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(54) **METHOD AND WRIST DEVICE**

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(57) **ABSTRACT**

The invention relates to a wrist device and to a method of determining movement information. The method comprises measuring acceleration from a movement of a wrist device worn by a user during the user's stepping; and determining movement pulses associated with a lateral movement generated by the user's stepping by using said acceleration.
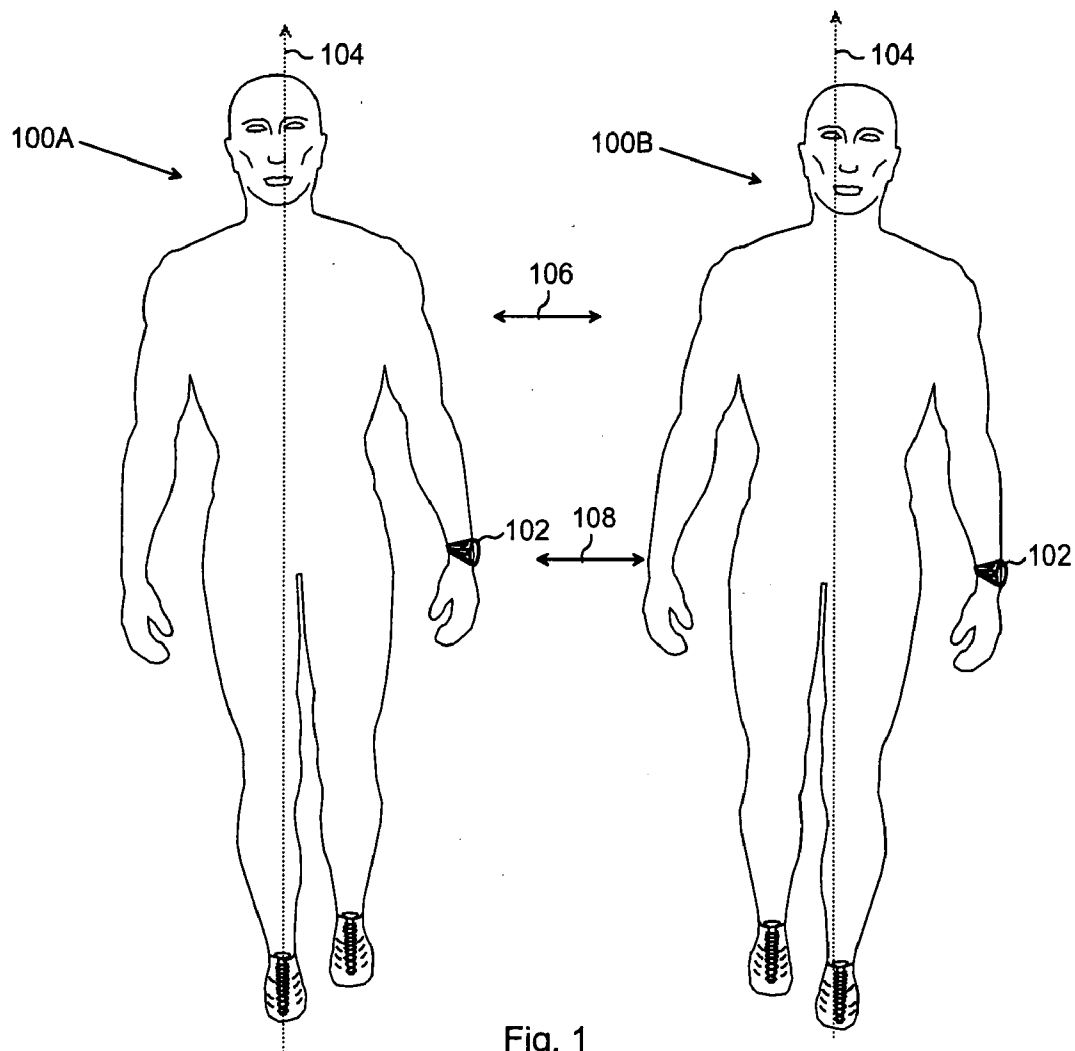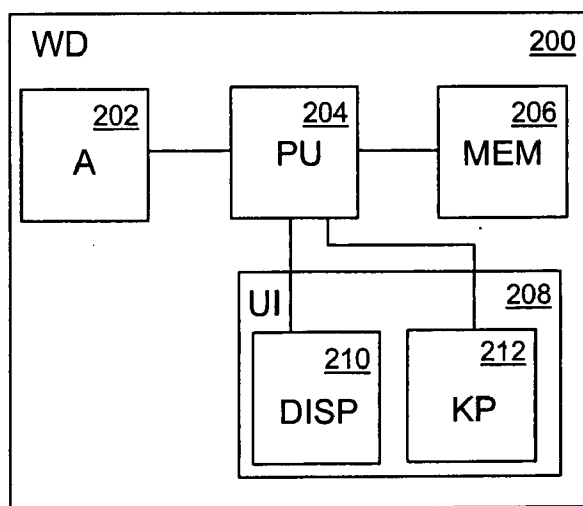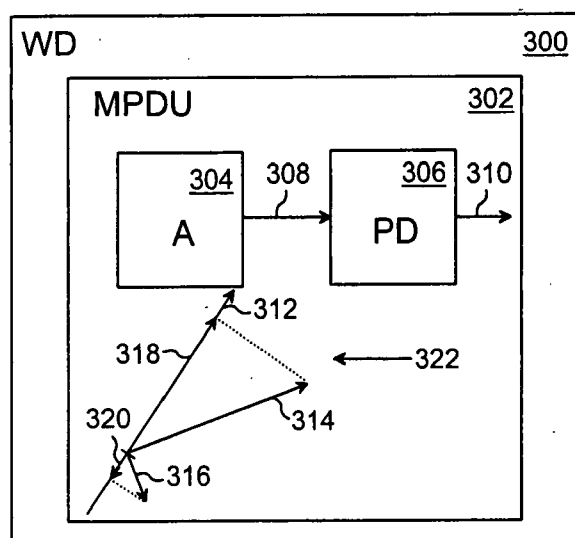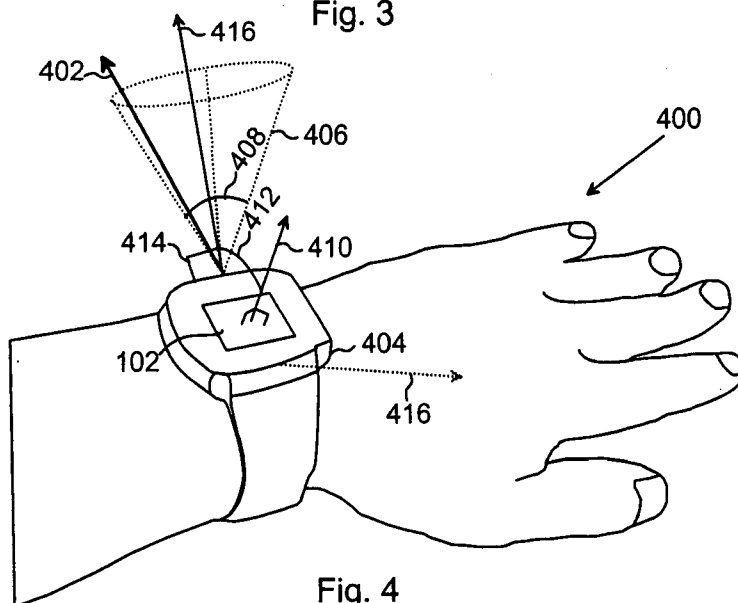
Fig. 1

Fig. 2

WD   300

MPDU   302

304   308   306   310

A   →   PD   →

312
318   ←   322
320   314
316

Fig. 3

416
402
408   406
412
414   410
102   404
416

400

Fig. 4

504
510   502   500
404   508
102
506

500

508

Fig. 5

WD   600

MPDU   602

604   612A   606   608   616
A   MA   PC
             612B

~618

~620

622

Fig. 6

400

~708

618 ~

~620

404   102   622

Fig. 7

~802   3A   3B   3C   3D

4A   4B   4C

~808

1A   1B   1C   1D

810

~806

2A   2B   2C

800

Fig. 8

900
START

MEASURE ACCELERATION FROM MOVEMENT OF   902
WRIST DEVICE WORN BY USER DURING USER'S STEPPING

DETERMINE MOVEMENT PULSES ASSOCIATED WITH 904
MOVEMENT GENERATED BY USER'S STEPPING
BY USING ACCELERATION IN DIRECTION OF
LATERAL MOVEMENT

END
906

Fig. 9

START
920

MEASURE SEVERAL DIRECTIONAL   922
ACCELERATION COMPONENTS

DETERMINE ACCELERATION IN DIRECTION OF   924
LATERAL MOVEMENT GENERATED BY USER'S STEPPING
BY COMBINING SEVERAL DIRECTIONAL
ACCELERATION COMPONENTS

DETERMINE MOVEMENT PULSES ASSOCIATED WITH   926
LATERAL MOVEMENT GENERATED BY USER'S STEPPING
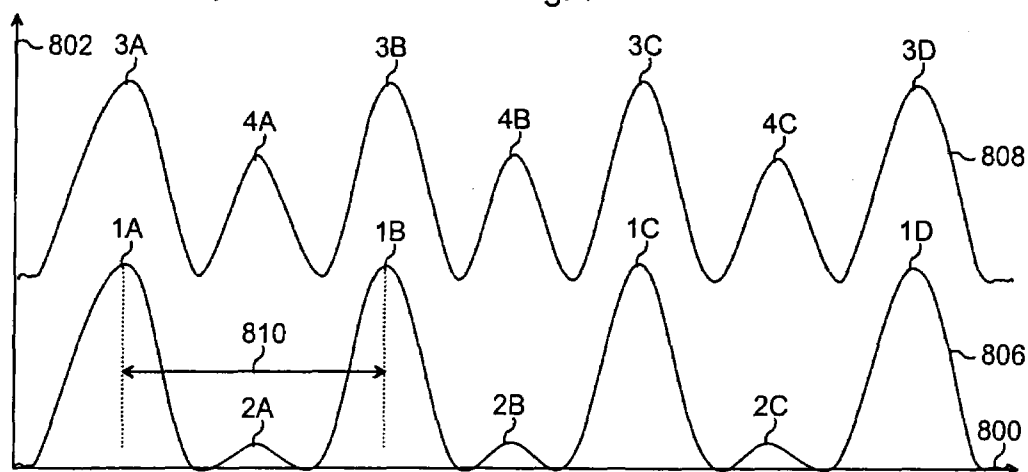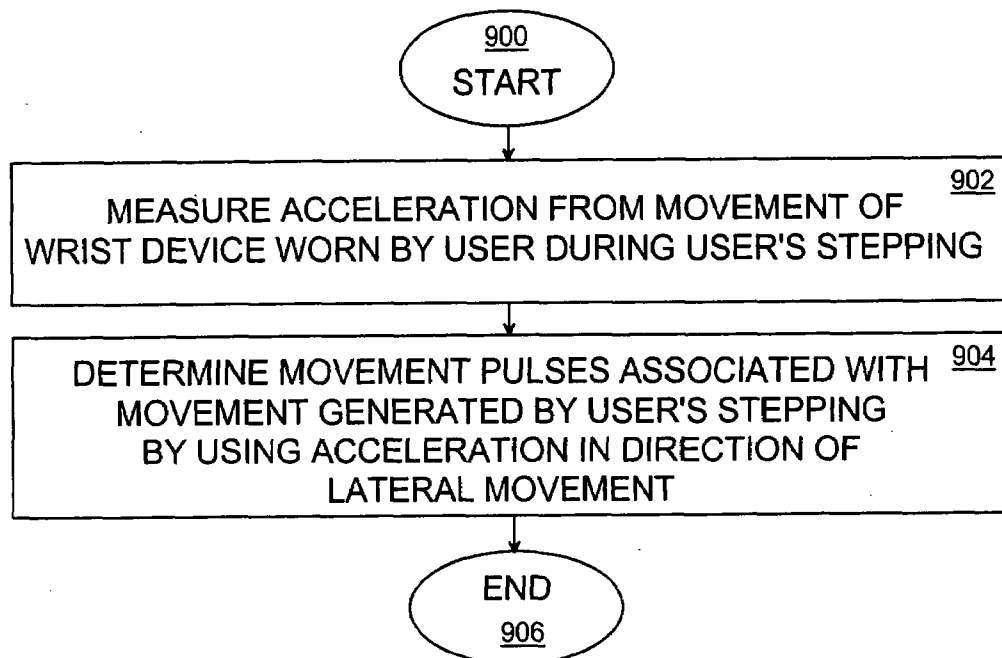BY USING LINEAR COMBINATION OF DIRECTIONAL
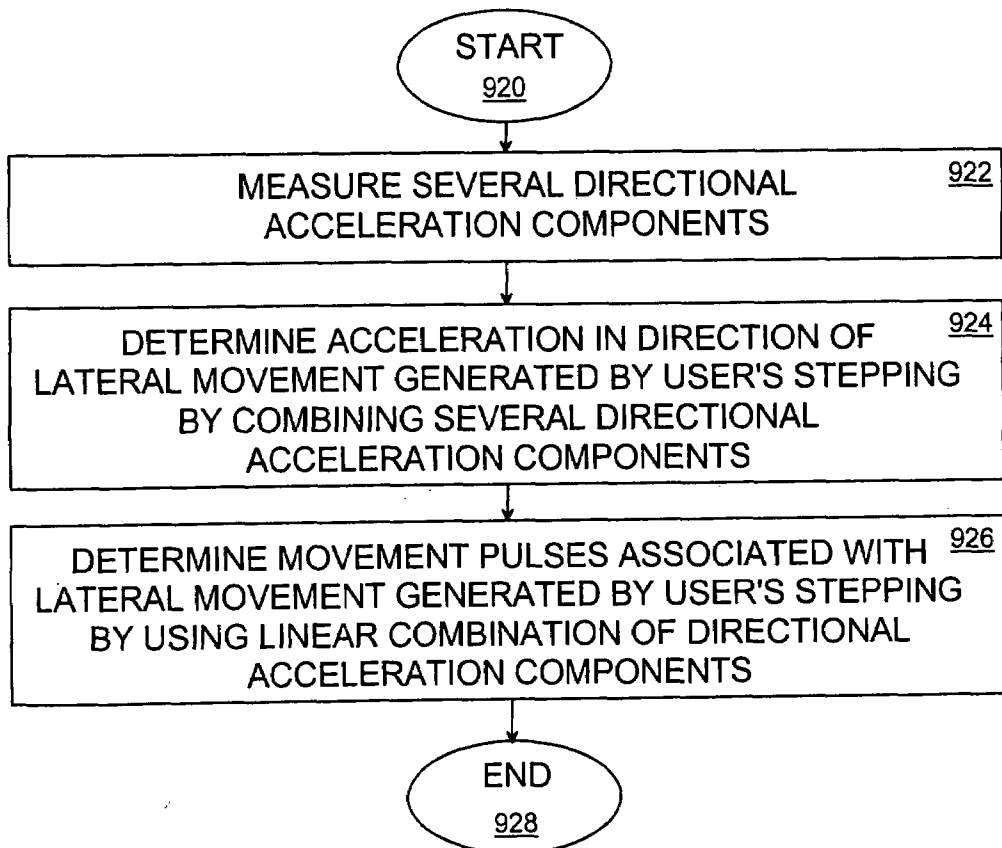ACCELERATION COMPONENTS

END
928

Fig. 10

METHOD AND WRIST DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to Finnish Patent Application Serial No. 20065359, filed on May 29, 2006, which is incorporated herein by reference.

BACKGROUND OF THE INVENTION

[0002] 1. Field of the Invention
[0003] The invention relates to a method of determining movement information and to a wrist device.
[0004] 2. Description of the Related Art
[0005] There are different manners of measuring the step frequency associated with the progressive movement achieved by a person's stepping. Known measuring methods include pedometers attachable to the pelvis or footwear and based on mechanical pendulums or acceleration sensors and measuring acceleration in one or more directions. Techniques also exist for determining movement magnetically by utilizing the earth's magnetic field.
[0006] Drawbacks in prior art solutions are caused by the complexity of the movements generated by a person's stepping and problems caused by the complexity of movements in the determination of step frequency. Accordingly, it is useful to inspect techniques for determining movement information.

SUMMARY OF THE INVENTION

[0007] The object of the invention is to provide a wrist device and a method so as to achieve a reliable determination of a user's movement information. A first aspect of the invention is to provide a wrist device comprising a movement pulse determination unit for measuring acceleration from a movement of the wrist device during a user's stepping, the movement pulse determination unit being configured to determine movement pulses associated with a lateral movement generated by the user's stepping by using said acceleration.
[0008] A second aspect of the invention is to provide a method comprising measuring acceleration from a movement of a wrist device worn by a user during the user's stepping; and determining movement pulses associated with a lateral movement generated by the user's stepping by using said acceleration.
[0009] Preferred embodiments of the invention are described in the dependent claims.
[0010] The invention is based on determining movement pulses associated with a lateral movement generated by a user's stepping. When the user steps, the user's center of gravity moves laterally as the user's bearing foot changes, each of the user's steps being associated with a change in the lateral movement of the center of gravity. This causes a period in the user's lateral movement that corresponds to the step pair frequency. The user's upper extremities follow movement of the center of gravity, whereby the same period occurs in the lateral movement of the upper extremities, enabling the measurement of the movement pulses associated with the lateral movement with a wrist device.
[0011] The wrist device and method of the invention bring forth a plurality of advantages. The movement pulses associated with the lateral movement generated by stepping correlate well with the step frequency, the number and amplitude of extra movement pulses being slight. Accordingly, the use of the lateral movement generated by stepping provides a reliable result in the determination of movement pulses and derived information obtained from the movement pulses.

BRIEF DESCRIPTION OF THE DRAWINGS

[0012] In the following, the invention will be described in more detail in connection with preferred embodiments with reference to the accompanying drawings, in which
[0013] FIG. 1 shows an example of a user's stepping dynamics;
[0014] FIG. 2 shows a first example of the structure of a wrist device;
[0015] FIG. 3 shows a second example of the structure of a wrist device;
[0016] FIG. 4 shows a first example of measurement geometry;
[0017] FIG. 5 shows a second example of measurement geometry;
[0018] FIG. 6 shows a third example of the structure of a wrist device; and
[0019] FIG. 7 shows a third example of measurement geometry;
[0020] FIG. 8 shows an example of the structure of movement pulses;
[0021] FIG. 9 shows a first example of a method in accordance with an embodiment of the invention; and
[0022] FIG. 10 shows a second example of a method in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

[0023] With reference to FIG. 1, let us study the dynamics of the stepping of a user of a wrist device 102, wherein the user switches the center of gravity from one foot to another. In situation 100A, the user leans on his/her right foot, and in situation 100B the user leans on his/her left foot. Progressive movement, such as walking or running, may be associated with stepping. Stepping may also take place in a state of suspended animation without progressive movement.
[0024] Between stepping steps 100A and 100B, the user's center of gravity 104 shifts laterally in order for the user to maintain balance. Hereby, a lateral movement 106 of the center of gravity 104 is generated by the stepping. When a plurality of successive shifts occurs in a user's stepping, the lateral movement 106 becomes periodic. A periodic lateral movement 106 may be interpreted as movement pulses.
[0025] A lateral movement 108 of the wrist device 102 is also associated with the lateral movement 106 of the center of gravity 104. Accordingly, the lateral movement 106 of the center of gravity 104 may be characterized by studying the lateral movement 108 of the wrist device, and determine the movement pulses generated by the stepping.
[0026] FIG. 2 shows an example of the structure of a wrist device 200. The wrist device 200 typically comprises a processing unit (PU) 204, a memory unit (MEM) 206, an acceleration sensor (A) 202, and a user interface (UI) 208.
[0027] The processing unit 204 may be implemented by using analog circuits, ASIC circuits (Application Specific Integrated Circuit), a digital processor, a memory and computer software. The processing unit 204 may constitute part of the computer of the wrist device 200. The processing unit

204 may execute a computer process according to encoded instructions stored in the memory unit 206 for determining movement information.

[0028] In an embodiment, the acceleration sensor 202 is based on piezo technology (piezoresistor). In piezoresistor technology, a material is used whose resistance changes as the material is compressed. Mass acceleration generates a force directed to the piezoresistor, and when constant current is led through the piezoresistor, the current acting over the piezoresistor changes according to the compression caused by acceleration.

[0029] In piezoelectric technology, a piezoelectric sensor generates the resistance when the acceleration sensor is accelerated.

[0030] In silicon bridge technology, a silicon chip is etched such that silicon mass remains on the silicon chip at the end of the silicon beam. When acceleration is directed to the silicon chip, the silicon mass directs a force to the silicon beam, changing the resistance of the silicon beam.

[0031] Micro-machined silicon technology is based on the use of a differential capacitor. Voice coil technology is based on the same principle as a microphone. Some examples of suitable movement sensors include: Analog Devices ADXL 105, Pewatron HW or VTI Technologies SCA series.

[0032] The acceleration sensor 202 may also be based on other technologies suitable for the purpose, for example a gyroscope integrated into a silicon chip, a micro-vibration placed in a panel mounting component or a mechanical pendulum.

[0033] Acceleration information generated by the acceleration sensor 202 may be transferred to the processing unit 204 or to the memory unit 206.

[0034] The user interface 208 typically comprises a display unit (DISP) 210 and a display controller. The display unit 210 may comprise LCD components (Liquid Crystal Display), for example. The display unit 210 may graphically and/or numerically display, to the user, a movement pulse accumulation or a secondary parameter value, such as the number of steps, the distance progressed or the energy consumption, determined from movement pulses characterizing the performance.

[0035] The user interface 124 may further comprise a keypad (KP) 212 allowing the user to input commands in the wrist device 200.

[0036] In an embodiment, the wrist device 200 is a pulse counter, in which case the wrist device 200 may comprise a receiver for receiving a signal transmitted from a pulse measurement unit. The pulse measurement unit may be a belt-like structure installed on the user's chest and comprising means for performing an electrocardiogram measurement (ECG) and for transmitting ECG information to the wrist device 200.

[0037] With reference to FIG. 3, a wrist device (WD) 300 comprises a movement pulse determination unit 302 for measuring acceleration from the movement of the wrist device 300 during the stepping of the user of the wrist device 300. The movement pulse determination unit 302 determines movement pulses associated with the lateral movement 108 generated by the user's stepping by the use of acceleration.

[0038] The movement determination unit 302 typically comprises an acceleration sensor (A) 304 and a pulse detector (PD) 306.

[0039] The acceleration sensor 304 determines instantaneous acceleration values and generates a data stream 308 characterizing the instantaneous acceleration values. The acceleration sensor 304 feeds the data stream 308 into the pulse detector 306.

[0040] The pulse detector 306 receives the data stream 308 and indicates acceleration variations associated with the lateral movement 108 from the data stream 306. The pulse detector 306 may calculate the pulses it identifies and output pulse information 310 for processing or storage.

[0041] The pulse detector 306 may be implemented for instance by means of computer software executed by means of the processing unit 204 according to FIG. 2 and stored in the memory unit 206.

[0042] In an embodiment of the invention, the acceleration sensor 304 measures acceleration in the direction of the lateral movement 108 generated by the user's stepping. The pulse detector 306 determines movement pulses associated with the user's lateral movement 108 by using said acceleration in the direction of the lateral movement 108.

[0043] The acceleration sensor 304 may be a one-dimensional acceleration sensor 304 for measuring acceleration in the direction of the lateral movement generated by stepping. FIG. 3 shows a vector diagram 322 comprising a measuring direction 312 of the one-dimensional acceleration sensor, acceleration 314 in the direction of the lateral movement 108 of the wrist device, and acceleration 316 perpendicular to the lateral movement 108. The acceleration 316 perpendicular to the lateral movement 108 may be caused by an upturned movement of the wrist device 300 generated in stepping or a movement in the direction of the user's progressive movement.

[0044] The one-dimensional acceleration sensor 302 measures projections of mutually orthogonal accelerations in the measuring direction 312. The projection of the acceleration 314 in the direction of the lateral movement 108 is shown by vector 318, and the projection of the acceleration 316 perpendicular to the lateral movement 108 is shown by a vector 320.

[0045] In an embodiment of the invention, the one-dimensional acceleration sensor 302 is oriented in the wrist device such that the projection of the acceleration 314 in the direction of the lateral movement 108 dominates with respect to the projections 320 of the accelerations 316 perpendicular to the lateral movement 108.

[0046] The orientation of the one-dimensional acceleration sensor 302 also takes account of the orientation of the acceleration sensor 304 with respect to the body of the wrist device 300, the orientation of the wrist device 300 with respect to the user's upper extremity, and the user's stepping style. The stepping style affects the way the reference part, such as the back of the hand or the carpal vertebra, of the user's upper extremity, moves during stepping.

[0047] With reference to the example of FIG. 4, in an embodiment of the invention, the one-dimensional acceleration sensor 304 is oriented such that the measuring direction 402 is restricted with respect to a normal vector 410 of the user's back of hand 400 at an angle of 45 degrees, and inside a cone 406 generated around the vector 416 perpendicular to the fingers, the spread angle 408 of the cone 406 being previously known. The spread angle 408 is 90 degrees, for example. In this case, the measuring distance 402 compensates for the differences occurring in the different users' stepping styles, the movements of the extremities and the

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installation of the wrist device **102**. The normal vector **410** may also be determined as a normal vector starting from the plane **404** of the wrist device **102**.

[0048] In the example of FIG. **4**, the angle **412** is 45 degrees, and the angle **414** is a right angle. The vector **416** determining the direction of the cone **406** may also be directed to the opposite side of the wrist device **404** in accordance with FIG. **4**.

[0049] The plane **404** of the wrist device may be determined for instance as the plane of the glass of the wrist device **102** or as a support plane of the wrist device **102** against the wrist. The plane **404** of the wrist device **102** may also be an imaginary plane.

[0050] With reference to FIG. **5**, in an embodiment, the one-dimensional acceleration sensor **304** is oriented to measure acceleration whose main component **510** is, during the use of the wrist device, at a plane determined by the normal vector **504** of the user's back of hand **500** and a vector **506** perpendicular with respect to the normal vector of the user's fingers **508** and back of hand **500**. The normal vector **504** may also be determined from the plane **404** of the wrist device **102**, and the plane **502** is an imaginary plane generated in a wristband-like manner around the user's wrist.

[0051] In an embodiment, the main measuring direction of the one-dimensional acceleration sensor **304** is substantially in the direction of the normal vector **504** of the plane **404** of the wrist device.

[0052] In an embodiment, the main measuring direction of the one-dimensional acceleration sensor **304** is at the plane **404** of the wrist device, and when the wrist device **500** is in use, in the direction of a vector, such as vector **510**, perpendicular to the user's fingers.

[0053] With reference to FIGS. **6** and **7**, the movement pulse determination unit **602** of the wrist device **600** measures a plurality of directional acceleration components **618**, **620**, **622** and determines acceleration **708** in the direction of the lateral movement generated by the user's stepping by combining the plurality of directional acceleration components **618** to **622**. In a vector presentation, acceleration as in the direction of the lateral movement may be presented in the form:

$$a_S = a_1\hat{a}_1 + a_2\hat{a}_3 + a_3\hat{a}_3, \tag{1}$$

wherein a_1, a_2 and a_3 are linear coefficients and $\hat{a}_1, \hat{a}_2$ and $\hat{a}_3$ are directional acceleration components **618** to **622**. The linear coefficients a_1, a_2 and a_3 may be selected such that a linear combination presents acceleration optimally in the direction of the lateral movement **108**. The linear coefficients a_1, a_2 and a_3 may be coefficients determined in the manufacturing stage of the wrist device **600** or they may be determined during use in the wrist device **600**. The linear coefficients may be calculated in the processing unit **204**, for example.

[0054] The wrist device **600** may comprise a multidimensional acceleration measurement unit (AMU) **604**, which measures acceleration in a plurality of directions. The measurement geometry is typically well determined, allowing a deterministic resultant acceleration to be calculated from the accelerations measured in the different directions. The measuring elements measuring the acceleration in different directions may be mutually perpendicular or a prearranged angle may exist therebetween. The acceleration measurement unit **604** may be implemented by means of a multidimensional acceleration sensor or a plurality of one-dimen-

sional acceleration sensors. The acceleration measurement unit **604** may additionally comprise a movement analyzer **606** for determining the linear combination of the directional acceleration components **618** to **622**.

[0055] The movement analyzer **606** receives signals **612A**, **612B**, which characterize acceleration components, from the acceleration measurement unit **604** and determines the linear coefficients of the acceleration signals, for example, by utilizing the pulse structure generated by the linear combination. The movement analyzer **606** may calculate the linear combination and feed the linear combination to the pulse detector **608**, which determines movement pulses associated with the lateral movement **108** by using said linear combination **614** of the directional components. The pulse information **616** may be further led to processing or for display to a user.

[0056] The movement analyzer **606** may be implemented by means of the processing unit **204** as a computer process, for example.

[0057] In FIG. **8**, an example of the structure of a movement pulse is studied. The horizontal axis **800** shows time in a random unit, and the vertical axis **802** shows the strength of the movement pulse in an acceleration unit, for example. The first curve **808** represents a situation wherein the movement pulses are determined in a random direction, such as in the longitudinal direction of the user's wrist. Pulses 3A to 3D characterize step pair frequency, and interference pulses 4A to 4C are generated by the reciprocal movement of the hands in the direction of travel, for example. In the situation of curve **808**, the interference pulses 4A to 4C may be interpreted as pulses characterizing the step pair frequency in pulse identification, whereby an erroneous step pair frequency is obtained as the result. In this situation, the amplitude of the interference pulses 4A to 4C maybe very different for different users, and, accordingly, the identification of the pulses 3A to 3D may be uncertain.

[0058] The second curve **806** represents a situation wherein the direction of the acceleration sensors is optimized for the measurement of the lateral movement **108**, and movement pulses 1A to 1D characterize the lateral movement. Interference pulses 2A to 2C are generated by a slightly erroneous orientation of the acceleration sensor. In this situation, the amplitude of the interference pulses 2A to 2C is significantly less than in the case of curve **808**, and an erroneous interpretation of the movement pulses is significantly less likely. In addition, the user-dependence of the amplitudes of the interference pulses 2A to 2C is slight. The step pair frequency is obtained by determining a time interval **810** of two successive movement pulses and by taking the inverse value from the time interval.

[0059] The movement pulses determined by the invention may be used for a plurality of purposes. The processing unit **204** may calculate the step pair frequency, the velocity, the path traveled and/or the energy consumption, for example, from the movement pulses.

[0060] With reference to FIGS. **9** and **10**, let us study methods according to embodiments of the invention.

[0061] With reference to FIG. **9**, the method starts at **900**.

[0062] At **902**, acceleration is measured from the movement of the wrist device worn by the user during the user's stepping.

[0063] At **904**, movement pulses associated with the lateral movement **108** generated by the user's stepping are determined by using said acceleration.

[0064] In an embodiment, at **902**, acceleration in the direction of the lateral movement **108** generated by the user's stepping is measured, and, at **904**, movement pulses associated with the lateral movement **108** generated by the user's stepping are determined by using said acceleration in the direction of the lateral movement.

[0065] In an embodiment, acceleration in the direction of the lateral movement generated by the user's stepping is measured at **902** with a one-dimensional acceleration sensor **304**.

[0066] In an embodiment, at **902**, acceleration in the direction of the lateral movement **108** generated by the user's stepping is measured with the one-dimensional acceleration sensor **304**, whose measurement direction is restricted relative to the normal vector of the user's back of hand at a 45-degree angle and inside a cone generated around a vector perpendicular to the fingers, the spread angle of the cone being previously known.

[0067] In an embodiment, at **902**, acceleration in the direction of the lateral movement generated by the user's stepping is measured with the one-dimensional sensor **304**, the main component of whose acceleration is at a plane determined by the normal vector of the user's back of hand and a vector perpendicular with respect to the normal vector of the user's fingers and back of hand.

[0068] The method ends at **906**.

[0069] With reference to FIG. **10**, the method starts at **920**.

[0070] At **922**, several directional acceleration components **618** to **622** are measured.

[0071] At **924**, a linear combination of the directional acceleration components **618** to **622** is determined, the combination being in the direction of the lateral movement **108** generated by the user's stepping.

[0072] At **926**, movement pulses associated with the lateral movement **108** generated by the user's stepping are determined by using several directional components **618** to **622**, such as the linear combination of the directional components **618** to **622**, for example.

[0073] The method ends at **928**.

[0074] The method may be implemented as a computer process to be stored in the memory unit **206** and to be executed in the processing unit **205**, for example. The computer process may be included in encoded instructions that may be implemented with some known programming language. The encoded instructions maybe included in a computer software product whose physical expression may be a memory means or a signal. The memory means may be an optical or magnetic memory data entry device, for example.

[0075] Although the invention is described above with reference to the example in accordance with the accompanying drawings, it will be appreciated that the invention is not to be so limited, but may be modified in a variety of ways within the scope of the appended claims.

What is claimed is:

1. A wrist device comprising:
 a movement pulse determination unit for measuring acceleration from a movement of the wrist device during a user's stepping, the movement pulse determination unit being configured to determine movement pulses associated with a lateral movement generated by the user's stepping by using said acceleration.

2. A wrist device as claimed in claim **1**, wherein the movement pulse determination unit is configured to measure acceleration in the direction of the lateral movement generated by the user's stepping and to determine movement pulses associated with the lateral movement generated by the user's stepping by using said acceleration in the direction of the lateral movement.

3. A wrist device as claimed in claim **2**, wherein the movement pulse determination unit comprises a one-dimensional acceleration sensor configured to measure acceleration in the lateral movement generated by stepping.

4. A wrist device as claimed in claim **3**, wherein the one-dimensional acceleration sensor is configured to measure acceleration in the measuring direction, the measuring direction being restricted with respect to a normal vector of the user's back of hand at an angle of 45 degrees, and inside a cone generated around a vector perpendicular to the fingers, the spread angle of the cone being previously known.

5. A wrist device as claimed in claim **3**, wherein the one-dimensional acceleration sensor is configured to measure acceleration in the measuring direction, the main component of the acceleration being, during the use of the wrist device, at a plane determined by a normal vector of the user's back of hand and a vector perpendicular with respect to the normal vector of the user's fingers and back of hand.

6. A wrist device as claimed in claim **1**, wherein the movement pulse determination unit is configured to measure a plurality of directional acceleration components and to determine acceleration in the direction of the lateral movement generated by the user's stepping by combining a plurality of directional acceleration components.

7. A wrist device as claimed in claim **6**, wherein the movement pulse determination unit comprises:
 a multidimensional acceleration measurement unit configured to measure a plurality of directional acceleration components;
 a movement analyzer for determining a linear combination of the directional acceleration components, the linear combination of the directional acceleration components being in the direction of the lateral movement generated by the user's stepping; and
 the movement pulse determination unit is configured to determine movement components associated with the lateral movement generated by the user's stepping by using said linear combination of the directional components.

8. A method of determining movement information comprising:
 measuring acceleration from a movement of a wrist device worn by a user during the user's stepping; and
 determining movement pulses associated with a lateral movement generated by the user's stepping by using said acceleration.

9. A method as claimed in claim **8**, wherein acceleration is measured in the direction of the lateral movement generated by the user's stepping;
 and movement pulses associated with the lateral movement generated by the user's stepping are determined by using said acceleration in the direction of the lateral movement.

10. A method as claimed in claim **8**, wherein acceleration in the direction of the lateral movement generated by the user's stepping is measured with a one-dimensional acceleration sensor.

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11. A method as claimed in claim **8**, wherein acceleration in the direction of the lateral movement generated by the user's stepping is measured with a one-dimensional acceleration sensor, the measuring direction of which is restricted with respect to a normal vector of the user's back of hand at an angle of 45 degrees, and inside a cone generated around a vector perpendicular to the fingers, the spread angle of the cone being previously known.

12. A method as claimed in claim **8**, wherein acceleration in the direaction of the lateral movement generated by the user's stepping is measured with a one-dimensional acceleration sensor, the main component of whose acceleration is, during the use of the wrist device, at a plane determined by a normal vector of the user's back of hand and a vector perpendicular with respect to the normal vector of the user's fingers and back of hand.

13. A method as claimed in claim **8**, wherein a plurality of directional acceleration components is measured; and acceleration is determined the direaction of the lateral movement

generated by the user's stepping by combining a plurality of directional acceleration components.

14. A method as claimed in claim **13**, wherein a plurality of directional acceleration components is measured; and a linear combination of the directional acceleration components is determined in the direction of the lateral movement generated by the user's stepping; and movement pulses associated with the lateral movement generated by the user's stepping are determined by using said linear combination of directional components.

15. A computer program comprising encoded instructions for executing a computer process of claim **8**.

16. A computer program product comprising a computer program of claim **15**.

17. A memory means comprising a computer program of claim **15**.

18. A signal comprising a computer program of claim **15**.

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