodes 61 to cease, the actuator 22 returns to its non-actuated state, as illustrated in Fig. 2.

It will be recognized by those skilled in the art that the term "lift" (as used in this document) does not necessarily refer to movement in a vertical dimension defined by the direction of the force of gravity, although it may do. It refers to the outwards movement of the surface 71 of the skin tissue 70 from its original, natural position.

After the surface 71 of the skin tissue 70 has been lifted, transmissive photoplethysmography is performed by the apparatus 10 at block 302 in fig. 3 while the actuator 22 is in its actuated state using the newly created optical path(s) through the skin tissue 70. This may involve performing pulse oximetry. The processor 12 may, for example, perform blood flow analysis (such as capillary blood circulation analysis) by analysing the light signals sensed by the light sensors 24 to determine (quantify) at least one physiological parameter such as heart rate (HR), heart rate variability (HRV) and/or peripheral capillary oxygen saturation (SpO_2). Alternatively or additionally, the processor 12 may perform tissue analysis related to tissue flexibility, collagen, etc. using the light signals sensed by the light sensors 24.

The processor 12 may cause the determined physiological parameter(s) may be transmitted to another apparatus by controlling one or more of the transceivers 26 to transmit an appropriate signal to the other apparatus.

When the actuator 22 is in its actuated state, light emitted by the light source 20 located in the first position 55 travels along a new optical path through the skin tissue 70 that was created by movement of the membrane 63 and the surface 71 of the skin tissue 70, and is sensed by the light sensor 24 at the second position 56. The new optical path may also be created, at least in part, by a change in orientation of the light source 20 located in the first position 55 and/or a change in orientation of the light sensor 24 located in the second position 56 due to movement of the membrane 63 on which they reside.

Light emitted by the light source 20 located in the second position 56 travels along a new optical path through the skin tissue 70 that was created by movement of the

membrane 63 and the surface 71 of the skin tissue 70, and is sensed by the light sensor 24 at the first position 55. The new optical path may also be created, at least in part, by a change in orientation of the light source 20 located in the second position 56 and/or a change in orientation of the light sensor 24 located in the first position 55 due to movement of the membrane 63 on which they reside.

The emission of light from the light source 20 located in the first position 55 is illustrated schematically by the arrow 53 in fig. 4. The emission of light from the light source 20 located in the second position 56 is illustrated schematically by the arrow 53 in fig. 4.

It will be apparent to those skilled in the art that it is not necessary for the apparatus 10 to comprise multiple light sources 20 and multiple light sensors 24 in order to perform transmissive photoplethysmography (and pulse oximetry) in the manner described above in relation to fig. 3. A potential benefit of having multiple light sources 20 and multiple light sensors 24 will be described below in relation to fig. 5.

The processor 12 analyses light signals emitted by the light sources 20 and sensed by the light sensors 24. The processor 12 may control the actuator 22 based, at least in part, on an analysis of the sensed light signals. The contact pressure applied to the surface 71 of the skin tissue 70 may have an effect on the quality of the light signal that is sensed by the light sensor(s) 24, and, by controlling the actuator 22 to adjust the contact pressure, the quality of the light signal being sensed can be optimised. The processor 12 may control the actuator 22 to optimise the sensed light signal in accordance with one or more quality metrics which might include, for instance, signal-to-noise ratio, amplitude and/or intensity.

The processor 12 may therefore operate in accordance with a feedback loop in which the light signal sensed by the light sensor(s) 24 is analysed over a period of time and the contact pressure applied to surface 71 of the skin tissue 70 is adjusted (increased and/or decreased) over that over of time to obtain an optimal reading. It has been found empirically that the application of a contact pressure increases the amplitude of the sensed light signal up to a given contact pressure, but further increases in the contact pressure can then cause the amplitude of the sensed light signal to decrease.

In some implementations, the apparatus 10 may further comprise a sensor for sensing the contact pressure/force applied to the surface 71 of the skin tissue 70 by the actuator

22. The sensor may, for example, be a strain gauge. The processor 12 may, for instance, obtain a reading from the sensor each time the contact pressure applied by the actuator 22 is changed (or increased). If the reading is indicative of the contact pressure/force exceeding a threshold, the processor 12 may control the actuator 22 to reduce the contact pressure in order to reduce or eliminate possible wearer discomfort.

If the light signal sensed by the light sensors 24 is weak (for instance, it has a property, such as amplitude or intensity, which is below a predetermined threshold), and the processor 12 has tried to optimise the sensed light signal in accordance with a quality metric, the processor 12 may control the one or more of the transceivers 26 to transmit an alert signal to another apparatus (such as a remote server, or a computer or a mobile device/telephone).

Fig. 5 illustrates a second flow chart of a method according to embodiments of the invention. The method illustrated in fig. 5 differs from that illustrated in fig. 3 in that at block 501 in fig. 5, the apparatus 10 operates in reflective photoplethysmography mode and performs reflective photoplethysmography. This may involve performing pulse oximetry. The processor 12 may, for example, analyse the light signals sensed by the light sensors 24 to determine (quantify) at least one physiological parameter such as heart rate (HR), heart rate variability (HRV) and/or peripheral capillary oxygen saturation (SpO_2).

As previously explained, fig. 2 illustrates a situation in which the apparatus 10 has been applied to the surface 71 of skin tissue 70 and the actuator 22 is in its non-actuated state, without any lifting of the surface 71 of the skin tissue 70. In order to perform reflective photoplethysmography, the processor 12 may control the light sources 20 to emit light, which is then reflected back to the light sensors 24 by the skin tissue 70.

Light emitted by the light source 20 at the first position 55 is reflected by the skin tissue 70 and sensed by the light sensor 24 at the first position 55, as illustrated by the arrows labelled with the reference numeral 51 in fig. 2. Light emitted by the light source 20 at the second position 56 is reflected by the skin tissue 70 and sensed by the light sensor 24 at the second position 56, as illustrated by the arrows labelled with the reference numeral 52 in fig. 2.

It may be quicker to make an initial measurement of a physiological parameter using reflective photoplethysmography and then switch to transmissive photoplethysmography, rather than begin using transmissive photoplethysmography.

At block 502 in fig. 5, processor 12 switches the apparatus 10 from operating in reflective photoplethysmography mode to operating in transmissive photoplethysmography mode and controls the actuator 22 to lift the surface 71 of the skin tissue 70 in order to create an optical path through the skin tissue 70 from a light source 20 to a light sensor 24 for transmissive photoplethysmography. This is done in the same manner as that described above in relation to block 301 in fig. 3.

In block 503 in fig. 5, transmissive photoplethysmography is performed in the manner described above in relation to block 302 in fig. 3.

In implementations having light sources 20 and light sensors 24 located at different positions (such as that described above where a light source 20 and a light sensor 24 are located at the first position 55 and a light source 20 and a light sensor 24 are located at the second position 56) light signals emitted by different light sources 20 may have different characteristics. For example, light emitted by the light source 20 in the first position 55 may be of a first wavelength (for example, green light) and light emitted by the light source 20 in the second position may be of a second, different, wavelength (for example red light). The light sensors 24 may be sensitive to (at least) both of those wavelengths of light. Alternatively or additionally, light emitted by the light source 20 in the first position 55 may be modulated differently from light emitted by the light source 20 in the second position.

This enables the processor 12 to determine whether reflective photoplethysmography or transmissive photoplethysmography is being performed. For example, if the processor 12 determines that the light sensor 24 located in the first position 55 is sensing light emitted by the light source 20 in the first position 55, it may determine that reflective photoplethysmography is being performed. If the processor 12 determines (alternatively or additionally) that the light sensor 24 located in the first position 55 is sensing light emitted by the light source 20 in the second position 56, it may determine that transmissive photoplethysmography is being performed. Sensed light emitted from different light sources 20 may be processed separately by the

processor 12. In some implementations, the results of the separate processing may be combined (for example, to produce an average).

Machine learning may be employed by the processor 12 to determine whether reflective photoplethysmography or transmissive photoplethysmography provides better (for instance, more accurate or reliable) readings in particular circumstances and the processes performed by the processor 12 when obtaining readings may be adjusted accordingly.

A technical effect of embodiments of the invention described above is that both reflective photoplethysmography and transmissive photoplethysmography can be performed using the apparatus 10. Furthermore, the apparatus 10 can switch between performing reflective photoplethysmography and transmissive photoplethysmography without having to be repositioned to a different location on the wearer's body. It may also be possible to perform reflective photoplethysmography and transmissive photoplethysmography simultaneously.

References to 'computer-readable storage medium' or a 'computer', 'processor' etc. should be understood to encompass not only computers having different architectures such as single/multi-processor architectures and sequential (Von Neumann)/parallel architectures but also specialized circuits such as field-programmable gate arrays (FPGA), application specific circuits (ASIC), signal processing devices and other processing circuitry. References to computer program, instructions, code etc. should be understood to encompass software for a programmable processor or firmware such as, for example, the programmable content of a hardware device whether instructions for a processor, or configuration settings for a fixed-function device, gate array or programmable logic device etc.

As used in this application, the term 'circuitry' refers to all of the following:
(a) hardware-only circuit implementations (such as implementations in only analog and/or digital circuitry) and
(b) to combinations of circuits and software (and/or firmware), such as (as applicable): (i) to a combination of processor(s) or (ii) to portions of processor(s)/software (including digital signal processor(s)), software, and memory(ies) that work together to cause an apparatus, such as a mobile phone or server, to perform various functions and

(c) to circuits, such as a microprocessor(s) or a portion of a microprocessor(s), that require software or firmware for operation, even if the software or firmware is not physically present.

This definition of 'circuitry' applies to all uses of this term in this application, including in any claims. As a further example, as used in this application, the term "circuitry" would also cover an implementation of merely a processor (or multiple processors) or portion of a processor and its (or their) accompanying software and/or firmware. The term "circuitry" would also cover, for example and if applicable to the particular claim element, a baseband integrated circuit or applications processor integrated circuit for a mobile phone or a similar integrated circuit in a server, a cellular network device, or other network device.

At least some of the blocks illustrated in figs 3 and 5 may represent steps in a method and/or sections of code in the computer program 16. The illustration of a particular order to the blocks does not necessarily imply that there is a required or preferred order for the blocks and the order and arrangement of the block may be varied. Furthermore, it may be possible for some blocks to be omitted.

Where a structural feature has been described, it may be replaced by means for performing one or more of the functions of the structural feature whether that function or those functions are explicitly or implicitly described.

Although embodiments of the present invention have been described in the preceding paragraphs with reference to various examples, it should be appreciated that modifications to the examples given can be made without departing from the scope of the invention as claimed. For example, the (relative) positioning of the elements 20, 22, 24, 28, 29, 34, 35, 61, 63, 65 of the apparatus 10 might not necessarily be the same as that illustrated in figs 2 and 4.

In the embodiments described above, at least one resilient member/spring 65 is provided to urge the membrane 63 away from the surface 71 of the skin tissue 70. In other embodiments, it may be possible to use an alternative biasing mechanism/member, such as a mere mass, depending on the orientation of the membrane 63 in use.

Features described in the preceding description may be used in combinations other than the combinations explicitly described.

Although functions have been described with reference to certain features, those functions may be performable by other features whether described or not.

Although features have been described with reference to certain embodiments, those features may also be present in other embodiments whether described or not.

Whilst endeavoring in the foregoing specification to draw attention to those features of the invention believed to be of particular importance it should be understood that the applicant claims protection in respect of any patentable feature or combination of features hereinbefore referred to and/or shown in the drawings whether or not particular emphasis has been placed thereon.

I/we claim:

CLAIMS

1. An apparatus, comprising:
a photoplethysmography light source;
a photoplethysmography light sensor configured to sense light signals emitted by the photoplethysmography light source; and
an actuator configured to lift a surface of skin tissue in order to create an optical path through the skin from the photoplethysmography light source to the photoplethysmography light sensor, for transmissive photoplethysmography.

2. The apparatus of claim 1, further comprising at least one processor configured to analyse light signals emitted by the photoplethysmography light sensor and sensed by the photoplethysmography light sensor.

3. The apparatus of claim 2, wherein the at least one processor is configured to control the actuator based at least in part on an analysis of the sensed light signals.

4. The apparatus of claim 1, 2 or 3, further comprising: a further photoplethysmography light sensor positioned to sense light signals emitted by the photoplethysmography light source and reflected from the skin tissue, for reflective photoplethysmography.

5. The apparatus of claim 4, wherein the further photoplethysmography light sensor is positioned, when the apparatus is positioned adjacent the surface of the skin tissue, to sense light signals emitted by the photoplethysmography light source and reflected from the skin tissue and without any lifting of the skin surface by the actuator.

6. The apparatus of claim 4 or 5, when dependent upon claim 2, wherein the at least one processor is configured to analyse light signals emitted by the photoplethysmography light sensor and sensed by the photoplethysmography light sensor when operating in a transmissive photoplethysmography mode, and configured to analyse light signals emitted by the photoplethysmography light source and sensed by the further photoplethysmography light sensor when operating in a reflective photoplethysmography mode.

7. The apparatus of any of the preceding claims, wherein the actuator comprises a membrane.

8. The apparatus of any of the preceding claims, wherein the apparatus is configured to sealingly attach to the surface of the skin tissue.

9. The apparatus of claim 7 or 8, further comprising a spring configured to urge the membrane away from the surface of the skin tissue.

10. The apparatus of any of the preceding claims, further comprising a housing defining an internal cavity for enabling the membrane to move in order to lift the surface of the skin tissue.

11. The apparatus of any of the preceding claims, further comprising a sensor for sensing pressure applied to the surface of the skin tissue by the actuator.

12. The apparatus of any of the preceding claims, wherein the actuator is an electro-active polymer pump.

13. The apparatus of any of the preceding claims, wherein the apparatus is a wearable device.

14. A method, comprising:
controlling lifting a surface of skin tissue in order to create an optical path through the skin tissue from a photoplethysmography light source to a photoplethysmography light sensor, for transmissive photoplethysmography.

15. A computer program comprising computer program instructions that, when performed by the at least one processor, cause the method of claim 14 to be performed.

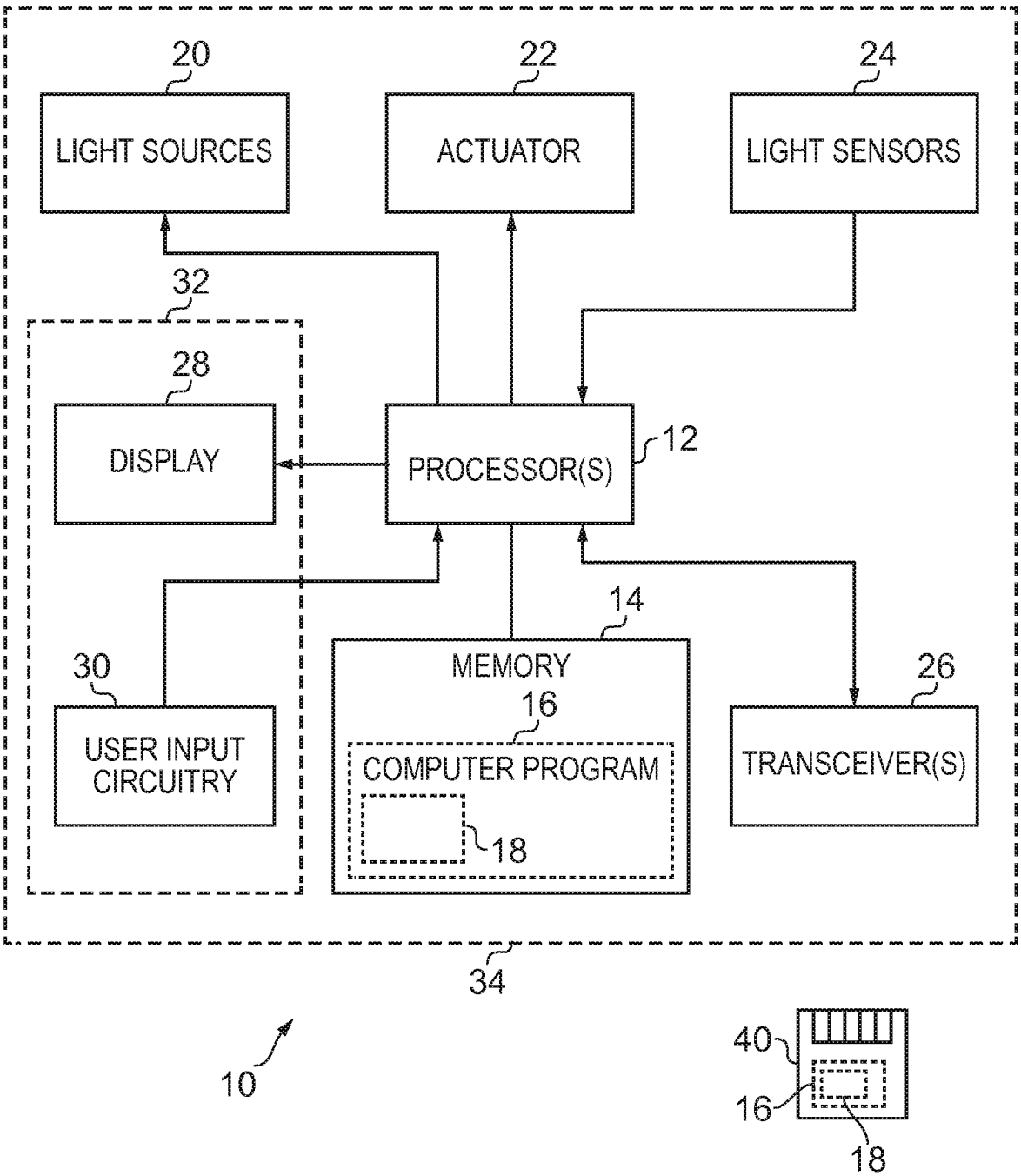

20
LIGHT SOURCES
22
ACTUATOR
24
LIGHT SENSORS
32
28
DISPLAY
PROCESSOR(S)
12
14
MEMORY
16
COMPUTER PROGRAM
18
30
USER INPUT CIRCUITRY
26
TRANSCEIVER(S)
34
10
40
16
18

FIG. 1

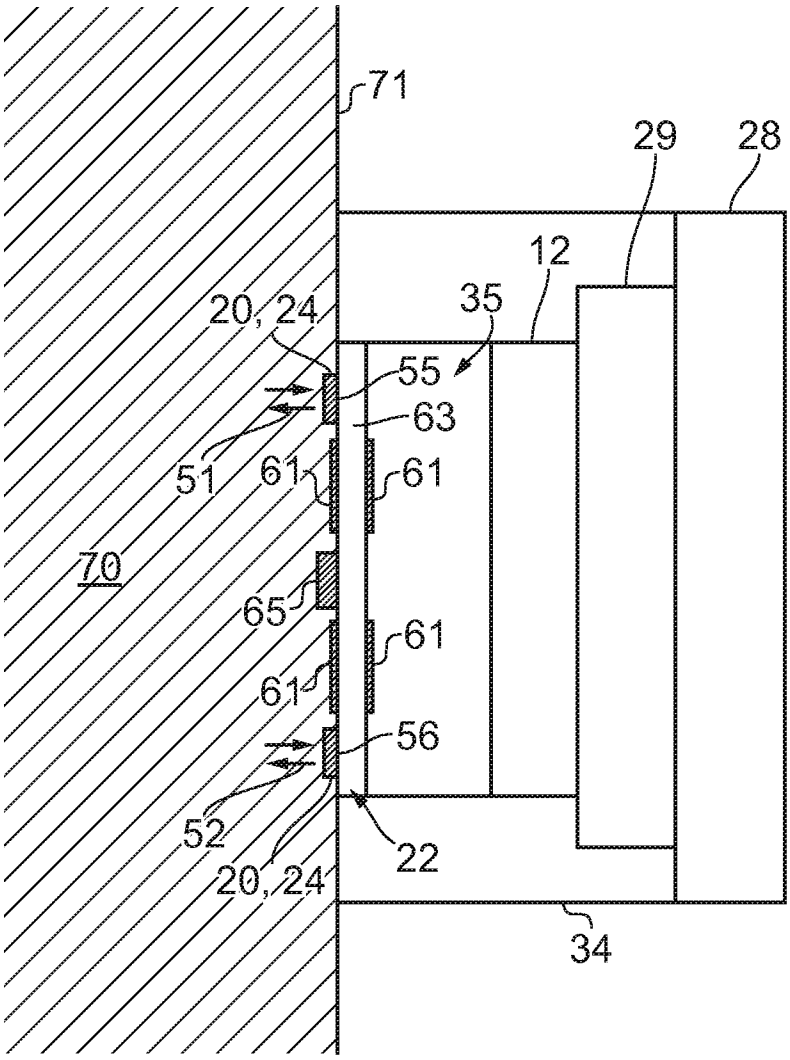


FIG. 2

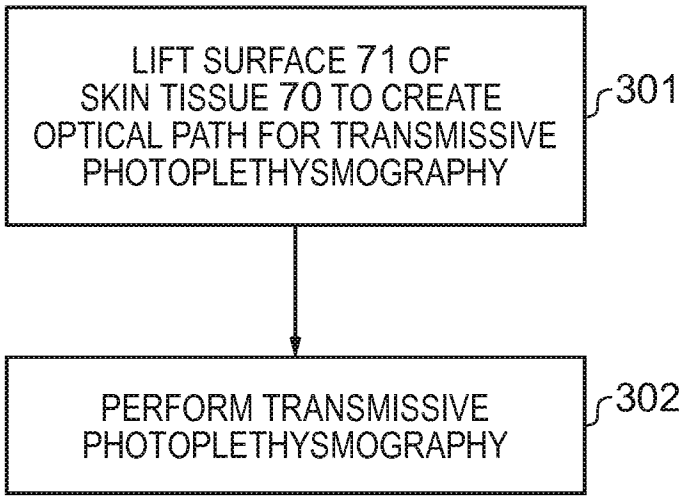

LIFT SURFACE 71 OF SKIN TISSUE 70 TO CREATE OPTICAL PATH FOR TRANSMISSIVE PHOTOPLETHYSMOGRAPHY
301
PERFORM TRANSMISSIVE PHOTOPLETHYSMOGRAPHY
302

FIG. 3

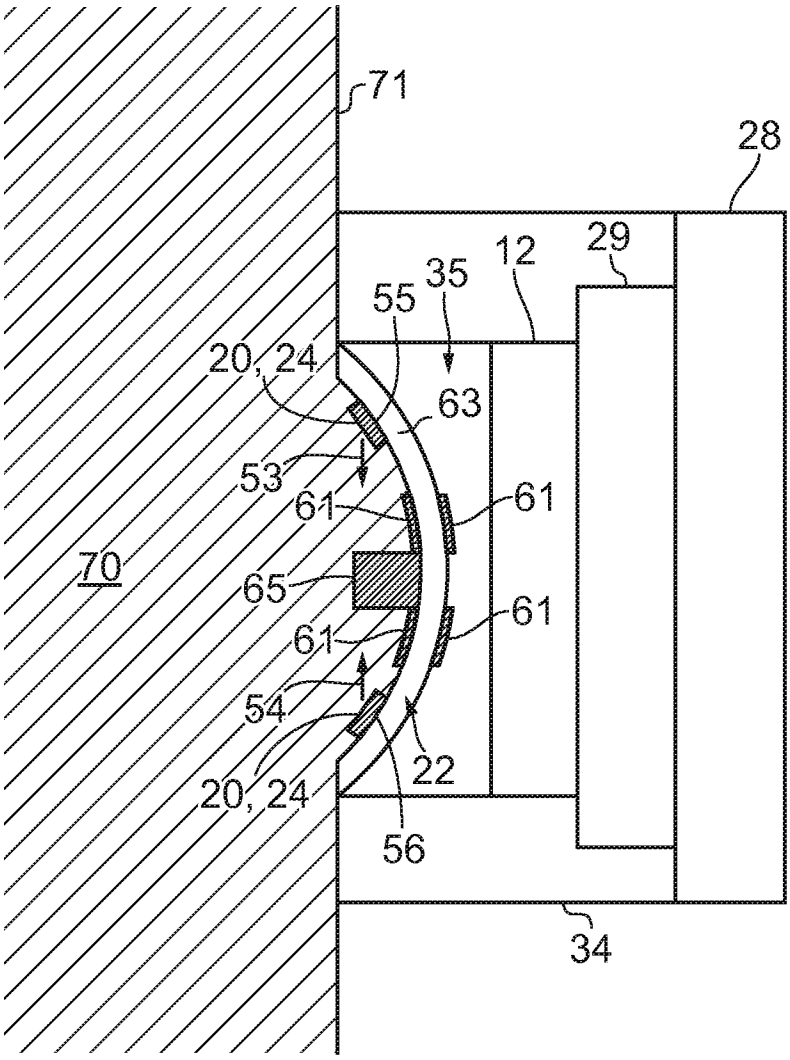


FIG. 4

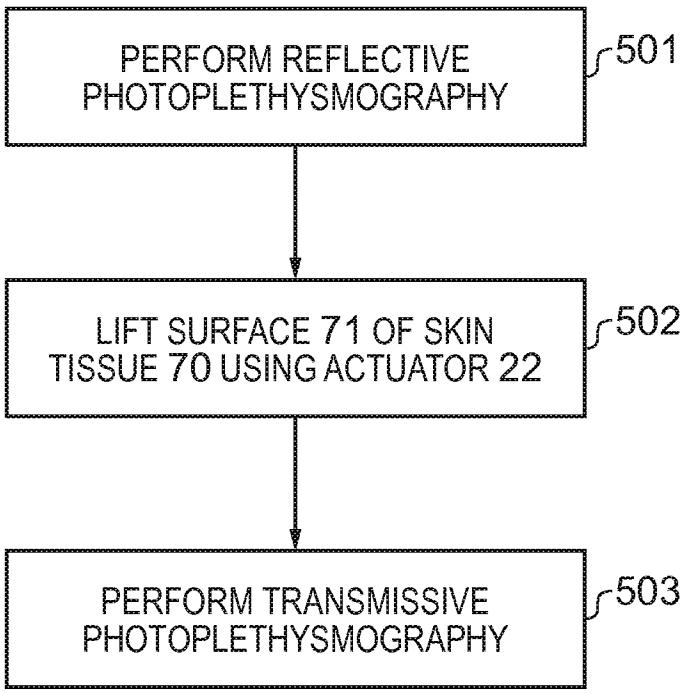

PERFORM REFLECTIVE PHOTOPLETHYSMOGRAPHY
501
LIFT SURFACE 71 OF SKIN TISSUE 70 USING ACTUATOR 22
502
PERFORM TRANSMISSIVE PHOTOPLETHYSMOGRAPHY
503

FIG. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2017/050702

A. **CLASSIFICATION OF SUBJECT MATTER**

See extra sheet

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)

IPC: A61B

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

FI, SE, NO, DK

Electronic data base consulted during the international search (name of data base, and, where practicable, search terms used)

EPODOC, WPIAP, EPO-Internal full-text databases, Google

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014058227 A1 (YAMANAKA MIKIHIRO [JP] et al.) 27 February 2014 (27.02.2014) D1 claim 14; paragraphs [0006], [0123] and [0218]; figures 1 and 4	1-15
A	US 6167290 A (YANG WEI [US] et al.) 26 December 2000 (26.12.2000)	
A	WO 2009141755 A1 (KONINKL PHILIPS ELECTRONICS NV [NL]) 26 November 2009 (26.11.2009)	
A	WO 2007015255 A2 (DUNE MEDICAL DEVICES LTD [IL]) 08 February 2007 (08.02.2007)	
P, A	US 2017119290 A1 (CAI LUJING [US] et al.) 04 May 2017 (04.05.2017)	

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

* Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

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

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
03 January 2018 (03.01.2018)	08 January 2018 (08.01.2018)

Name and mailing address of the ISA/FI
Finnish Patent and Registration Office
FI-00091 PRH, FINLAND
Facsimile No. +358 29 509 5328

Authorized officer
Jesper Lundbom
Telephone No. +358 29 509 5000

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2017/050702

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
US 2014058227 A1	27/02/2014	JP 2012247269 A	13/12/2012
		JP 5203488 B2	05/06/2013
		WO 2012160893 A1	29/11/2012
US 6167290 A	26/12/2000	None	
WO 2009141755 A1	26/11/2009	None	
WO 2007015255 A2	08/02/2007	AT 387141 T	15/03/2008
		AU 2002360209 A1	30/07/2003
		CA 2533161 A1	03/02/2005
		CA 2533161 C	23/04/2013
		CA 2594427 A1	13/07/2006
		CA 2603025 A1	05/10/2006
		CA 2603025 C	20/05/2014
		CA 2616962 A1	08/02/2007
		CN 1852678 A	25/10/2006
		CN 100473336 C	01/04/2009
		CN 101184435 A	21/05/2008
		CN 101184435 B	15/12/2010
		CN 101252878 A	27/08/2008
		CN 101252878 B	05/06/2013
		CN 101437455 A	20/05/2009
		CN 101437455 B	13/03/2013
		CN 101606158 A	16/12/2009
		CN 101606158 B	02/04/2014
		CN 101991415 A	30/03/2011
		CN 101991415 B	10/04/2013
		CN 103271718 A	04/09/2013
		CN 103271718 B	07/07/2017
		CN 103330545 A	02/10/2013
		DE 02795418 T1	23/06/2005
		DE 60225336 D1	10/04/2008
		DE 60225336 T2	26/02/2009
		EP 1460936 A2	29/09/2004
		EP 1460936 B1	27/02/2008
		EP 1653852 A2	10/05/2006
		EP 1740102 A2	10/01/2007
		EP 1843696 A2	17/10/2007
		EP 1890596 A2	27/02/2008
		EP 1890596 B1	02/10/2013
		EP 1919273 A2	14/05/2008
		EP 2118801 A2	18/11/2009

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2017/050702

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
		EP 2152153 A1	17/02/2010
		EP 2152153 B1	02/09/2015
		EP 2418599 A2	15/02/2012
		ES 2302865 T3	01/08/2008
		ES 2434851 T3	17/12/2013
		ES 2550478 T3	10/11/2015
		HK 1069967 A1	18/07/2008
		IL 173231 D0	11/06/2006
		IL 173231 A	30/11/2010
		JP 2005514996 A	26/05/2005
		JP 4271581 B2	03/06/2009
		JP 2007507245 A	29/03/2007
		JP 4777886 B2	21/09/2011
		JP 2009501898 A	22/01/2009
		JP 5308812 B2	09/10/2013
		JP 2010512221 A	22/04/2010
		JP 5620108 B2	05/11/2014
		JP 2013031668 A	14/02/2013
		JP 6054106 B2	27/12/2016
		JP 2008526347 A	24/07/2008
		JP 2009508539 A	05/03/2009
		US 2003187366 A1	02/10/2003
		US 6813515 B2	02/11/2004
		US 2005021019 A1	27/01/2005
		US 7082325 B2	25/07/2006
		US 2005107718 A1	19/05/2005
		US 7184824 B2	27/02/2007
		US 2003138378 A1	24/07/2003
		US 7505811 B2	17/03/2009
		US 2006253107 A1	09/11/2006
		US 7720532 B2	18/05/2010
		US 2006264738 A1	23/11/2006
		US 7809425 B2	05/10/2010
		US 2009062637 A1	05/03/2009
		US 7899515 B2	01/03/2011
		US 2008039742 A1	14/02/2008
		US 7904145 B2	08/03/2011
		US 2007179397 A1	02/08/2007
		US 8019411 B2	13/09/2011
		US 2008021343 A1	24/01/2008
		US 8032211 B2	04/10/2011
		US 2007032747 A1	08/02/2007
		US 8116845 B2	14/02/2012
		US 2007260156 A1	08/11/2007
		US 8195282 B2	05/06/2012
		US 2007032739 A1	08/02/2007
		US 8721565 B2	13/05/2014

INTERNATIONAL SEARCH REPORT
Information on Patent Family Members

International application No.
PCT/FI2017/050702

Patent document cited in search report	Publication date	Patent family members(s)	Publication date
		US 2012238867 A1	20/09/2012
		US 9226979 B2	05/01/2016
		US 2012123244 A1	17/05/2012
		US 9526460 B2	27/12/2016
		US 2009253978 A1	08/10/2009
		US 9750425 B2	05/09/2017
		US 2007255169 A1	01/11/2007
		US 2008154090 A1	26/06/2008
		US 2008287750 A1	20/11/2008
		US 2009187109 A1	23/07/2009
		US 2010222647 A1	02/09/2010
		WO 03060462 A2	24/07/2003
		WO 2005009200 A2	03/02/2005
		WO 2005089065 A2	29/09/2005
		WO 2006072947 A2	13/07/2006
		WO 2006103665 A2	05/10/2006
		WO 2007083310 A2	26/07/2007
		WO 2008072238 A2	19/06/2008
		WO 2008132714 A2	06/11/2008
		WO 2008132750 A1	06/11/2008
US 2017119290 A1	04/05/2017	None	

INTERNATIONAL SEARCH REPORT

International application No.
PCT/FI2017/050702

CLASSIFICATION OF SUBJECT MATTER

IPC
A61B 5/024 (2006.01)
A61B 5/00 (2006.01)
A61B 5/1455 (2006.01)