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(54) **GAIT DETECTION METHOD AND APPARATUS**

VERFAHREN UND VORRICHTUNG ZUR ERKENNUNG VON GÄNGEN

PROCÉDÉ ET APPAREIL DE DÉTECTION DE DÉMARCHE

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(73) Proprietor: **Nordic-Neurostim ApS**
9220 Aalborg Øst (DK)

(72) Inventors:
- **HENNINGS, Kristian**
  9200 Aalborg SV (DK)
- **HANSEN, Morten**
  9280 Storvorde (DK)

(74) Representative: **AWA Sweden AB**
P.O. Box 5117
200 71 Malmö (SE)

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Description

Technical Field

[0001] The present invention relates to a method and a device for use in gait rehabilitation for detecting a foot being lifted.

Background

[0002] A patient suffering from deteriorated ability to walk is severely affected by such a condition. The inability to walk may for instance be caused by a disease or trauma to the central nervous system, such as stroke, spinal cord injury, and multiple sclerosis.

[0003] For such patients, gait rehabilitation is an important step to improve quality of life of the patient. Gait rehabilitation may involve providing the patient with an electrical stimulation, which may induce a withdrawal reflex activating nerves of the patient to cause a muscle contraction such that a foot is lifted. Electrical stimulation may thus be used in training for restore ability of the patient to send nerve signals for lifting the foot.

[0004] There are known methods of providing electrical stimulation for providing a patient with an improved gait. For instance, in US 8,788,049 a gait modulation system is disclosed comprising a sensor for transducing at least one parameter related to gait of the patient and a muscle stimulator for performing functional electrical stimulation of at least one muscle of the lower limb. The system may be used constantly, such that the system helps the patient to properly walk. However, this also implies that the system needs to be able to determine when a patient is not walking, such that unintended stimulations are not provided.

[0005] US 2013/0096466 discloses a sensor system and method configured to take multiple channels of sensors, and based on context and user behavior reflected in the signals, identifies specified channels for sensing according to a sensing policy. The sensing policy is used to reduce the amount of data sampled, such that it is possible to reconstruct the values of the non sampled sensors efficiently. The sensing policy is influenced by user and system's behavior and can be assigned either offline or in real time.

[0006] US 2015/0080979 discloses a gait modulation system including: (a) a sensor device including a sensor adapted for associating with at least one lower limb of the patient, the sensor for transducing at least one parameter related to a gait of the patient, so as to obtain gait data related to the gait, and (b) a muscle stimulator including: (i) an electrical stimulation circuit, the circuit adapted to supply an electrical stimulation output to an electrode array for performing functional electrical stimulation of at least one muscle of the lower limb, and (ii) a microprocessor, operatively connected to the at least one sensor, the microprocessor adapted for: receiving a stream of gait information based on the gait data; processing the gait information, and controlling the stimulation output based on the processing of the gait information, and wherein the microprocessor is further adapted to identify a failure in the stream of gait information, and to consequently control the electrical stimulation circuit to deliver a fail-safe stimulation output over a portion of a duration of the failure.

Summary of the Invention

[0007] It is an object of the invention to provide simple and reliable detection of a foot being lifted. The detection may thus e.g. be used for timing of electrical stimulation or for analysis of the gait of a patient.

[0008] These and other objects of the invention are at least partly met by the invention as defined in the independent claims. Preferred embodiments are set out in the dependent claims.

[0009] According to a first aspect of the invention, there is provided a method in gait rehabilitation for detecting a foot being lifted, said method comprising: continuously receiving a plurality of signals from respective pressure sensors, which are mounted beneath a foot of a person in order to record a pressure asserted by the person against ground when walking, each signal providing a time sequence of values representing asserted pressure on the respective pressure sensor; processing the received plurality of signals, wherein said processing comprises, for each signal, assigning states to the respective pressure sensor for determining when the foot is being lifted for walking, and wherein said assigning of states comprises: comparing the values representing asserted pressure to an upper threshold and identifying a value above the upper threshold, upon identifying a value being above the upper threshold, comparing the sequence of values to the upper threshold and determining a duration during which the sequence of values are continuously above the upper threshold; comparing the determined duration to a time threshold and identifying that the sequence of values are maintained above the upper threshold for a duration exceeding the time threshold; and upon identifying a duration exceeding the time threshold assigning a prepared state to the sensor; and when the sensor is in the prepared state, comparing the sequence of values to a lower threshold and identifying a value below the lower threshold providing an indication that the foot is potentially lifted; and upon identifying a value below the lower threshold assigning an unprepared state to the sensor.

[0010] Thanks to the invention, the lifting of a foot may be detected by relatively simple processing of recorded signals. The detection of lifting of a foot is not related to a periodicity of steps, such that each time a foot is lifted, it is individually detected.

[0011] Such detection may be especially advantageous in gait rehabilitation, wherein a training phase for teaching the patient to walk is utilized. The training phase may make use of powerful electrical stimulations for

causing the withdrawal reflex. Thus, the method in gait rehabilitation may not be used continuously, but rather during limited periods of training. Then, it may not be relevant to determine whether the foot is lifted for changing weight or whether the foot is lifted for walking.

[0012] By detecting that asserted pressure has been applied during a period of time and, then, detecting that asserted pressure decreases below a lower threshold, an indication that the foot is lifted is identified. Thus, a simple way of detecting that a foot is lifted is provided. The asserted pressure needs to be applied during a substantial period of time, in order for the sensor to be assigned a prepared state. Hence, a detection of the foot being lifted is not done when a pressure is briefly asserted, such as may occur when the patient is sitting.

[0013] According to an embodiment, said processing further comprises, when assigning an unprepared state to a first sensor, determining whether a prepared state is assigned to a second sensor and comparing a priority of the first sensor and the second sensor.

[0014] The invention according to this embodiment may enable the detection of a foot being lifted to be related to a position of the foot where pressure is asserted. This implies that a reliable detection of a foot being lifted may be performed even for patients that have trouble to lift the entire foot.

[0015] The priorities of the first and second sensors may thus be advantageously used for determining lifting of a foot for persons having impaired gait so as to enable use of the detection of a foot being lifted as input for stimulating gait. For instance, the priorities of the pressure sensors may be used for successfully detecting lifting of a foot for persons having a gait where the heel never touches the ground and for persons having a gait where the heel touches the ground, but the forefoot never leaves the ground.

[0016] According to a second aspect of the invention, there is provided a device for use in gait rehabilitation for detecting a foot being lifted, said device comprising: at least one input contact for continuously receiving a plurality of signals from respective pressure sensors, which are mounted beneath a foot of a person in order to record a pressure asserted by the person against ground when walking, each signal providing a time sequence of values representing asserted pressure on the respective pressure sensor; a processing unit, wherein said processing unit is configured to process the received plurality of signals, wherein said processing comprises, for each signal, assigning states to the respective pressure sensor for determining when the foot is being lifted for walking, and wherein said assigning of states comprises: comparing the values representing asserted pressure to an upper threshold and identifying a value above the upper threshold, upon identifying a value being above the upper threshold, comparing the sequence of values to the upper threshold and determining a duration during which the sequence of values are continuously above the upper threshold; comparing the determined duration to a time threshold and identifying that the sequence of values are maintained above the upper threshold for a duration exceeding the time threshold; and upon identifying a duration exceeding the time threshold assigning a prepared state to the sensor; and when the sensor is in the prepared state, comparing the sequence of values to a lower threshold and identifying a value below the lower threshold providing an indication that the foot is potentially lifted; and upon identifying a value below the lower threshold assigning an unprepared state to the sensor.

[0017] According to an embodiment, said processing further comprises, when assigning an unprepared state to a first sensor, determining whether a prepared state is assigned to a second sensor and comparing a priority of the first sensor and the second sensor.

[0018] The device according to the second aspect of the invention may be used for implementing the method according to the first aspect of the invention.

[0019] According to an embodiment of the method, said processing further comprises, when assigning an unprepared state to a first sensor, providing a trigger signal for stimulating gait of the person on a condition that no other sensor with a higher priority is in a prepared state.

[0020] Hence, the method may be used for timing of trigger signals for providing an electrical stimulation in gait rehabilitation. By means of the trigger signal only being provided on condition that no other sensor with a higher priority is in a prepared state, the method may ensure that the trigger signal is not falsely provided, when only an insignificant part of the foot is lifted.

[0021] However, it should be understood that the method may be used also for mere analysis of the gait, which may be used e.g. in designing a gait rehabilitation for the patient. Thus, the method may include merely detecting when a foot is lifted, which detection may then be used as data for performing an analysis of the gait.

[0022] According to an embodiment, said assigning of states further comprises assigning the unprepared state to all sensors, when a trigger signal is provided. This implies that when a first sensor having a high priority detects a foot being lifted to cause the trigger signal to be provided, a second sensor that may also be in a prepared state may not shortly thereafter cause another trigger signal to be provided by means of the pressure value of the second sensor also falling below the lower threshold.

[0023] According to an embodiment, said assigning of states further comprises, when the sensor is in the unprepared state and a value of the signal is below the lower threshold, maintaining the sensor in the unprepared state until a predetermined time period has lapsed and thereafter assigning a ready state to the sensor, wherein, after an unprepared state has been assigned to the sensor, said assigning of the prepared state to the sensor is only possible if the ready state has first been assigned to the sensor.

[0024] This implies that after a trigger signal has been

provided, a predetermined time period must lapse, before a sensor may be brought into the prepared state. Thus, two subsequent trigger signals may not be provided within an interval less than the predetermined time period.

[0025] According to an embodiment, the predetermined time period is at least 150 ms. The predetermined time period may be set to ensure that subsequent trigger signals may not be provided within an unrealistically small interval. For patients having relatively normal gait, the predetermined time period may be set to at least 150 ms.

[0026] However, the predetermined time period may be set to other values. For instance, if the method is to be used on a patient having severely impaired gait, the predetermined time period may be set to at least 400 ms, or even, 500 ms.

[0027] According to an embodiment, a priority of each of the sensors is pre-set in a processing unit for processing the received plurality of signals. Thus, the sensors may be set up to have appropriate priorities before gait rehabilitation is started. Such priorities may be provided on manufacture or installation of a system for use in gait rehabilitation.

[0028] According to another embodiment, the method further comprises, before receiving signals from the pressure sensors, receiving an indication of the priority of each of the sensors. Thus, the priority of the sensors may be set, e.g. when a patient is prepared for gait rehabilitation. This may for instance imply that a sensor may be freely positioned on a foot of the patient, and the priority of the sensor may be set depending on in what position on the foot the sensor was positioned.

[0029] According to an embodiment, the plurality of sensors include a heel sensor, adapted and intended for mounting on a heel of the person, a lateral forefoot sensor, adapted and intended for mounting on a lateral forefoot of the person, and a medial forefoot sensor, adapted and intended for mounting on a medial forefoot of the person.

[0030] According to an embodiment, the heel sensor is set to have the highest priority. The heel sensor may thus detect lifting of a foot even if the forefoot never leaves the ground in an impaired gait of a person.

[0031] According to an embodiment, the time threshold is at least 70 ms. This implies that a pressure needs to be asserted at least during 70 ms in order to allow a sensor to be assigned a prepared state.

[0032] The invention is defined by appended claims 1-11.

Brief Description of Drawings

[0033] The above, as well as additional objects, features and advantages of the present inventive concept, will be better understood through the following illustrative and non-limiting detailed description of preferred embodiments of the present invention, with reference to the appended drawings. In the drawings like reference numerals will be used for like elements unless stated otherwise.

Fig. 1 is a schematic view of a system for use in gait rehabilitation.

Fig. 2 is a schematic view of a control device in the system of Fig. 1.

Fig. 3 is a flow chart of a method for detecting a foot being lifted.

Fig. 4 is a chart illustrating a signal provided by a pressure sensor for detecting a foot being lifted.

Detailed Description

[0034] Detailed embodiments of the present invention will now be described with reference to the drawings.

[0035] Referring now to Fig. 1, a system 10 for use in gait rehabilitation will be first explained. The system 10 may be used by a caregiver, which may monitor and provide a treatment to a patient having an impaired gait.

[0036] The system 10 may comprise a plurality of pressure sensors 12. The pressure sensors 12 may be adapted to be mounted beneath a foot of the patient. The pressure sensors 12 may for instance be arranged to be attached to a foot sole of the patient, e.g. by having a sticky surface which may be applied to the foot sole.

[0037] According to an embodiment, a plurality of pressure sensor 12 may be arranged on a common carrier. The carrier may have a shape corresponding to a foot and may thus fit to be arranged as an insole in a shoe of the patient.

[0038] The pressure sensors 12 may be arranged to record a pressure asserted by the patient, when the pressure sensors 12 are mounted beneath the foot. Each pressure sensor 12 may thus be arranged to generate a sequence of pressure measurements.

[0039] Each pressure sensors 12 may further comprise a communication unit, such that the pressure sensor 12 may communicate the generated sequence of pressure measurements to an external unit.

[0040] The pressure sensor 12 may comprise a communication unit for wireless communication, such that the generated sequence of pressure measurements may be communicated wirelessly. For instance, the communication unit may be arranged to transmit radio frequency signals, e.g. using Bluetooth®.

[0041] According to an embodiment, the pressure sensor 12 may comprise a wired connection for communicating the generated sequence of pressure measurements. The plurality of pressure sensors 12 may be jointly connected such that the respective generated sequence of pressure measurements are communicated through a common wired connection.

[0042] As shown in more detail in Fig. 2, the system 10 may further comprise a control device 20. The control device 20 may be connected to the plurality of pressure sensors 12. Alternatively, the control device 20 may comprise an antenna for receiving wireless communication from the pressure sensors 12.

[0043] The generated sequences of pressure measurements may thus be received by at least one input contact 22 of the control device 20. The input contact 22 may thus receive a plurality of signals from the pressure sensors 12. Each signal may provide a time sequence of values representing asserted pressure on the respective pressure sensor 12.

[0044] The input contact 22 may further be connected to a processing unit 24 within the control device 20. The processing unit 24 may thus receive the plurality of signals and may process the signals. The signals may be processed for detecting a foot being lifted, as will be further explained below.

[0045] The processing unit 24 may be implemented as a microprocessor, which may be programmable for controlling operation of the microprocessor. For instance, the processing unit 24 may be a central processing unit (CPU). The processing unit 24 may alternatively be a special-purpose circuitry for providing only specific logical operations. Thus, the processing unit 24 may be provided in the form of an ASIC or FPGA.

[0046] The control device 20 may further comprise a non-volatile memory 26. The memory 26 may store application(s), which may be loaded into a working memory of the processing unit 24 for controlling the processing performed by the processing unit 24. The application(s) may for instance provide an algorithm for processing the received plurality of signals for determining when a foot is being lifted for walking.

[0047] The control device 20 may further be connected to an electrode (not shown) for providing electrical stimulation to the patient. The electrode may be attached to the patient, such that when an electrical pulse is provided through the electrode, the electrical pulse may induce a withdrawal reflex of the patient. For instance, the electrode may be arranged under the foot sole of the patient.

[0048] The processing unit 24 may be arranged to provide a trigger signal. The trigger signal may be sent to a pulse generating unit within the control device 20 for providing an electrical stimulation by the electrode. Alternatively, the pulse generating unit may be separate from the control device 20, and the trigger signal may be sent to the pulse generating unit through wired or wireless connection between the control device 20 and the pulse generating unit.

[0049] The control device 20 may be arranged in a housing containing electrical components of the control device 20. However, it should be realized that the control device 20 may be divided in a plurality of physical units.

[0050] The control device 20 may comprise a hook or any other attachment means arranged on an outer side of the housing such that the control device 20 may be attached to the patient or clothes of the patient during gait rehabilitation, or to a caregiver. For instance, the control device 20 may be suspended from a belt of the patient or the caregiver, or may be suspended around a neck of the patient or the caregiver.

[0051] The control device 20 may further provide a user interface, which allows input to the control device 20 for controlling functionality of the control device 20. For instance, the user interface may comprise buttons, switches and the like arranged on an outer side of the housing for allowing input to be made directly on the control device 20. Alternatively, the user interface may be provided as an application of an external unit, such as a mobile phone or computer, which may communicate with the control device 20.

[0052] A caregiver may input information to the control device 20 for controlling a rehabilitation program to be performed on a patient. The input may be parameters to the control device 20, such as an intensity of electrical stimulation to be provided or parameters for controlling a process of detecting a foot being lifted.

[0053] Referring now to Fig. 3, a method for detecting a foot being lifted will be explained. The method comprises continuously receiving, step 102, a plurality of signals from respective pressure sensors 12. Each signal provides a time sequence of values representing asserted pressure on the respective pressure sensor 12. In Fig. 4, such a signal from one pressure sensor 12 is shown and the method will be explained in relation to the signal shown in Fig. 4.

[0054] Firstly, an upper threshold 32 and a lower threshold 34 are defined. These thresholds 32, 34 may be pre-defined in the algorithm or may be set by a caregiver. The thresholds are used for detecting that a change in state may be occurring as further explained below.

[0055] A state is assigned to the sensor 12, in dependence of values representing the asserted pressure. The assigned state of the sensor 12 may be used for determining when a foot is lifted.

[0056] Initially, the sensor 12 is assigned a "Ready" state. In the "Ready" state, the values representing asserted pressure are compared, step 104, to the upper threshold 32.

[0057] When it is identified that the value is above the upper threshold, the sensor 12 is assigned a "Preparing" state. This implies that the patient is preparing to take a step, as the foot is pressed down. In the "Preparing" state, the sequence of values are compared to the upper threshold 32 to ensure that the asserted pressure is above the upper threshold 32 for a substantial time period.

[0058] A duration during which the sequence of values are continuously above the upper threshold 32 is thus compared to a time threshold 36, step 106. If the values fall below the upper threshold 32 too early, the sensor 12 is again assigned the "Ready" state. However, if the values are maintained above the upper threshold 32 for a duration exceeding the time threshold 36, the sensor 12 is assigned a "Prepared" state.

[0059] This implies that the patient has now asserted a substantial pressure for a substantial time and is prepared to lift the foot for walking.

[0060] In the "Prepared" state, the sequence of values

are compared to the lower threshold 34. When it is identified, step 108, that a value falls below the lower threshold 34, the identification may be used as an indication that the foot is potentially lifted. The sensor 12 is assigned an "Unprepared" state and is maintained in this state for a predetermined time period 38. Thereafter, the sensor 12 is again assigned the "Ready" state. The predetermined time period 38 is used to ensure that a certain time passes, before a new detection of the foot being lifted can be made. The sensor 12 can only be assigned the "Preparing" state from the "Ready" state.

[0061] In the above, the processing of a signal from a single pressure sensor 12 is described. However, the control device 20 receives signals from a plurality of sensors 12.

[0062] The plurality of sensors 12 may be provided with different priorities. This implies that the identification of an indication that the foot is potentially lifted based on a signal from a single pressure sensor 12 may be further analyzed in relation to states of other pressure sensors 12.

[0063] Thus, when a first sensor is assigned the "Unprepared" state, a determination is made, step 110, whether a second sensor is assigned a "Prepared" state. If so, the priorities of the first and the second sensors are compared, step 112.

[0064] If the second sensor has a higher priority, it is determined that the foot is not actually lifted. Rather, a large pressure is still asserted on a pressure sensor 12 having larger significance for the determination of the foot being lifted.

[0065] In an embodiment, three pressure sensors 12 may be used, including a heel sensor which is mounted on the heel, a lateral forefoot sensor which is mounted on the lateral forefoot and a medial forefoot sensor which is mounted on the medial forefoot.

[0066] The heel sensor may be assigned priority 2, whereas the lateral forefoot sensor and the medial forefoot sensor may be assigned priority 1.

[0067] This implies that if the heel sensor is in a "Prepared" state, the identification of an indication that the foot is potentially lifted based on the lateral forefoot sensor or the medial forefoot sensor is not given any weight. In such case, it is only when the heel of the patient is lifted that the detection of the foot being lifted for walking is made.

[0068] However, patients having impaired gait may not be able to bring the heel in contact with ground. Such patients may be walking merely with the forefoot in contact with ground. Thanks to the lateral forefoot sensor and medial forefoot sensor being used with a different priority than the heel sensor, these lateral forefoot and medial forefoot sensors may be used for detecting a patient with impaired gait lifting the foot for walking. Still the lateral forefoot and medial forefoot sensors may not trigger a detection of the foot being lifted for a patient using the heel in contact with ground during walking.

[0069] If a sensor 12 is brought to the "Unprepared" state and it is determined that no other sensor 12 is in the "Prepared" state or no sensor 12 with a higher priority is in the "Prepared" state, a detection that the foot is being lifted is made, step 114.

[0070] The detection that a foot is lifted may cause the processing unit 24 to provide a trigger signal for providing an electrical stimulation by the electrode. Thus, the patient may be provided with an electrical stimulation helping the patient to lift the foot for walking.

[0071] When it is detected that a foot is lifted, all sensors 12 are assigned the "Unprepared" state, regardless of their previous state, and maintained in this state for the predetermined time period 38. However, if the value representing asserted pressure is above the lower threshold 34, which may occur for a sensor 12 having lower priority than the sensor 12 causing detection of the foot being lifted, the sensor 12 is maintained in the "Unprepared" state as long as the values representing asserted pressure are above the lower threshold 34. When the value representing asserted pressure falls below the lower threshold 34, the predetermined time period 38 starts and the sensor 12 is maintained in the "Unprepared" state until the predetermined time period 38 has expired.

[0072] The time threshold 36 and the predetermined time period 38 may be pre-defined in the algorithm or may be set by a caregiver as parameters to be used for a session of gait rehabilitation.

[0073] The time threshold 36 should not be too short, such that a detection of lifting of a foot may be made due to the patient very briefly asserting a high pressure on a pressure sensor 12. However, the time threshold 36 should not be too long, such that the algorithm may miss to detect a foot being lifted, due to the sensor never being assigned the "Prepared" state. In one embodiment, the time threshold 36 may be set to 70 ms. In another embodiment, the time threshold 36 may be set to 100 ms.

[0074] The predetermined time period 38 shold not be too short, such that a detection of lifting of a foot may be falsely made, e.g. shortly after a heel being lifted, another detection may be made based on the forefoot being lifted. However, the predetermined time period 38 should not be too long, such that the algorithm may miss to detect a foot being lifted, due to the algorithm not being ready to make a detection when a subsequent lifting of the foot is made. In one embodiment, the predetermined time period 38 may be set to 150 ms. This may be suitable for a patient having a relatively normal gait. In another embodiment, the predetermined time period 38 may be set to 400 ms, or even 500 ms, which may be suitable for a patient having severely impaired gait.

[0075] The priorities of the pressure sensors 12 may be pre-defined in the algorithm or may be set by a caregiver as parameters to be used for a session of gait rehabilitation.

[0076] For instance, the pressure sensors 12 may be adapted for specific placement in relation to the foot, e. g. by all the pressure sensors 12 being arranged on a

common carrier, which may have a shape corresponding to a foot. It may thus be known for each signal, at which position on the foot the respective pressure sensor 12 is arranged, and the algorithm may thus be provided with pre-defined priorities for handling the signals accordingly.

[0077] However, if the pressure sensors 12 are individually positioned by a caregiver before a session of gait rehabilitation, the caregiver may also define the priorities in order for the algorithm to correctly interpret received signals.

[0078] Further, it should be realized that the caregiver may define other priorities to pressure sensors 12 depending on the gait of the patient to adapt the detection of lifting of a foot to the specific patient.

[0079] In the above the invention has mainly been described with reference to a limited number of embodiments. The invention is defined by appended claims 1-11.

Claims

1. A method in gait rehabilitation for detecting a foot being lifted, said method comprising:

continuously receiving (102) a plurality of signals from respective pressure sensors (12), which are mounted beneath a foot of a person in order to record a pressure asserted by the person against ground when walking, each signal providing a time sequence of values representing asserted pressure on the respective pressure sensor (12);
processing by means of a processing unit (24) the received plurality of signals,
characterized in that said processing comprises, for each signal, assigning states to the respective pressure sensor (12) for determining when the foot is being lifted for walking, and wherein said assigning of states comprises:

comparing (104) the values representing asserted pressure to an upper threshold (32) and identifying a value above the upper threshold (32),
upon identifying a value being above the upper threshold (32), comparing the sequence of values to the upper threshold (32) and determining a duration during which the sequence of values are continuously above the upper threshold (32); comparing (106) the determined duration to a time threshold (36) and identifying that the sequence of values are maintained above the upper threshold (32) for a duration exceeding the time threshold (36); and upon identifying a duration exceeding the time threshold (36) assigning a prepared state to the sensor (12); and
when the sensor (12) is in the prepared state, comparing the sequence of values to a lower threshold (34) and identifying (108) a value below the lower threshold (34) providing an indication that the foot is potentially lifted; and upon identifying a value below the lower threshold (34) assigning an unprepared state to the sensor (12); and

wherein said processing further comprises, when assigning an unprepared state to a first sensor, determining (110) whether a prepared state is assigned to a second sensor and comparing (112) a priority of the first sensor and the second sensor.

2. The method according to claim 1, wherein said processing further comprises, when assigning an unprepared state to a first sensor, providing a trigger signal for stimulating gait of the person on a condition that no other sensor with a higher priority is in a prepared state.

3. The method according to claim 2, wherein said assigning of states further comprises assigning the unprepared state to all sensors (12), when a trigger signal is provided.

4. The method according to any one of the preceding claims, wherein said assigning of states further comprises, when the sensor (12) is in the unprepared state and a value of the signal is below the lower threshold (32), maintaining the sensor (12) in the unprepared state until a predetermined time period (38) has lapsed and thereafter assigning a ready state to the sensor (12), wherein, after an unprepared state has been assigned to the sensor (12), said assigning of the prepared state to the sensor (12) is only possible if the ready state has first been assigned to the sensor (12).

5. The method according to claim 4, wherein the predetermined time period (38) is at least 150 ms.

6. The method according to any one of the preceding claims, wherein a priority of each of the sensors (12) is pre-set in a processing unit (24) for processing the received plurality of signals.

7. The method according to any one of claims 1-5, further comprising, before receiving signals from the pressure sensors (12), receiving an indication of the priority of each of the sensors (12).

8. The method according to any one of the preceding claims, wherein the plurality of sensors (12) include

a heel sensor, adapted and intended for mounting on a heel of the person, a lateral forefoot sensor, adapted and intended for mounting on a lateral forefoot of the person, and a medial forefoot sensor, adapted and intended for mounting on a medial forefoot of the person.

9. The method according to claim 8, wherein the heel sensor is set to have a highest priority.

10. The method according to any one of the preceding claims, wherein said time threshold (36) is at least 70 ms.

11. A device for use in gait rehabilitation for detecting a foot being lifted, said device (20) comprising:

at least one input contact (22) for continuously receiving a plurality of signals from respective pressure sensors (12), which are mounted beneath a foot of a person in order to record a pressure asserted by the person against ground when walking, each signal providing a time sequence of values representing asserted pressure on the respective pressure sensor (12);
a processing unit (24),
characterized in that said processing unit (24) is configured to process the received plurality of signals, wherein said processing comprises, for each signal, assigning states to the respective pressure sensor (12) for determining when the foot is being lifted for walking, and wherein said assigning of states comprises:

comparing the values representing asserted pressure to an upper threshold (32) and identifying a value above the upper threshold (32),
upon identifying a value being above the upper threshold (32), comparing the sequence of values to the upper threshold (32) and determining a duration during which the sequence of values are continuously above the upper threshold (32); comparing the determined duration to a time threshold (36) and identifying that the sequence of values are maintained above the upper threshold (32) for a duration exceeding the time threshold (36); and upon identifying a duration exceeding the time threshold (36) assigning a prepared state to the sensor (12); and
when the sensor (12) is in the prepared state, comparing the sequence of values to a lower threshold (34) and identifying a value below the lower threshold (34) providing an indication that the foot is potentially lifted; and upon identifying a value below the lower threshold (34) assigning an unprepared state to the sensor (12); and

wherein said processing further comprises, when assigning an unprepared state to a first sensor, determining whether a prepared state is assigned to a second sensor and comparing a priority of the first sensor and the second sensor.

Patentansprüche

1. Verfahren in der Gangrehabilitation zum Erfassen eines angehobenen Fußes, das Verfahren umfassend:

kontinuierliches Empfangen (102) mehrerer Signale von jeweiligen Drucksensoren (12), die unter einem Fuß einer Person angebracht sind, um einen von der Person beim Gehen auf den Boden ausgeübten Druck aufzuzeichnen, wobei jedes Signal eine Zeitfolge von Werten bereitstellt, die den ausgeübten Druck auf den jeweiligen Drucksensor (12) repräsentieren;
Verarbeiten der empfangenen mehreren Signale mittels einer Verarbeitungseinheit (24),
dadurch gekennzeichnet, dass das Verarbeiten für jedes Signal die Zuordnung von Zuständen zu dem jeweiligen Drucksensor (12) zum Bestimmen, wann der Fuß zum Gehen angehoben wird, umfasst, und wobei die Zuordnung von Zuständen umfasst:

Vergleichen (104) der Werte, die den ausgeübten Druck mit einem oberen Schwellenwert (32) darstellen und Identifizieren eines Wertes über dem oberen Schwellenwert (32),
beim Identifizieren eines Wertes, der über dem oberen Schwellenwert (32) liegt, Vergleichen der Wertefolge mit dem oberen Schwellenwert (32) und Bestimmen einer Dauer, während der die Wertefolge kontinuierlich über dem oberen Schwellenwert (32) liegt; Vergleichen (106) der bestimmten Dauer mit einer Zeitschwelle (36) und Identifizieren, dass die Wertefolge für eine die Zeitschwelle (36) überschreitende Dauer über dem oberen Schwellenwert (32) gehalten wird; und beim Identifizieren einer die Zeitschwelle (36) überschreitenden Dauer das Zuweisen eines vorbereiteten Zustandes an den Sensor (12); und
wenn sich der Sensor (12) in dem vorbereiteten Zustand befindet, Vergleichen der Wertefolge mit einem unteren Schwellenwert (34) und Identifizieren (108) eines Wer-

tes unterhalb des unteren Schwellenwertes (34), was eine Anzeige bereitstellt, dass der Fuß potenziell angehoben ist; und beim Identifizieren eines Wertes unterhalb des unteren Schwellenwertes (34) das Zuweisen eines nicht vorbereiteten Zustandes an den Sensor (12); und wobei das Verarbeiten ferner, wenn einem ersten Sensor ein nicht vorbereiteter Zustand zugewiesen wird, das Bestimmen (110), ob einem zweiten Sensor ein vorbereiteter Zustand zugewiesen ist, und das Vergleichen (112) einer Priorität des ersten Sensors und des zweiten Sensors umfasst.

2. Verfahren nach Anspruch 1, wobei das genannte Verarbeiten ferner, wenn einem ersten Sensor ein unvorbereiteter Zustand zugewiesen wird, das Bereitstellen eines Triggersignals zur Stimulation des Gangs der Person unter der Bedingung umfasst, dass sich kein anderer Sensor mit einer höheren Priorität in einem vorbereiteten Zustand befindet.

3. Verfahren nach Anspruch 2, wobei das Zuweisen von Zuständen ferner das Zuweisen des unvorbereiteten Zustands an alle Sensoren (12) umfasst, wenn ein Triggersignal bereitgestellt wird.

4. Verfahren nach einem der vorhergehenden Ansprüche, wobei das Zuweisen der Zustände ferner umfasst, wenn sich der Sensor (12) im nicht vorbereiteten Zustand befindet und ein Wert des Signals unter dem unteren Schwellenwert (32) liegt, das Halten des Sensors (12) im nicht vorbereiteten Zustand bis zum Ablauf einer vorgegebenen Zeitspanne (38) und danach das Zuweisen eines Bereitschaftszustandes an den Sensor (12), wobei nach dem Zuweisen eines nicht vorbereiteten Zustandes an den Sensor (12) dieses Zuweisen des vorbereiteten Zustandes an den Sensor (12) nur möglich ist, wenn dem Sensor (12) zuvor der Bereitschaftszustand zugewiesen wurde.

5. Verfahren nach Anspruch 4, wobei die vorgegebene Zeitspanne (38) mindestens 150 ms beträgt.

6. Verfahren nach einem der vorhergehenden Ansprüche, wobei eine Priorität für jeden der Sensoren (12) in einer Verarbeitungseinheit (24) zum Verarbeiten der empfangenen mehreren Signale voreingestellt wird.

7. Verfahren nach einem der Ansprüche 1 bis 5, das ferner vor dem Empfangen von Signalen von den Drucksensoren (12) eine Anzeige der Priorität für jeden der Sensoren (12) umfasst.

8. Verfahren nach einem der vorhergehenden Ansprüche, wobei die mehreren Sensoren (12) einen Fersensensor, der zum Befestigen an einer Ferse der Person geeignet und bestimmt ist, einen lateralen Vorderfußsensor, der zum Befestigen an einem lateralen Vorderfuß der Person geeignet und bestimmt ist, und einen medialen Vorderfußsensor, der zum Befestigen an einem medialen Vorderfuß der Person geeignet und bestimmt ist, umfassen.

9. Verfahren nach Anspruch 8, wobei der Fersensensor auf die höchste Priorität eingestellt wird.

10. Verfahren nach einem der vorhergehenden Ansprüche, wobei die Zeitschwelle (36) mindestens 70 ms beträgt.

11. Vorrichtung zum Verwenden in der Gangrehabilitation zum Erfassen eines angehobenen Fußes, die Vorrichtung (20) umfassend:

mindestens einen Eingangskontakt (22) zum kontinuierlichen Empfangen mehrerer Signale von jeweiligen Drucksensoren (12), die unter einem Fuß einer Person angebracht sind, um einen von der Person beim Gehen auf den Boden ausgeübten Druck aufzuzeichnen, wobei jedes Signal eine Zeitfolge von Werten bereitstellt, die den ausgeübten Druck auf den jeweiligen Drucksensor (12) repräsentieren;
eine Verarbeitungseinheit (24),
dadurch gekennzeichnet, dass die Verarbeitungseinheit (24) so konfiguriert ist, dass sie die empfangenen mehreren Signale verarbeitet, wobei das Verarbeiten für jedes Signal das Zuweisen von Zuständen an den jeweiligen Drucksensor (12) zum Bestimmen, wann der Fuß zum Gehen angehoben wird, umfasst, und wobei die Zuordnung von Zuständen umfasst:

Vergleichen der Werte, die den ausgeübten Druck mit einem oberen Schwellenwert (32) darstellen und Identifizieren eines Wertes über dem oberen Schwellenwert (32),
beim Identifizieren eines Wertes, der über dem oberen Schwellenwert (32) liegt, Vergleichen der Wertefolge mit dem oberen Schwellenwert (32) und Bestimmen einer Dauer, während der die Wertefolge kontinuierlich über dem oberen Schwellenwert (32) liegt; Vergleichen der bestimmten Dauer mit einer Zeitschwelle (36) und Identifizieren, dass die Wertefolge für eine die Zeitschwelle (36) überschreitende Dauer über dem oberen Schwellenwert (32) gehalten wird; und beim Identifizieren einer die Zeitschwelle (36) überschreitenden Dauer das Zuweisen eines vorbereiteten Zustandes an den Sensor (12); und

wenn sich der Sensor (12) in dem vorbereiteten Zustand befindet, Vergleichen der Wertefolge mit einem unteren Schwellenwert (34) und Identifizieren eines Wertes unterhalb des unteren Schwellenwertes (34), was eine Anzeige bereitstellt, dass der Fuß potenziell angehoben ist; und beim Identifizieren eines Wertes unterhalb des unteren Schwellenwertes (34) das Zuweisen eines nicht vorbereiteten Zustandes an den Sensor (12); und
wobei das Verarbeiten ferner, wenn einem ersten Sensor ein nicht vorbereiteter Zustand zugewiesen wird, das Bestimmen, ob einem zweiten Sensor ein vorbereiteter Zustand zugewiesen ist, und das Vergleichen einer Priorität des ersten Sensors und des zweiten Sensors umfasst.

Revendications

1. Procédé utilisé dans la rééducation de la marche, pour la détection d'un pied en train d'être soulevé, ledit procédé comprenant :

la réception continue (102) d'une pluralité de signaux provenant de capteurs de pression respectifs (12), lesquels sont montés sous un pied d'une personne pour enregistrer une pression exercée par la personne sur le sol pendant la marche, chaque signal fournissant une séquence temporelle de valeurs représentant une pression exercée sur le capteur de pression respectif (12) ;
le traitement, à l'aide d'une unité de traitement (24), de la pluralité de signaux reçus,
caractérisé en ce que pour chaque signal, ledit traitement comprend l'attribution d'états au capteur de pression respectif (12) pour déterminer à quel moment le pied est soulevé pour marcher, et dans lequel ladite attribution d'états comprend :

la comparaison (104) des valeurs représentant la pression exercée avec un seuil supérieur (32) et l'identification d'une valeur au-dessus du seuil supérieur (32),
lors de l'identification d'une valeur au-dessus du seuil supérieur (32), la comparaison de la séquence de valeurs avec le seuil supérieur (32) et la détermination d'une durée pendant laquelle la séquence de valeurs tombe continuellement au-dessus du seuil supérieur (32) ; la comparaison (106) de la durée déterminée avec un seuil temporel (36) et l'identification du maintien de la séquence de valeurs au-dessus du seuil supérieur (32) pour une durée dépassant le seuil temporel (36) ; et en cas d'identification d'une durée dépassant le seuil temporel (36), l'attribution d'un état prédéfini au capteur (12) ; et
lorsque le capteur (12) est dans l'état prédéfini, la comparaison de la séquence de valeurs avec un seuil inférieur (34) et l'identification (108) d'une valeur en dessous du seuil inférieur (34), indiquant que le pied est potentiellement soulevé ; et en cas d'identification d'une valeur en dessous du seuil inférieur (34), l'attribution d'un état non prédéfini au capteur (12) ; et dans lequel ledit traitement comprend en outre, lors de l'attribution d'un état non prédéfini à un premier capteur, la détermination (110) de l'attribution d'un état prédéfini à un deuxième capteur et la comparaison (112) d'une priorité du premier capteur et du deuxième capteur.

2. Procédé selon la revendication 1, dans lequel ledit traitement comprend en outre, lors de l'attribution d'un état non prédéfini à un premier capteur, l'émission d'un signal de déclenchement pour stimuler la marche de la personne à condition qu'aucun autre capteur avec une priorité supérieure ne soit dans un état prédéfini.

3. Procédé selon la revendication 2, dans lequel l'attribution d'états comprend en outre l'attribution de l'état non prédéfini à tous les capteurs (12) lorsqu'un signal de déclenchement est émis.

4. Procédé selon l'une quelconque des revendications précédentes, dans lequel ladite attribution d'états comprend en outre, lorsque le capteur (12) est dans l'état non prédéfini et qu'une valeur du signal tombe en dessous du seuil inférieur (32), le maintien du capteur (12) dans l'état non prédéfini jusqu'à l'écoulement d'une période de temps prédéterminée (38), puis l'attribution d'un état prêt au capteur (12), dans lequel, après l'attribution d'un état non prédéfini au capteur (12), ladite attribution de l'état prédéfini au capteur (12) sera possible uniquement si l'état prêt a d'abord été attribué au capteur (12).

5. Procédé selon la revendication 4, dans lequel la période de temps prédéterminée (38) est d'au moins 150 ms.

6. Procédé selon l'une quelconque des revendications précédentes, dans lequel une priorité de chacun des capteurs (12) est préréglée dans une unité de traitement (24) pour le traitement de la pluralité de signaux reçus.

7. Procédé selon l'une quelconque des revendications

1 à 5, comprenant en outre, avant la réception de signaux en provenance des capteurs de pression (12), la réception d'une indication de la priorité de chacun des capteurs (12).

8. Procédé selon l'une quelconque des revendications précédentes, dans lequel la pluralité de capteurs (12) comprend un capteur de talon, adapté et prévu pour être monté sur un talon de la personne, un capteur d'avant-pied latéral, adapté et prévu pour être monté sur un avant-pied latéral de la personne, et un capteur d'avant-pied central, adapté et prévu pour être monté sur un avant-pied central de la personne.

9. Procédé selon la revendication 8, dans lequel le capteur de talon est réglé pour avoir la priorité la plus élevée.

10. Procédé selon l'une quelconque des revendications précédentes, dans lequel ledit seuil temporel (36) s'élève à au moins 70 ms.

11. Dispositif destiné à être utilisé dans la rééducation de la marche, pour la détection d'un pied en train d'être soulevé, ledit dispositif (20) comprenant :

au moins un contact d'entrée (22) destiné à recevoir continuellement une pluralité de signaux provenant de capteurs de pression respectifs (12), lesquels sont montés sous un pied d'une personne pour enregistrer une pression exercée par la personne sur le sol pendant la marche, chaque signal fournissant une séquence temporelle de valeurs représentant une pression exercée sur le capteur de pression respectif (12) ;
une unité de traitement (24),
caractérisé en ce que ladite unité de traitement (24) est configurée pour traiter la pluralité de signaux reçus, dans lequel, pour chaque capteur, ledit traitement comprend l'attribution d'états au capteur de pression respectif (12) pour déterminer à quel moment le pied est soulevé pour marcher, et dans lequel ladite attribution d'états comprend :

la comparaison des valeurs représentant la pression exercée avec un seuil supérieur (32) et l'identification d'une valeur au-dessus du seuil supérieur (32),
lors de l'identification d'une valeur au-dessus du seuil supérieur (32), la comparaison de la séquence de valeurs avec le seuil supérieur (32) et la détermination d'une durée pendant laquelle la séquence de valeurs tombe continuellement au-dessus du seuil supérieur (32) ; la comparaison de la durée déterminée avec un seuil temporel (36) et l'identification du maintien de la séquence de valeurs au-dessus du seuil supérieur (32) pour une durée dépassant le seuil temporel (36) ; et en cas d'identification d'une durée dépassant le seuil temporel (36), l'attribution d'un état prédéfini au capteur (12) ; et
lorsque le capteur (12) est dans l'état prédéfini, la comparaison de la séquence de valeurs avec un seuil inférieur (34) et l'identification d'une valeur en dessous du seuil inférieur (34), indiquant que le pied est potentiellement soulevé ; et en cas d'identification d'une valeur en dessous du seuil inférieur (34), l'attribution d'un état non prédéfini au capteur (12) ; et
dans lequel ledit traitement comprend en outre, lors de l'attribution d'un état non prédéfini à un premier capteur, la détermination de l'attribution d'un état prédéfini à un deuxième capteur et la comparaison d'une priorité du premier capteur et du deuxième capteur.

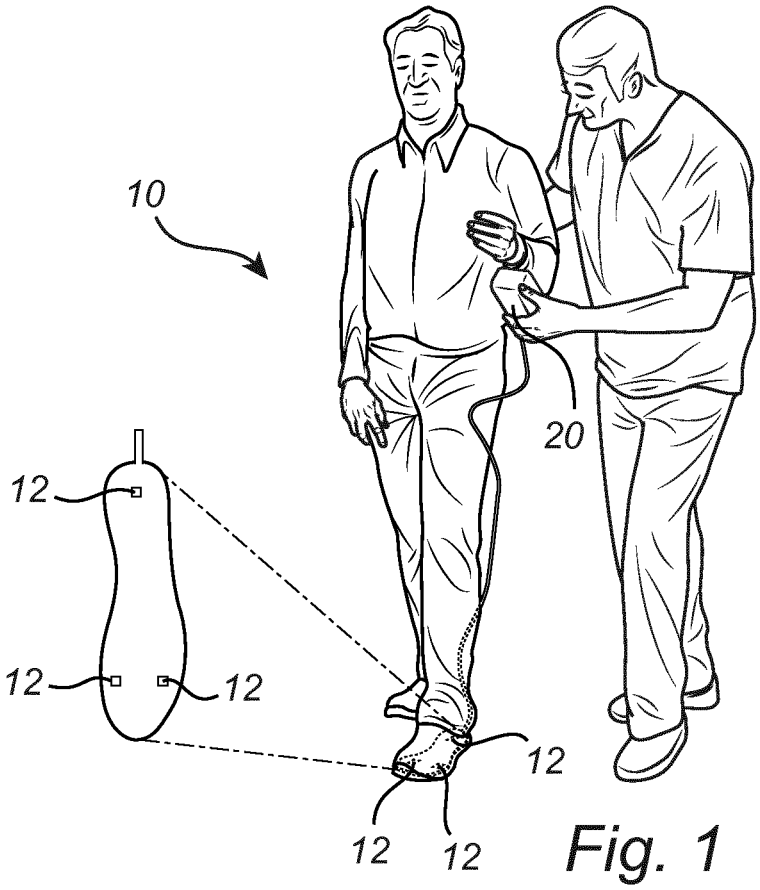

Fig. 1

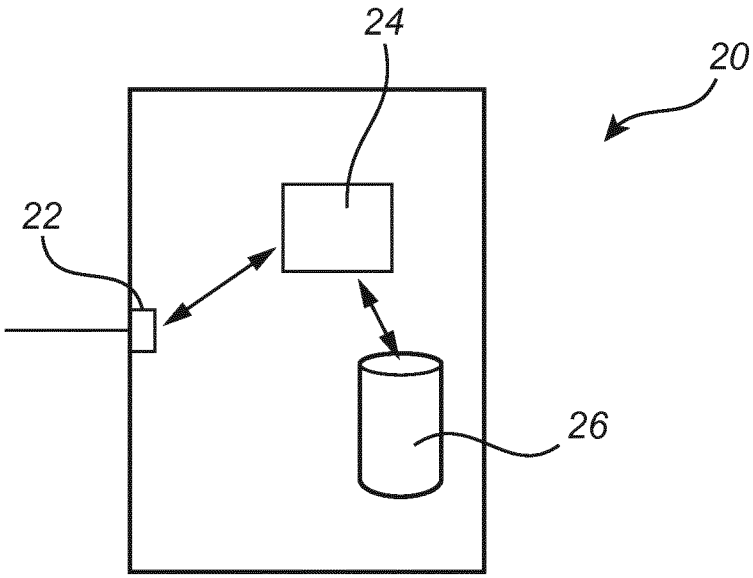

Fig. 2

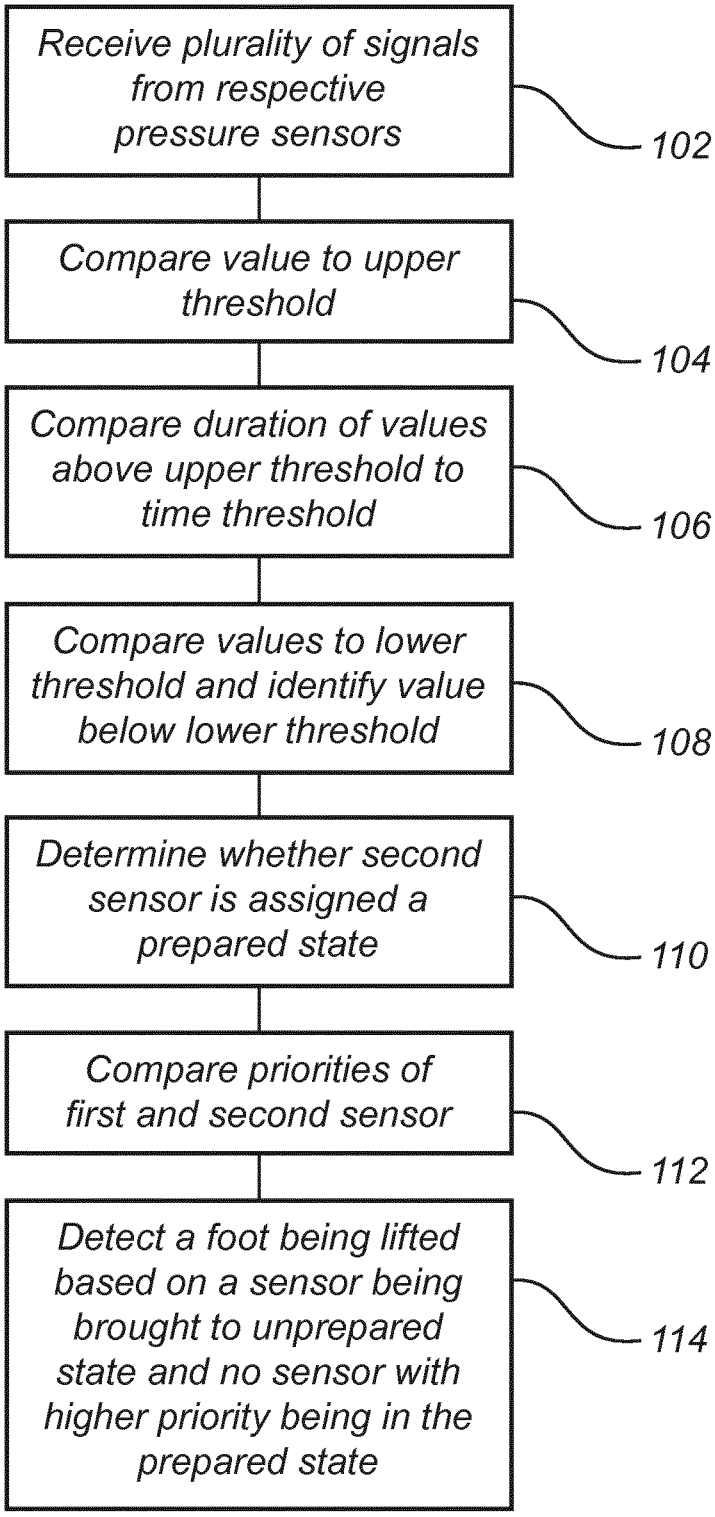
Receive plurality of signals from respective pressure sensors
102
Compare value to upper threshold
104
Compare duration of values above upper threshold to time threshold
106
Compare values to lower threshold and identify value below lower threshold
108
Determine whether second sensor is assigned a prepared state
110
Compare priorities of first and second sensor
112
Detect a foot being lifted based on a sensor being brought to unprepared state and no sensor with higher priority being in the prepared state
114

Fig. 3

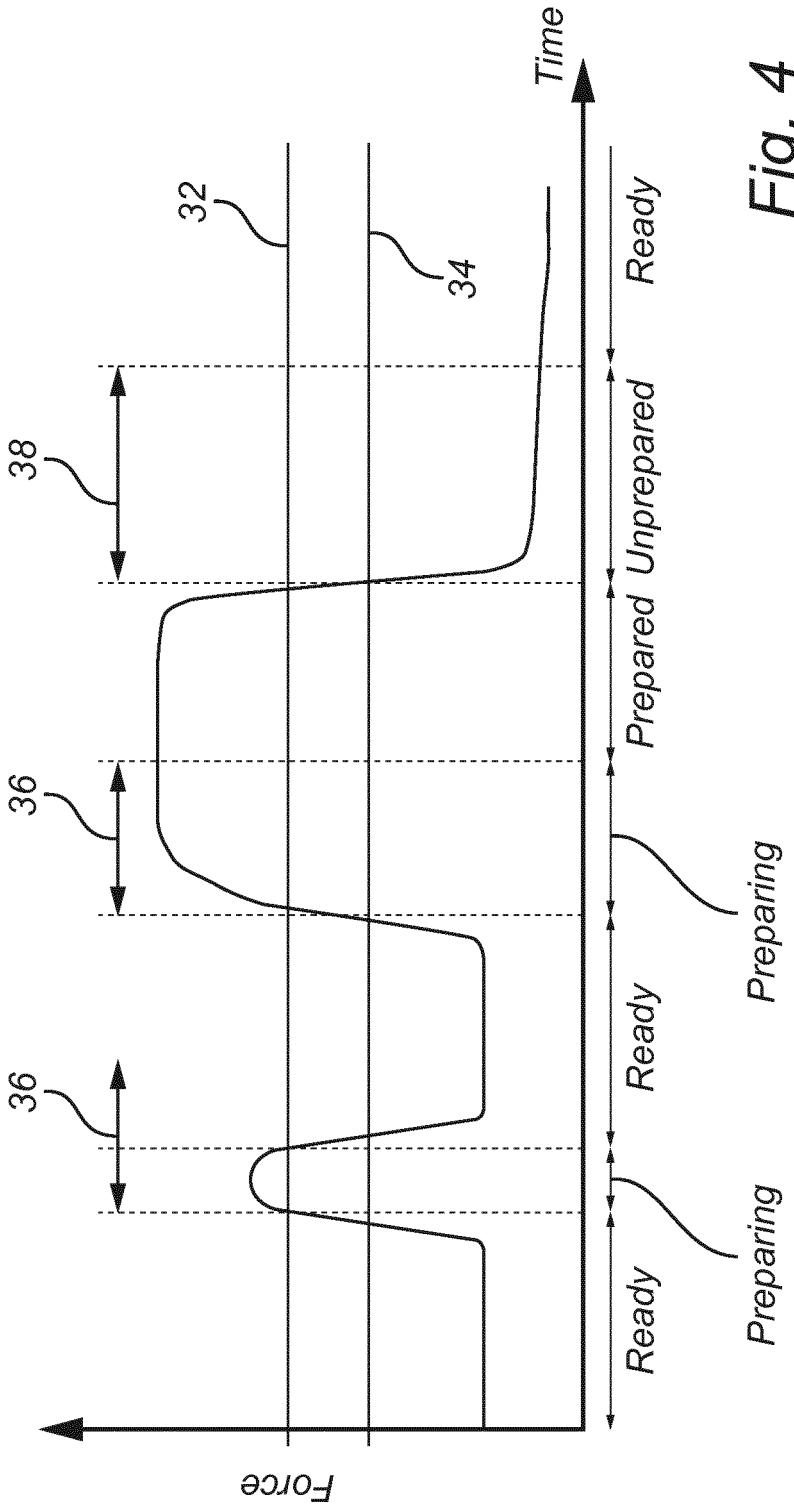
Force
Time
32
34
38
36
36
Ready
Preparing
Ready
Prepared
Unprepared
Preparing
Ready

Fig. 4

REFERENCES CITED IN THE DESCRIPTION

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专利名称(译)	步态检测算法		
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当前申请(专利权)人(译)	NORDIC NEUROSTIM APS		
[标]发明人	HENNINGS KRISTIAN HANSEN MORTEN		
发明人	HENNINGS, KRISTIAN HANSEN, MORTEN		
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优先权	1650021 2016-01-08 SE		
其他公开文献	EP3399911B1		
外部链接	Espacenet		

摘要(译)

一种用于步态康复的方法，用于检测脚被抬起，该方法包括：从安装在人脚下方的各个压力传感器（12）接收（102）多个信号，每个信号提供表示所称压力的值的时间序列；以及 处理接收到的信号，其中，对于每个信号，所述处理包括将状态分配给相应的压力传感器（12），以确定何时抬起脚来行走，并且其中，所述状态分配包括：识别值序列为 保持高于上限阈值（32）的时间超过时间阈值（36）；并根据这种识别将准备好的状态分配给传感器（12）； 当传感器（12）处于准备状态时，识别（108）低于下限阈值（34）的值，该值指示脚可能被抬起； 在这种识别之后，将未准备好的状态分配给传感器（12）； 并且其中所述处理还包括，当将未准备状态分配给第一传感器时，确定（110）是否将准备状态分配给第二传感器，并且比较（112）第一传感器和第二传感器的优先级。