

(19) World Intellectual Property
Organization
International Bureau



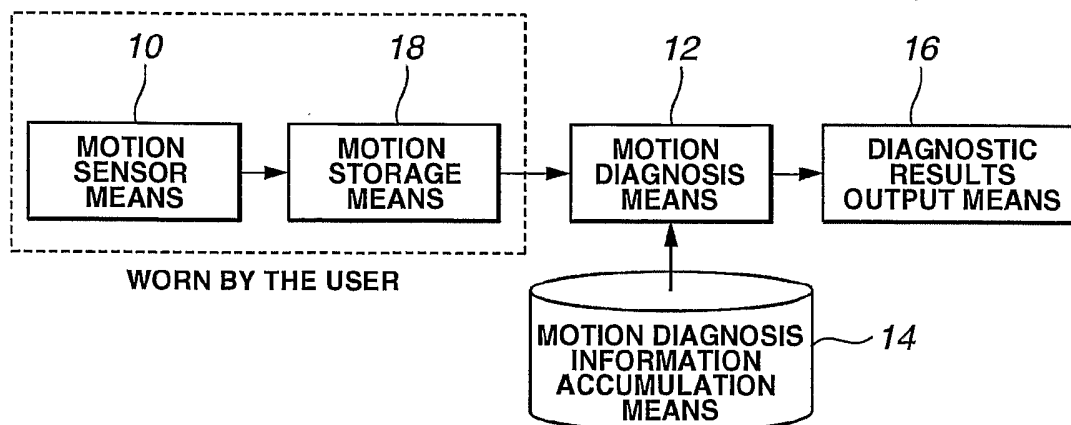
(43) International Publication Date
2 December 2004 (02.12.2004)

PCT

(10) International Publication Number
WO 2004/103176 A1

- (51) International Patent Classification⁷: A61B 5/11
- (21) International Application Number: PCT/JP2004/007402
- (22) International Filing Date: 24 May 2004 (24.05.2004)
- (25) Filing Language: English
- (26) Publication Language: English
- (30) Priority Data:
2003-145400 22 May 2003 (22.05.2003) JP
- (71) Applicant (for all designated States except US): GM & M COMPANY, INC. [JP/JP]; #104, 5-10-5, Higashi-gotanda,, Shinagawa-ku,, Tokyo 1410022 (JP).
- (72) Inventors; and
- (75) Inventors/Applicants (for US only): OBA, Toshihiko [JP/JP]; 2-2, Nakatsuru 1-chome,, Oita-shi,, Oita8700939 (JP). MATSUSHITA, Soichiro [JP/JP]; 1-40-3, Hikari-cho,, Kokubunji-shi,, Tokyo1850034 (JP).
- (74) Agents: INABA, Yoshiyuki et al.; TMI ASSOCIATES 23rd Floor, Roppongi Hills Mori Tower, 6-10-1, Roppongi Minato-ku, Tokyo 1066123 (JP).
- (81) Designated States (unless otherwise indicated, for every kind of national protection available): AE, AG, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BW, BY, BZ, CA, CH, CN, CO, CR, CU, CZ, DE, DK, DM, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MA, MD, MG, MK, MN, MW, MX, MZ, NA, NI, NO, NZ, OM, PG, PH, PL, PT, RO, RU, SC, SD, SE, SG, SK, SL, SY, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, YU, ZA, ZM, ZW.
- (84) Designated States (unless otherwise indicated, for every kind of regional protection available): ARIPO (BW, GH, GM, KE, LS, MW, MZ, NA, SD, SL, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European (AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HU, IE, IT, LU, MC, NL, PL, PT, RO, SE, SI, SK, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, ML, MR, NE, SN, TD, TG).
- Published:
— with international search report
— before the expiration of the time limit for amending the claims and to be republished in the event of receipt of amendments
- For two-letter codes and other abbreviations, refer to the "Guidance Notes on Codes and Abbreviations" appearing at the beginning of each regular issue of the PCT Gazette.

(54) Title: BALANCE FUNCTION DIAGNOSTIC SYSTEM AND METHOD BALANCE FUNCTION DIAGNOSTIC SYSTEM AND METHOD



(57) Abstract: A balance diagnostic apparatus and system is given a portable size and weight and also expands the places of use and methods of use to a large range, thus achieving an environment wherein anyone can undergo diagnosis of balance disorders at any time or any place. At least motion sensor means 10 and motion storage means 18 that temporarily stores signals that represent motion from the motion sensor means 10 are worn on the body of the user. Moreover, once the motion situation is stored in the motion storage means 18, the input of the motion diagnosis means 12 is connected to the output of the motion storage means 18 to obtain the output of diagnostic results with this balance function diagnostic system.

WO 2004/103176 A1

DESCRIPTION

BALANCE FUNCTION DIAGNOSTIC SYSTEM AND METHOD

BACKGROUND OF THE INVENTION

5 The present invention relates to an apparatus that is worn on the body of the user and that is used in a system that supports therapeutic knowledge-based diagnosis of the functions of balance by obtaining information on unconsciously occurring motions such as sway or inclination of the body, and to said system. This system is effective in diagnosing not only diseases of the balance function and also states of functional deterioration such as the state of fatigue, for example.

10 In the diagnosis of balance disorders including dizziness or vertigo, the publication of unexamined Japanese patent application (Kokai) No. JP-A 8-215176, for example, presents a known examination apparatus and system called a Stabilometer that calculates the distribution of weight applied to the soles of the feet together with the time that the user is standing straight up, thereby analyzing unconscious motions of the body (JP-A 8-215176).

15 With this system, the user steps onto an apparatus that resembles a weighing scale for home use, so that the distribution of force acting on the horizontal surface of the scale is measured by strain gages or other force sensors, and thus the diagnosis is performed by merely having the user stand on the apparatus.

20 The information measured by this apparatus is the change over time in the position of the center of gravity of the body as estimated by the distribution of force applied to the soles of the feet. Motion patterns are collected in advance from those of healthy persons and persons with characteristic diseases related to balance function disorders. These motion patterns are collected over a fixed period of time of 30 seconds or 60 seconds for each of the states of eyes being open and eyes being closed. When a new motion pattern is collected from a user, a diagnosis of balance function is performed by statistical identification of a

motion pattern from the pre-collected motion patterns which is closest to the new motion pattern collected from the user.

The apparatus and diagnostic method based on this scheme is listed in *Shakai Hoken Shinryō Hōshū ni Kan-suru Ika Tensū Hyō no Kaishaku*

5 [Interpretation of the Medical Score Table Pertaining to Social Insurance Medical Treatment and Diagnosis Remuneration] published by the Ministry of Health, Labour and Welfare (Ministry of Health and Welfare at the time of publication) on March 16, 1994 (Notification No. 25 of the Health Insurance Bureau), and is being used for diagnosis in insurance and medical treatment facilities within Japan.

10 In the diagnosis of sense of balance function based on the prior art, the user stands upon the horizontal surface of a scale-like apparatus and the distribution of weight applied to the soles of the feet is measured, so the apparatus must have a horizontal surface of at least sufficient surface area to stand on with both feet. In addition, it must be able to withstand a weight of at least several dozen kilograms
15 while also being able to detect the slight unconscious motions (typically on the order of several millimeters when taken as the distance of motion of the position of the center of gravity). Thus when sensors such as the strain gages currently in use are used, it is indispensable for the examination apparatus to have a certain amount of weight.

20 To wit, it is necessary to make the horizontal surface out of a material that both prevents damage to the apparatus due to body weight and also reversibly bends under body weight with good reproducibility, so a heavy metal plate is typically used as this material.

Moreover, from the nature of the apparatus in that it measures the weight
25 distribution, it is preferable that gravity act in the direction perpendicular to the horizontal surface upon which the user stands, so it is necessary for the installation position of the measurement apparatus to be calibrated in advance with respect to gravity applied to the horizontal surface.

Due to the above, from the standpoint of limitations on the size and weight
30 of the apparatus and the installation location, it is quite difficult for a conventional sense of balance function diagnostic apparatus to be made portable and used in

everyday life. In addition, due to the principle of operation of the apparatus, it cannot be used in locations without gravity.

Moreover, with a diagnostic apparatus based on the prior art, the user must be standing on both feet for at least a fixed period of time, for example, 30 seconds
5 or 60 seconds. For this reason, the people who can be diagnosed are limited to those who can stand straight on both feet, so it is a diagnostic method that cannot be used on persons who may have a disorder of the sense of balance function, but have difficulty maintaining the standing position for long periods of time, or persons who are not easily measured in the standing position due to other
10 symptoms.

In this manner, with a sense of balance diagnostic apparatus according to the prior art, the situation is not such that anyone can undergo diagnosis easily at any time or any place.

15 SUMMARY OF THE INVENTION

Thus, the present invention came about in order to solve the aforementioned problems and its object is to make the diagnostic apparatus one of a portable size and weight and also expand the places of use and methods of use to a much greater range than those based on the prior art, thus achieving an
20 environment wherein anyone can undergo diagnosis of balance disorders at any time or any place.

With the prior art, the user stands upon a scale-like apparatus and the diagnosis of balance disorders is performed based on the principle of measuring the distribution of gravity acting on the soles of the feet. However, the present
25 invention utilizes the measurement of motion at characteristic locations on the body, namely the positions of the head and waist of the user where the so-called "vertigo or dizziness" phenomenon acts, thus using motion sensor means for measuring these motions. In addition, motion diagnosis means that processes signals from the motion sensor means and gives appropriate diagnostic results is
30 also used.

In addition, in a configuration wherein the motion diagnosis means is not portable but rather is installed such that it is physically isolated from the motion sensor means, by making motion storage means, which temporarily stores signals from the motion sensor means using a semiconductor memory or other storage device, portable together with the motion sensor means, it is possible to adopt a configuration where diagnosis is performed by having the user carry only an even more compact and lighter apparatus.

To wit, the present invention provides a balance function diagnostic system comprising a portable terminal unit that can be worn on the body of the user and an analytical apparatus that analyzes the data from this portable terminal unit, wherein said portable terminal unit comprises motion sensor means that detects the motion of the body of said user, said analytical apparatus comprises motion diagnosis means that processes signals from said motion sensor means and performs diagnosis of balance function based on prerecorded motion diagnosis information, and where said balance function diagnostic system is constituted such that it is able to analyze the motion of said user and output diagnostic information related to balance function.

Here, the "detection of motion" is defined to include the detection of characteristic motions that appear together with disorder or deterioration of the sense of balance, including for example, speed in linear motion, acceleration, angular velocity around various central axes of rotation, and the like.

In addition, the present invention provides a balance function diagnostic system comprising a portable terminal unit that can be worn on the body of the user and an analytical apparatus that analyzes the data from this portable terminal unit, wherein said portable terminal unit comprises motion sensor means that detects the motion of the body of said user and motion storage means that stores signals from said motion sensor means, said analytical apparatus comprises motion diagnosis means that processes signals from said motion sensor means and performs diagnosis of balance function based on prerecorded motion diagnosis information, and where said system is constituted such that it is able to analyze the motion of said user and output diagnostic information related to balance function.

In addition, the present invention provides a balance function diagnostic system comprising a portable terminal unit that can be worn on the body of the user and an analytical apparatus that analyzes the data from this portable terminal unit, wherein said portable terminal unit comprises motion sensor means that
5 detects the motion of the body of said user and motion information sending means that sends signals from said motion sensor means wirelessly to the outside, said analytical apparatus comprises motion information receiving means that receives signals from said motion information transmission means and obtains signals from said motion sensor means, motion diagnosis means that processes signals from
10 said motion sensor means and performs diagnosis of balance function based on prerecorded motion diagnosis information, and where said system is constituted such that it is able to analyze the motion of said user and output diagnostic information related to balance function.

In addition, said motion diagnosis means may further comprise stimulus
15 generation means that applies sensory stimuli to said user, so by sharing information related to the characteristics of sensory stimuli applied to said user by said stimulus generation means in said motion diagnosis means, it is possible to analyze signals from said motion sensor means with respect to specific stimuli and output diagnostic information for the balance function.

In addition, the present invention provides a portable terminal unit used in a
20 balance function diagnostic system having a constitution as described above, where said motion sensor means is constituted such that it can be mounted on the top of the head of said user, and where said portable terminal unit is constituted so as to have detection sensitivity in at least the anterior/posterior direction and the
25 left/right direction with respect to the head.

In addition, the present invention provides a portable terminal unit used in a
balance function diagnostic system having a constitution as described above, where said motion sensor means is constituted such that it can be mounted in the waist area of said user, and where said portable terminal unit is constituted so as to
30 have detection sensitivity in at least the anterior/posterior direction and the left/right direction with respect to the centerline of the body of said user.

In addition, the present invention provides a diagnostic apparatus used in a balance function diagnostic system having a constitution as described above.

In addition, the present invention provides a computer-readable program for the purpose of executing said motion analysis means in the diagnostic apparatus having a constitution as described above. This program can also be
5 stored on recording media.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a balance function diagnostic system
10 according to Embodiment 1 of the present invention.

FIG. 2 is a block diagram of a balance function diagnostic system according to Embodiment 2 of the present invention.

FIG. 3 is a block diagram of a balance function diagnostic system according to Embodiment 3 of the present invention.

FIG. 4 is a block diagram of a balance function diagnostic system
15 according to Embodiment 4 of the present invention.

FIG. 5 is a block diagram of a balance function diagnostic system according to Embodiment 5 of the present invention.

FIG. 6 is a block diagram of a balance function diagnostic system
20 according to Embodiment 6 of the present invention.

FIG. 7 is a functional block diagram illustrating the constitution of a balance function diagnostic system according to the present invention.

FIG. 8 is a flowchart of one example of the processing of information by a balance function diagnostic system according to the present invention.

FIG. 9 is a diagram illustrating the acceleration trace pattern of a user
25 obtained from an acceleration sensor.

FIG. 10 is a diagram illustrating an example of finding the surface area based on the aforementioned acceleration trace pattern.

FIG. 11 is a diagram illustrating an example of finding the total trace length
30 from the aforementioned acceleration trace pattern.

FIG. 12 is a diagram illustrating the results of a Fourier transform from the time signal $f(t)$ to the frequency function $F(\omega)$.

DETAILED DESCRIPTION OF THE DRAWINGS AND THE PRESENTLY
5 PREFERRED EMBODIMENTS

(Embodiment 1)

FIG. 1 illustrates Embodiment 1 of the present invention, where signals representing the motion of the body of the user detected by motion sensor means 10 are provided as input to motion diagnosis means 12. The motion diagnosis means 12 calculates, from the signals that represent motion, physical characteristic quantities which are various parameters stored in motion diagnosis information accumulation means 14 that describe physical motion, such as the acceleration, velocity, displacement and frequency components, for example. In addition, by performing a comparison with prerecorded physical characteristic quantities
15 acquired from healthy persons and non-healthy persons with specific disorders of balance function, namely by comparing with motion diagnosis information, the diagnosis of balance function is performed. Moreover the diagnostic results are output via diagnostic results output means 16.

In this Embodiment, on the body of the user is worn at least the motion sensor means 10 but other constituent elements, namely the motion diagnosis means 12, motion diagnosis information accumulation means 14 and diagnostic results output means 16 need not necessarily be worn on the body of the user.
20

However, in the case that the motion sensor means 10 and the motion diagnosis means 12 are connected by physical wiring or namely electrical signal wiring, there is the possibility that the presence of wiring may impede the natural motions of the user, so it is more preferable that all of the means be worn on the body of the user.
25

(Embodiment 2)

FIG. 2 illustrates Embodiment 2 of the present invention, where at least motion sensor means 10 and motion storage means 18 that temporarily stores signals representing motion from the motion sensor means 10 are worn on the
30

body of the user. Moreover, once the situation of motion is stored in the motion storage means 18, by connecting the output of the motion storage means 18 to the input of the motion diagnosis means 12, diagnostic result output is obtained in the same manner as the procedure recited in Embodiment 1.

5 In this Embodiment, the only constituent elements that must be on the body of the user are the motion sensor means 10 and the motion storage means 18, and the electrical signal wiring or other physical wiring need be provided between the motion storage means 18 and the motion diagnosis means 12 only after the measurement of the motion of the user is complete, so it is possible to make the
10 measurements required for diagnosis without impeding the natural motions of the user.

(Embodiment 3)

FIG. 3 illustrates Embodiment 3 of the present invention, where the motion storage means 18 in Embodiment 2 is replaced by motion information sending
15 means 20 worn by the user and motion information receiving means 22 that need not necessarily be worn by the user, so that motion information is transmitted between the two by a wireless method as a motion information signal.

To wit, in this Embodiment, the only constituent elements that must be worn on the body of the user are the motion sensor means 10 and the motion
20 information sending means 20, while the other constituent elements, namely the motion information receiving means 22, motion diagnosis means 12, motion diagnosis information accumulation means 14 and diagnostic results output means 16 need not necessarily be worn on the body of the user.

In this Embodiment, the equipment worn on the body of the user is
25 minimized while the measured information is transmitted in real time to outside equipment that performs the motion diagnosis, so it is possible to perform motion diagnosis that requires real-time response without impeding the natural motions of the user.

(Embodiment 4)

30 FIG. 4 illustrates Embodiment 4 of the present invention, where the balance function diagnostic system according to Embodiment 1 is combined with stimulus

generation means 24, which actively applies sensory stimuli to the user and is coupled to the motion diagnosis means 12.

Here, the sensory stimuli generated by the stimulus generation means 24 may be, for example, visual stimuli given to the user by the projection of moving images onto a large screen, a light source that is given varying intensity, a head-mounted display worn on the head of the user, or other presentation of images from equipment that projects images near the eye, auditory stimuli including stereo or other three-dimensional stimuli given in an auditory manner, or active stimuli that act with physical force on the body of the user, such as pressure applied on the back of the user, for example.

In this Embodiment, in addition to the stimulus generation means 24 which gives these kinds of stimuli, by transmitting to the motion diagnosis means 12 information as to when the stimulus generation means 24 gave what kind of stimuli to the user, it is possible to easily identify the corresponding signals from the motion sensor, thus making active diagnosis of balance function possible.

In addition, the stimulus generation means 24 according to this embodiment may also be used together with Embodiment 2 or 3 of the present invention, and in either case the weight of equipment that must be worn on the body of the user can be reduced and also the natural motions of the user are not impeded by physical electrical signal wiring or the like, so it is possible to perform motion diagnosis of the user under application of external stimuli in a more natural situation.

(Embodiment 5)

FIG. 5 illustrates an example of the balance function diagnostic apparatus 1 according to Embodiment 5 of the present invention, being an example where a motion sensor 30 consists of force sensors or acceleration sensors, mounted on the top of the head, that are sensitive in the anterior/posterior direction and the left/right direction with respect to the head.

Note that at the time of measurement, it is preferable that the head of the user be in the same orientation as when standing straight with respect to the ground, namely the top of the head should be furthest from the ground. In the diagnosis of

balance function, measurement of physical sway of the head is effective, but with this Embodiment, it is possible to measure not only coordinate translation of the head in the anterior/posterior direction and in the left/right direction, but also the angle of the top of the head with respect to the horizontal plane of the ground, and
 5 namely the change in orientation of the head can also be acquired as motion information supplied for diagnosis. To wit, by using acceleration sensors that are sensitive with respect to gravity (static accelerometers), it is possible to calculate the angle of the top of the head with respect to the gravity direction.

Now, taking θ to be the angle of the top of the head with respect to the
 10 horizontal plane of the ground, G to be the acceleration due to gravity and a to be the acceleration measured by the acceleration sensor, the relationship

$$a = G \cdot \sin \theta \dots \dots \dots (1)$$

holds true. Here, if θ is extremely small, specifically when it is smaller than approximately 5° , then the relationship $\sin \theta \approx \theta$ holds true (provided that the units
 15 of θ are radians), so the relationship can be expressed as:

$$a \approx G \cdot \theta \dots \dots \dots (2)$$

This means that when the user wears the sensor on the top of the head, as long as the angle with respect to the ground can be maintained within an error range of roughly 5° or less, then the change in orientation of the head of the user,
 20 namely the fluctuation in θ can be read as the fluctuation in the measured acceleration a . Accordingly, even without calibrating the relationship between the orientation (angle) and acceleration each time the sensor is mounted on the top of the head, sway of the top of the head can be measured with good reproducibility.

Note that since the acceleration sensor is sensitive to the angle with respect
 25 to the ground, or namely to the degree of action of gravity, the acceleration thus measured includes that due to linear motion and that corresponding to the change in angle. Thus, in order to make more accurate measurement possible, for the change in angle, it is possible to use a gyro sensor which is a sensor sensitive to rotary motion and thus achieve isolation from linear motion. However, in actual
 30 measurements, the change in the angle with respect to the ground is mostly a slow

change in contrast to linear motion, so by extracting from the signal from the acceleration sensor only the high-frequency components, namely the components that change with a period of roughly 2 cycles per second or greater, it is possible to perform appropriate diagnosis. In this case, the diagnosis is performed after
5 removing as noise the signal components output from the acceleration sensor (e.g., the low-frequency components) due to the change in posture of the user.

In addition, regarding coordinate translation of the top of the head in the forward and backward, left and right directions also, if the dispersion in the mounting position of the motion sensor on the top of the head is less than $\pm 5^\circ$ as
10 an angle of inclination, because $\sin 5^\circ \approx 0.08$, it is possible to measure the acceleration of motion in the forward and backward, left and right directions to an error of roughly 10% or less.

In addition, with the motion sensor mounted on the top of the head, limitations due to the clothing of the user are few and by adopting a constitution
15 like that of a hair band or headphones, it has an advantage that it can be used easily by anyone.

Note that the sensors that can be used as motion sensors include acceleration sensors that calculate acceleration by measuring the forces acting on a weight in the interior of the sensor, along with gyro sensors that measure the
20 angular velocity, but from the nature of measuring fluctuations at the top of the head, it is preferable to measure motion in at least the two directions of forward and backward/left and right with respect to the orientation of the top of the head in the standing position.

(Embodiment 6)

25 FIG. 6 illustrates an example of the balance function diagnostic apparatus 2 according to Embodiment 6 of the present invention, being an example where motion sensor means 34 consists of a motion sensor worn at the waist of the user and secured to the front of the body at the waist using a belt-like jig 32.

The waist is the part of the body that serves as the base for nearly all of the
30 motions of the human body, so random motions that are meaningless in the diagnosis of balance function occur less readily than in the extremities such as the

hands or feet and thus highly reliable motion information is obtained.

Accordingly, while the motion sensor is placed on the front of the body at the waist in this embodiment, similar meritorious effects can be obtained even if it is placed at the center of the back.

5 Measurement of body sway is effective in the diagnosis of balance function, so measurement of the forward and backward/left and right motions of the waist area which is near the center of the body is effective, and thus it is preferable to use acceleration sensors or angular velocity sensors that are sensitive in these respective directions.

10 Here follows a description of the functions of the various components of the balance function diagnostic system according to the present invention. FIG. 7 is a functional block diagram illustrating the constitution of a balance function diagnostic system 3 according to the present invention. In the balance function diagnostic system 3 in this figure, acceleration sensors 36 serving as the motion
15 sensor means for detecting motion in the X-axis and motion in the Y-axis are electrically connected to analog/digital converters 40 and 42, respectively, and moreover the analog/digital converters 40 and 42 are electrically connected to a microcomputer 44. In addition, the microcomputer 44 is provided with an electrically connected diagnostic information memory 46, startup switch 48,
20 diagnostic result output device 50 and speaker 52. Here follows a description of the constitution of each.

 First, the acceleration sensor 36 serving as the motion sensor means will be described. The acceleration sensor 36 consists of a sensor for detecting motion in the X-axis 36a and a sensor for detecting motion in the Y-axis 36b, thus
25 calculating the acceleration by measuring the forces acting on a weight in the interior of the sensor.

 Note that from the standpoint of the object of the present invention which is to diagnose balance function, it is preferable for the acceleration sensor 36 to be mounted on the top of the head as shown in FIG. 5 or at the waist as shown in
30 FIG. 6. For example, by mounting an acceleration sensor on the top of the head, it is possible to measure sway at the top of the head with good reproducibility and

low error, without calibrating the relationship between the orientation (angle) and acceleration. In addition, by mounting an acceleration sensor at the waist which is equivalent to the center of the body, random motions that are meaningless in the diagnosis of balance function occur less readily than in the extremities such as the hands or feet and thus highly reliable motion information is obtained. Note that when mounting at the waist, it is preferably mounted at the position of the navel which is near the center of gravity of the human body and positioned along the centerline of the body.

In order to measure the acceleration corresponding to the typical body sway of a healthy person which is 10-20/1000 G (where G is the acceleration due to gravity) with adequate resolution, the acceleration sensor 36 used in the present invention preferably has sufficient resolution to resolve an acceleration of roughly 5/1000 G or less.

Next, the microcomputer 44 will be described. The microcomputer 44 has the function of performing arithmetic processing on the acceleration signals received from the acceleration sensor 36 based on the characteristic quantity data used to determine a diagnosis. Specifically, it has a diagnostic information memory 46 as the motion diagnosis accumulation means that stores information used to determine a diagnosis, and motion diagnosis means (not shown) that analyzes signals received from the acceleration sensor 36 based on the motion characteristic quantity data used to determine a diagnosis, and has the function of providing output of the results of this process to the diagnostic result output device 50 and speaker 52 to be described later.

The diagnostic result output device 50 is a device that provides output of the diagnostic results from the microcomputer 44 to the outside, so that the diagnostic results can be displayed on the screen of a monitor, or the diagnostic results can be printed by a printer or the like on paper media.

The analog/digital converters 40 and 42 are devices that convert the analog signals output from the acceleration sensor 36 into digital signals. The speaker 52 is a device used to convey the start of measurement with a sound, provide voice output of the diagnostic results from the microcomputer 44, provide voice output

of operating signals for the operator, and otherwise serve as an auxiliary output of the diagnostic result output device 50. The analog/digital converters 40 and 42 and speaker 52 are not particularly limited in their type, so commercially available units may be used.

5 In addition, the balance function diagnostic system 3 according to the present invention may also comprise motion storage means that temporarily stores information from the acceleration sensor 36, motion information sending means that sends information from the acceleration sensor 36 wirelessly, and motion
10 information receiving means that receives signals from the motion information transmission means and transmits those signals to the motion diagnosis means.

Here follows a description of one example of information processing by the balance function diagnostic system 3 according to the present invention, made with reference to the flowchart given in FIG. 8.

When the startup switch of the balance function diagnostic system of the
15 present invention is moved to ON (ST1), the balance function diagnostic system starts up and measurement by the acceleration sensor starts several seconds after the startup switch is ON. Thus, it is preferable that the diagnostic apparatus be attached to the body before the startup switch is turned ON. However, the time from startup to the start of measurement can be set appropriately depending on the
20 situation, such as in the case in which the person to undergo diagnosis performs the measurement himself/herself, or the case in which another person operates the apparatus.

The timing of the start/end of measurement can be indicated using a LED or other light, but there are cases in which an optical notification method is not
25 appropriate, such as in the case that the user performs the measurement alone and the main apparatus is not within the field of view of the user or if the user must close their eyes as a condition of measurement. In this case, the start and end of measurement are audibly conveyed to the user in the form of sound effects from the speaker (ST2).

30 The motion data collected from the acceleration sensor may be the physical characteristic quantities of acceleration, velocity, displacement and frequency

components, for example, which are stored in the computer by the motion storage means (ST3). The stored motion data may be stored temporarily and deleted at the time of the end of measurement, or overwritten with newly collected motion data at the time of the next measurement.

5 Measurement can typically be performed in 30 to 60 seconds, but the measurement time can also be set appropriately depending on the condition of the user. For example, a patient with severe impairment of the brain function may find it difficult to maintain the standing position for a fixed period of time, so the measurement time may be set to the shortest value, or when examining a patient
10 on the first examination for a diagnosis of dizziness or vertigo, it is necessary to determine the degree of dizziness, so the measurement time can be set to the longest value, or other changes are possible.

When the collection of motion data is complete, a sound effect or the like notifies the user of the end of measurement (ST4). At this time, they user may
15 remove the diagnostic apparatus from the body.

At the same time, the microcomputer calculates the motion characteristic quantities of the collected motion data (ST5). As a result, the motion characteristic quantities thus obtained are compared against motion characteristic quantities measured and recorded previously from healthy persons or non-healthy
20 persons with specific disorders of balance function, or namely compared against diagnostic determination data as motion diagnostic information (ST6).

The information obtained as a result of the comparison is output from the diagnostic result output device as diagnostic information (ST7). At this time, the diagnostic information may be displayed on the screen of a display or the like or
25 printed on paper media by a printer or the like.

Note that the measurement may be performed while standing or while sitting, and there is no need for the user to be standing continuously during measurement as is required with a prior-art balance diagnostic apparatus.

Here follows a description of the method of processing kinetic motion data
30 obtained from the acceleration sensor. FIG. 9 presents a motion trace from a user

as obtained from the acceleration sensor. In the illustrated example, the mounting location of the acceleration sensor is the top of the head as shown in FIG. 5.

When an acceleration sensor 54 is mounted on the top of the head of a person, the left/right sway (lateral sway) in the X-axis direction in FIG. 9(a) are detected, and the anterior/posterior sway (longitudinal sway) in the Y-axis direction in FIG. 9(b) are detected. FIG. 9(b) illustrates the value of the acceleration over time as a trace pattern. In this figure, from the acceleration value at time t_1 and the acceleration value at time t_2 , it is possible to find a characteristic quantity that indicates how much the axis of the body has swayed over a fixed period of time.

FIG. 10 illustrates an example of finding the surface area based on the acceleration trace pattern described above. As shown in this figure, the length of the outermost periphery is calculated from the two-dimensional acceleration trace. Then, the surface area of the range enclosed by the outermost periphery (the blackened-out range) is found to find a characteristic quantity that represents how much the head of the user swayed over how much of a range at most.

In addition, it is also possible to find the kinetic energy amount necessary to move the head of the user. FIG. 11 presents an example of finding the total trace length from the acceleration trace pattern. The trace of acceleration is plotted over time from the time t_1 to t_2, t_3, \dots, t_n , and the distances between the plotted points are found as the trace lengths L_1, L_2, \dots . Moreover, as illustrated below, by adding up the length L_1 of the acceleration trace from time t_1 to time t_2 , the length L_2 of the acceleration trace from time t_2 to time t_3, \dots the length of the acceleration trace from time t_{n-1} to time t_n , it is possible to find a characteristic quantity indicating just how much kinetic energy was used to move the head of the user during the measurement time (the total trace length).

$$\begin{aligned} \text{total trace length} = & \text{length } L_1 \text{ of the acceleration trace from time } t_1 \text{ to time } t_2 \\ & + \text{length } L_2 \text{ of the acceleration trace from time } t_2 \text{ to time } t_3 \\ & + \text{length of the acceleration trace from time } t_{n-1} \text{ to time } t_n \end{aligned}$$

Moreover, when as a result of measurement, the relationship between time and acceleration takes the form of the graph in FIG. 12(a), if a Fourier transform is

performed from the time signal $f(t)$ to the frequency function $F(\omega)$, a graph illustrating the relationship of the amplitude to the frequency such as that in FIG. 12(b) is obtained. In this graph, it is possible to find the vibration energy over a stipulated range of frequencies (the range indicated by arrows) as a characteristic quantity. Note that this characteristic quantity can be found for both the X-axis and the Y-axis.

The balance function diagnostic apparatus and system according to the present invention was described in the case of being used to measure the balance function of a human, but the balance function diagnostic apparatus and system according to the present invention can also be applied to a standing two-legged walking-type robot. In this case, by subjecting the information obtained from the motion sensor to information processing by the microcomputer and by reflecting the diagnostic results in the operation of the hands and feet or other extremities, it becomes possible to form a posture that will prevent the robot from toppling over. Even in the case that the robot should topple, it is also possible to send the robot commands to form a posture that will minimize the shock upon toppling.

In addition, the balance function diagnostic apparatus and system according to the present invention performs measurements using an acceleration sensor or other motion sensor mounted upon a portion of the body, so the presence of gravity is not assumed as in the case of the scale-type measurements according to the prior art, and there are also no limitations on location. Thus, it can also be used in a zero-gravity environment such as that in space.

As described above, by having the user wear motion sensor means upon their body and calculating the characteristic motions of parts of the body related to the balance function, it is possible to achieve a balance function diagnostic apparatus and system that can be used by anyone at any time or any place, which is difficult with the prior art.

In addition, because of the characteristic of the apparatus and system according to the present invention of being able to be used at any time or any place, the user can perform daily diagnosis of the balance function with no necessity for

the user to go to a medical facility, so the state of health can be easily determined on an everyday basis.

In addition, dizziness or vertigo becomes a major problem in space, but the apparatus and system according to the present invention can be used even in a
5 zero-gravity environment such as that of space.

In addition, the diagnostic apparatus and system according to the present invention may also be utilized to perform quantitative evaluation of the balance function, evaluation of the gravity of balance disorders, evaluation of the degree of improvement of balance disorders, evaluation of the effectiveness of treatment, as
10 an index of development of the balance function, and for inferring the damaged organ causing balance disorder, etc.

CLAIMS

1. A balance function diagnostic system comprising:
a motion sensor wearable on a user that detects bodily motion of the user;
5 and
a motion analyzer that analyzes signals from the motion sensor based on
prerecorded motion diagnosis information and performs diagnosis of balance
function of the user.
- 10 2. A balance function diagnostic system according to claim 1, wherein the
bodily motion is detected as any of a velocity, an acceleration, an angular velocity
and a frequency.
- 15 3. A balance function diagnostic system according to claim 1, wherein the
motion analyzer is placed separately from the use and wirelessly connected to the
motion sensor.
4. A balance function diagnostic system according to claim 1, wherein the
motion sensor is provided with a motion storage wearable on the user that stores
20 the signals from the motion sensor.
5. A balance function diagnostic system according to claim 1, wherein the
prerecorded motion diagnosis information is obtained from healthy persons.
- 25 6. A balance function diagnostic system according to claim 1, wherein the
prerecorded motion diagnosis information is obtained from non-healthy persons.
7. A balance function diagnostic system according to claim 1, further
comprising a stimulus generator that applies a sensory stimulus to the user.

8. A balance function diagnostic system according to claim 7, wherein the sensory stimulus comprises a visual stimulus.
9. A balance function diagnostic system according to claim 8, wherein the
5 visual stimulus comprises moving images projected on a screen.
10. A balance function diagnostic system according to claim 8, wherein the visual stimulus comprises a light emitted at varying intensity.
- 10 11. A balance function diagnostic system according to claim 7, wherein the sensory stimulus comprises an auditory stimulus.
12. A balance function diagnostic system according to claim 7, wherein the sensory stimuli comprise a physical stimulus that is exerted on the user.
15
13. A balance function diagnostic system according to claim 1, wherein the motion sensor is attached to the head of the user.
14. A balance function diagnostic system according to claim 1, wherein the
20 motion sensor is attached to the waist of the user.
15. A balance function diagnostic system according to claim 1, wherein the motion sensor comprises an acceleration sensor sensitive to gravity.
- 25 16. A balance function diagnostic system according to claim 1, wherein the motion sensor comprises a gyro sensor.
17. A balance function diagnostic system according to claim 1, wherein low-
frequency components are removed from the signals from the motion sensor
30 before they are analyzed.

18. A balance function diagnostic system according to claim 1, wherein signal components resulting from a change in posture of the user are removed from the signals from the motion sensor before they are analyzed.
- 5 19. A balance function diagnostic system according to claim 1, wherein the motion sensor measures motions in two directions in a plane.
20. A balance function diagnostic system according to claim 1, further comprising a diagnostic output device that outputs diagnostic results from the
10 motion analyzer.
21. A balance function diagnostic system according to claim 20, wherein the diagnostic results comprise a two-dimensional trace pattern representing motion of the user over a time.
15
22. A balance function diagnostic system according to claim 21, wherein the diagnostic results comprise a calculated area encompassed by the trace pattern.
23. A balance function diagnostic system according to claim 21, wherein the
20 diagnostic results comprise a total trace length of the trace pattern.
24. A balance function diagnostic system according to claim 21, wherein the diagnostic results comprises energy spent in the detected motion.
- 25 25. A balance function diagnostic system according to claim 1, wherein the motion sensor detects bodily motion of the user being in a sitting position.
26. A balance function diagnostic system according to claim 1, further comprising a sensory signal output device that output a sensory signal to the user
30 when a start and/or an end of detecting bodily motion of the user.

27. A balance function diagnostic system according to claim 26, wherein the sensory signal output device is a speaker.
28. A balance function diagnostic system according to claim 26, wherein the
5 sensory signal output device is an LED.
29. A balance function diagnostic system comprising:
a motion sensor wearable on a user that detects bodily motion of the user;
a stimulus generator that applies a sensory stimulus to the user; and
10 a motion analyzer that analyzes signals from the motion sensor and
performs diagnosis of balance function of the user.
30. A balance function diagnostic system according to claim 29, wherein the
bodily motion is detected as any of a velocity, an acceleration, an angular velocity
15 and a frequency.
31. A balance function diagnostic system according to claim 29, wherein the
motion analyzer is placed separately from the use and wirelessly connected to the
motion sensor.
20
32. A balance function diagnostic system according to claim 29, wherein the
motion sensor is provided with a motion storage wearable on the user that stores
the signals from the motion sensor.
- 25 33. A balance function diagnostic system according to claim 29, wherein the
sensory stimulus comprises a visual stimulus.
34. A balance function diagnostic system according to claim 33, wherein the
visual stimulus comprises moving images projected on a screen.
30

35. A balance function diagnostic system according to claim 33, wherein the visual stimulus comprises a light emitted at varying intensity.
36. A balance function diagnostic system according to claim 29, wherein the
5 sensory stimulus comprises an auditory stimulus.
37. A balance function diagnostic system according to claim 29, wherein the sensory stimulus comprises a physical stimulus that is exerted on the user.
- 10 38. A balance function diagnostic system according to claim 29, wherein the motion sensor is attached to the head of the user.
39. A balance function diagnostic system according to claim 29, wherein the motion sensor is attached to the waist of the user.
- 15 40. A balance function diagnostic system according to claim 29, wherein the motion sensor comprises an acceleration sensor sensitive to gravity.
41. A balance function diagnostic system according to claim 29, wherein the
20 motion sensor comprises a gyro sensor.
42. A balance function diagnostic system according to claim 29, wherein low-frequency components are removed from the signals from the motion sensor before they are analyzed.
- 25 43. A balance function diagnostic system according to claim 29, wherein signal components resulting from a change in posture of the user are removed from the signals from the motion sensor before they are analyzed.
- 30 44. A balance function diagnostic system according to claim 29, wherein the motion sensor measures motions in two directions in a plane.

44. A balance function diagnostic system according to claim 29, further comprising a diagnostic output device that outputs diagnostic results from the motion analyzer.
- 5
45. A balance function diagnostic system according to claim 44, wherein the diagnostic results comprise a two-dimensional trace pattern representing motion of the user over a time.
- 10 46. A balance function diagnostic system according to claim 45, wherein the diagnostic results comprise a calculated area encompassed by the trace pattern.
47. A balance function diagnostic system according to claim 45, wherein the diagnostic results comprise a total trace length of the trace pattern.
- 15
48. A balance function diagnostic system according to claim 45, wherein the diagnostic results comprises energy spent in the detected motion.
49. A balance function diagnostic system according to claim 29, wherein the motion sensor detects bodily motion of the user being in a sitting position.
- 20
50. A balance function diagnostic system according to claim 29, further comprising a sensory signal output device that output a sensory signal to the user when a start and/or an end of detecting bodily motion of the user.
- 25
51. A balance function diagnostic system according to claim 50, wherein the sensory signal output device is a speaker.
52. A balance function diagnostic system according to claim 50, wherein the sensory signal output device is an LED.
- 30

53. A method of diagnosing a balance function, comprising the steps of:
attaching a motion sensor to a bodily part of a user;
detecting by the motion sensor accelerations of bodily motion of the user;
analyzing the detected accelerations to recognize them as a trace pattern;
5 and
calculating a total trace length of the trace pattern.
54. A method of diagnosing a balance function, comprising the steps of:
attaching a motion sensor a bodily part of a user;
10 applying a sensory stimulus to the user;
detecting by the motion sensor accelerations of bodily motion of the user;
and
analyzing the detected accelerations to quantify the bodily motion of the
user.
15
55. A method according to claim 54, wherein the sensory stimulus comprises a
visual stimulus.
56. A method according to claim 55, wherein the visual stimulus comprises
20 moving images projected on a screen.
57. A method according to claim 55, wherein the visual stimulus comprises a
light emitted at varying intensity.
- 25 58. A method according to claim 54, wherein the sensory stimulus comprises
an auditory stimulus.
59. A method according to claim 54, wherein the sensory stimulus comprise a
physical stimulus that is exerted on the user.
30

FIG.1

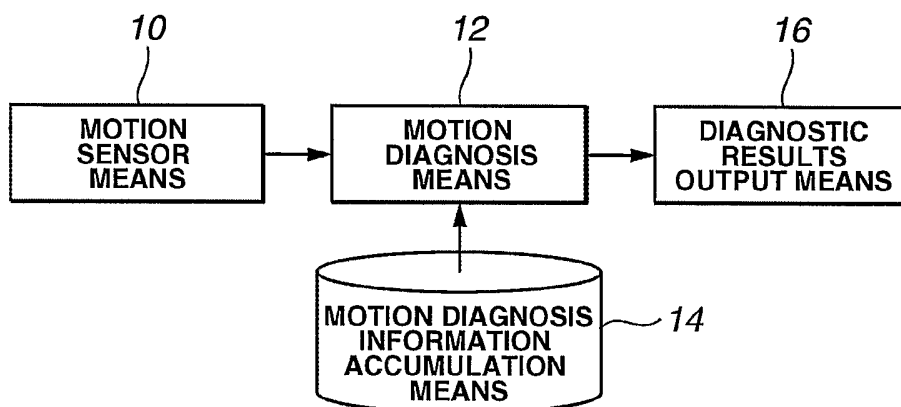


FIG.2

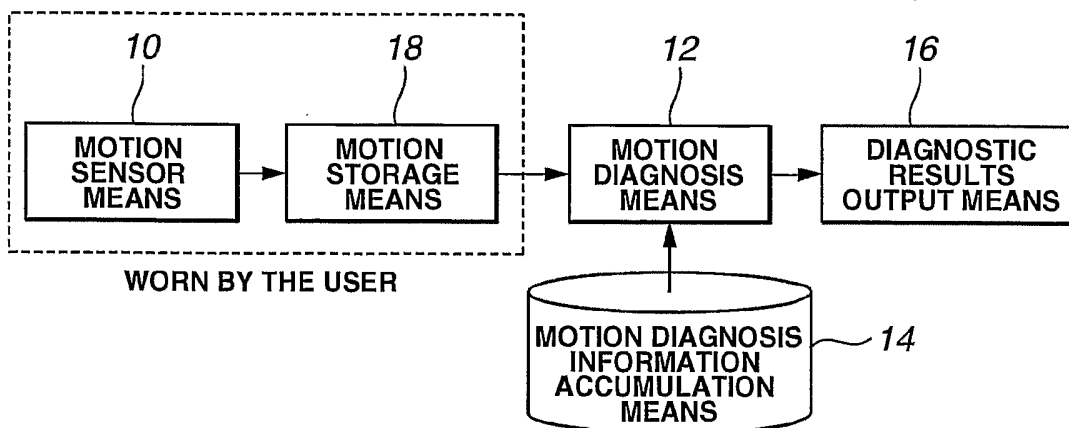


FIG.3

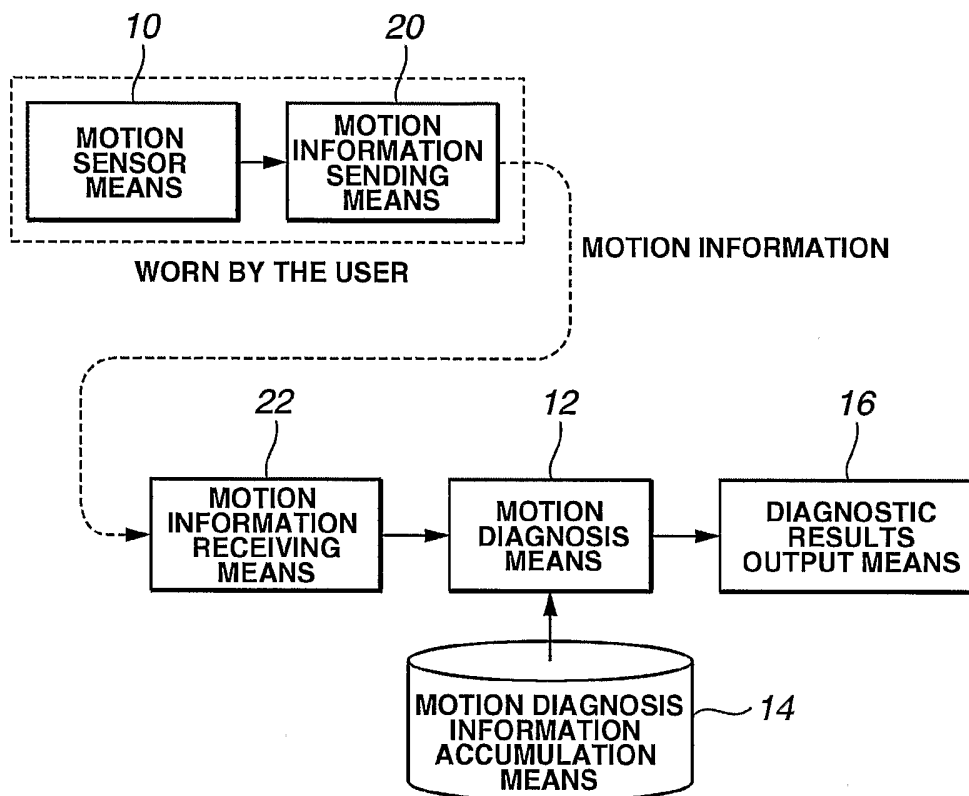
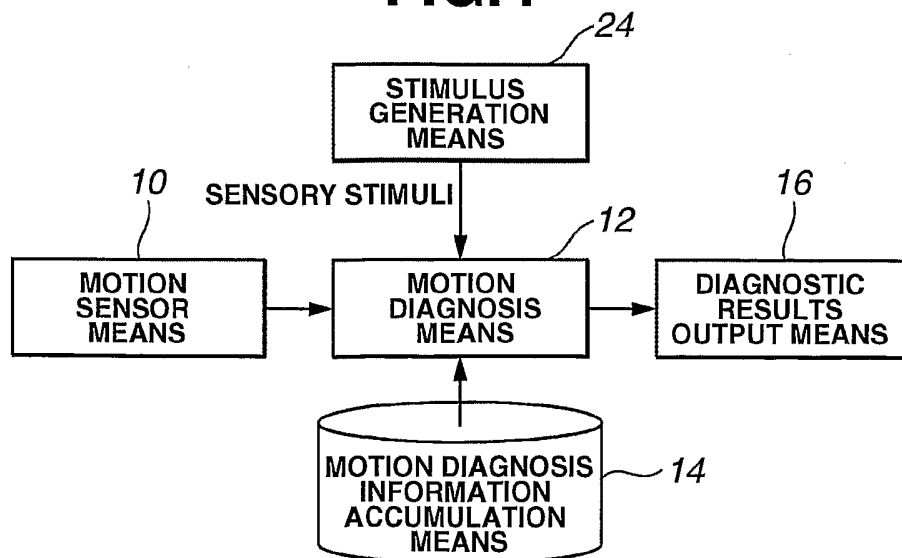


FIG.4



3/6

FIG.5

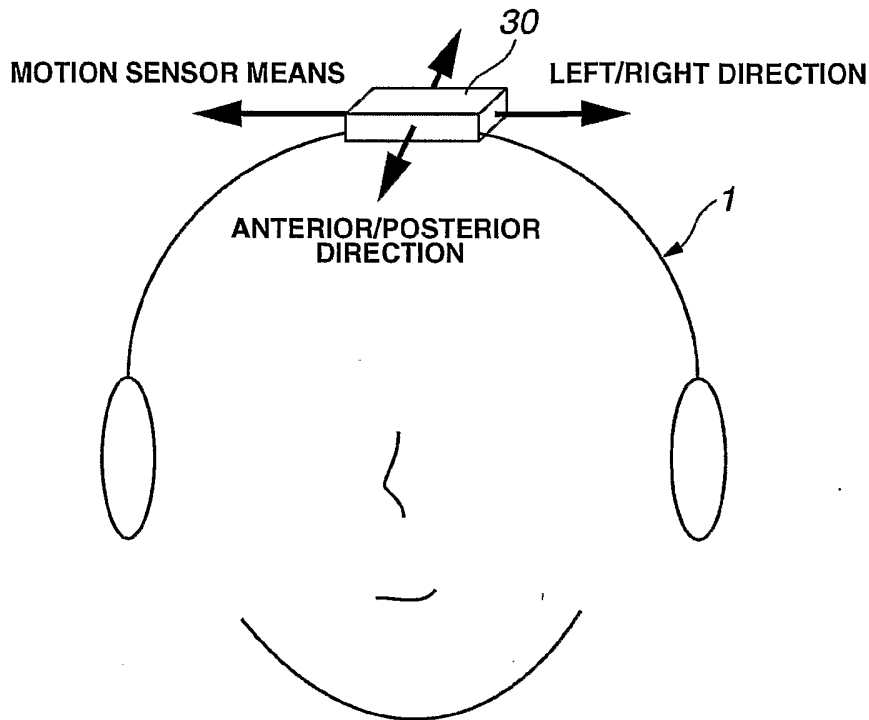


FIG.6

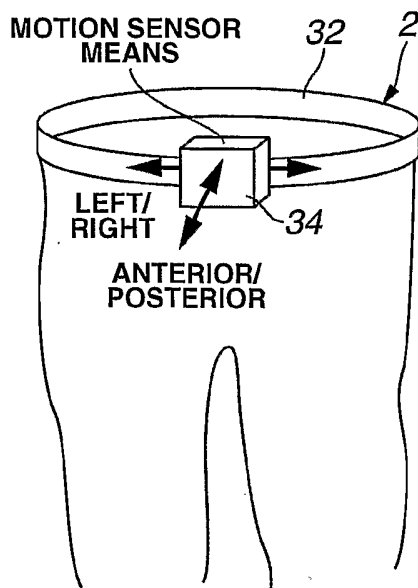


FIG.7

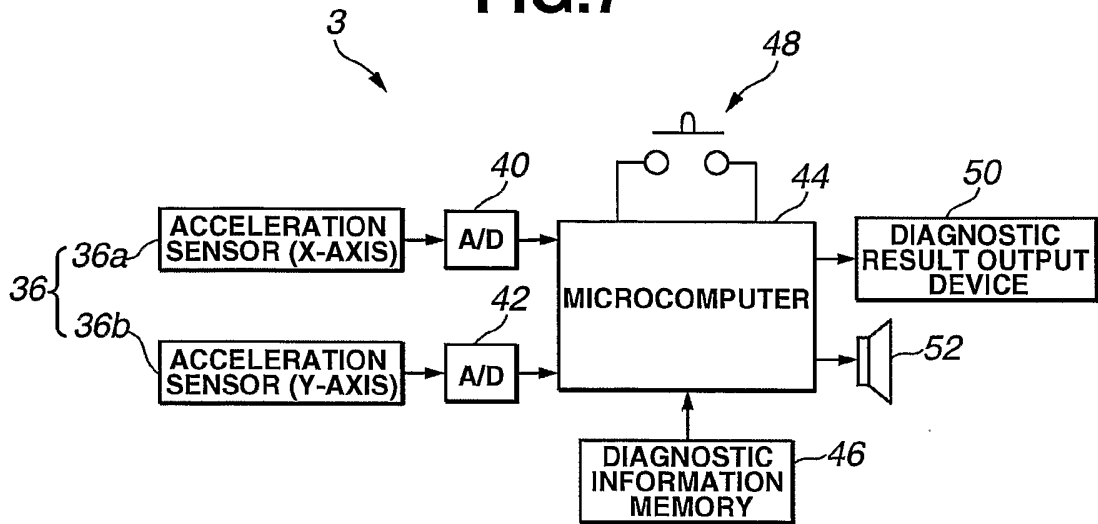


FIG.8

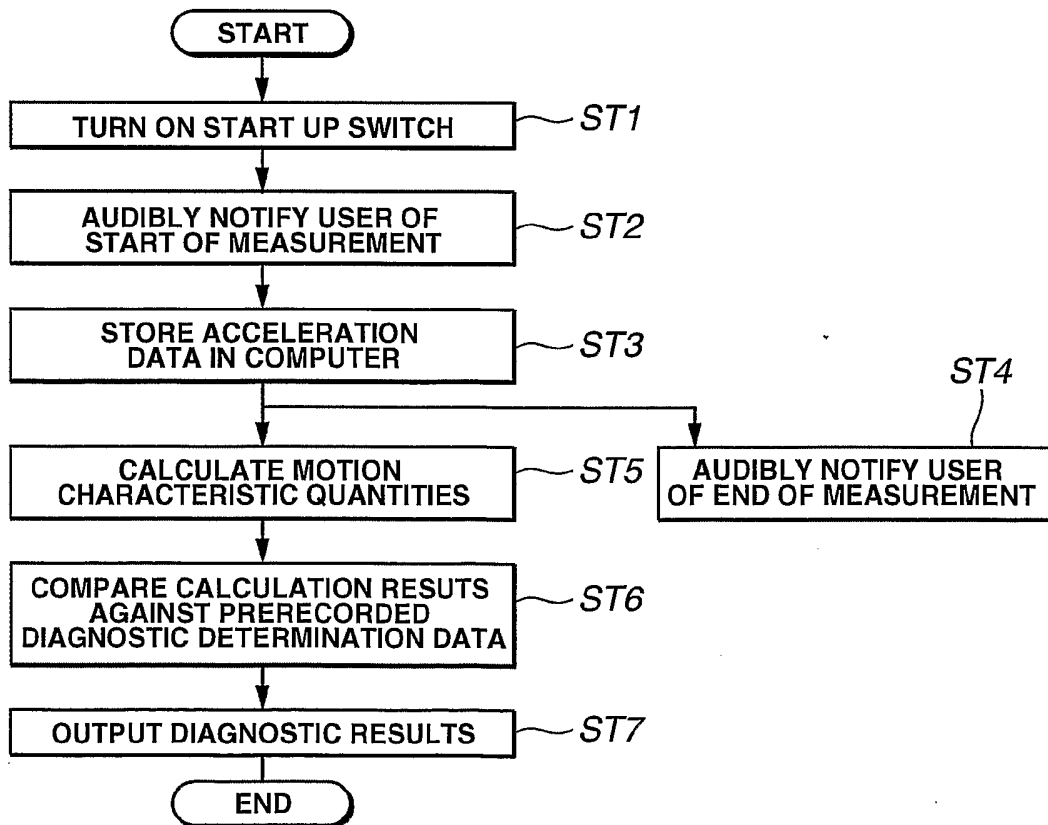


FIG.9

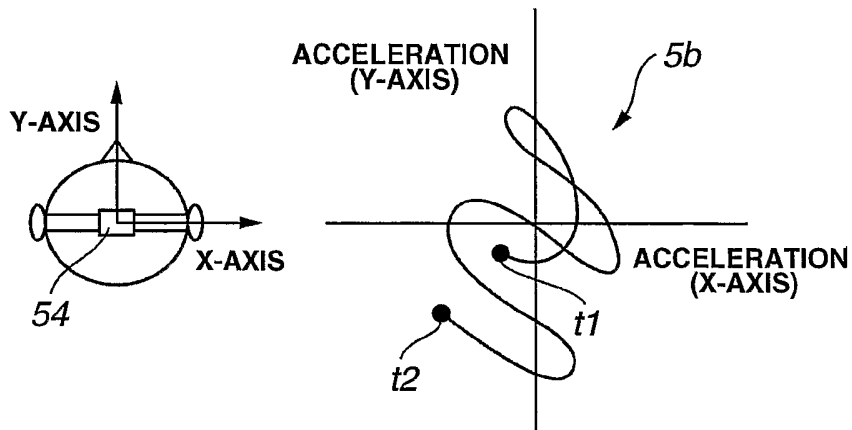


FIG.10

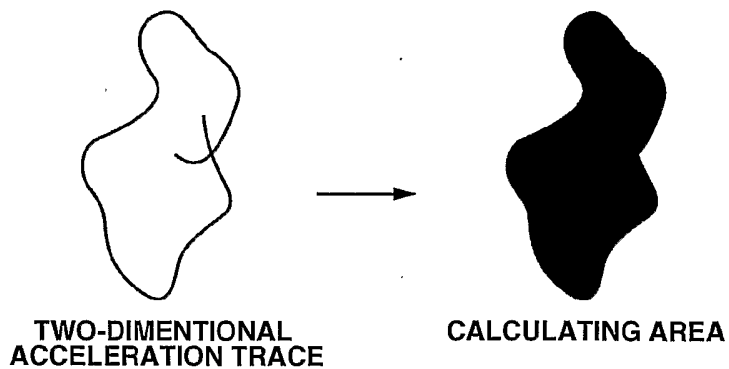


FIG.11

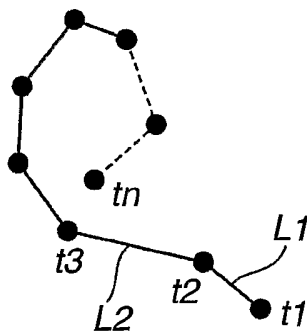
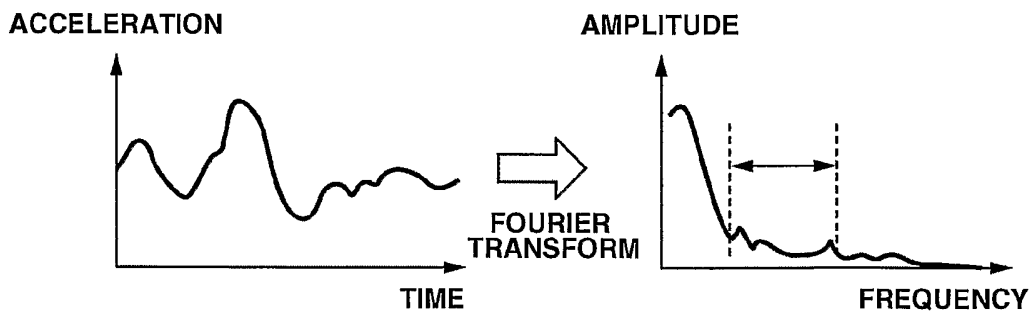


FIG.12A

FIG.12B



INTERNATIONAL SEARCH REPORT

International Application No
PCT/JP2004/007402

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7 A61B5/11

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 7 A61B

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

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

EPO-Internal

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 5 919 149 A (ALLUM JOHN H) 6 July 1999 (1999-07-06)	1-15, 19-39, 44-52, 60
Y	column 6, line 57 - column 7, line 7 column 7, line 49 - column 8, line 47 column 10, line 22 - line 61 column 11, line 27 - line 50 column 12, line 37 - column 13, line 62 column 15, line 57 - column 16, line 2	15-18, 40-43
Y	EP 1 195 139 A (ECOLE POLYTECH) 10 April 2002 (2002-04-10) paragraphs '0016!', '0039!', '0042!'	15-18, 40-43

Further documents are listed in the continuation of box C.

Patent family members are listed in 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 document 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.
- *Z* document member of the same patent family

Date of the actual completion of the international search

11 October 2004

Date of mailing of the international search report

18/10/2004

Name and mailing address of the ISA
European Patent Office, P.B. 5818 Patentlaan 2
NL - 2280 HV Rijswijk
Tel. (+31-70) 340-2040, Tx. 31 651 epo nl,
Fax: (+31-70) 340-3016

Authorized officer

Martelli, L

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

Continuation of Box II.1

Claims Nos.: 53-59

Rule 39.1(iv) PCT - Diagnostic method practised on the human or animal body

Continuation of Box II.2

The present application contains two claims numbered 44; the second one is referred to in this International Search Report as claim 60.

The applicant's attention is drawn to the fact that claims relating to inventions in respect of which no international search report has been established need not be the subject of an international preliminary examination (Rule 66.1(e) PCT). The applicant is advised that the EPO policy when acting as an International Preliminary Examining Authority is normally not to carry out a preliminary examination on matter which has not been searched. This is the case irrespective of whether or not the claims are amended following receipt of the search report or during any Chapter II procedure. If the application proceeds into the regional phase before the EPO, the applicant is reminded that a search may be carried out during examination before the EPO (see EPO Guideline C-VI, 8.5), should the problems which led to the Article 17(2) declaration be overcome.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/JP2004/007402

Box II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. Claims Nos.: 53-59
because they relate to subject matter not required to be searched by this Authority, namely:
Rule 39.1(iv) PCT - Diagnostic method practised on the human or animal body
2. Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
see FURTHER INFORMATION sheet PCT/ISA/210
3. Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1. As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. As only some of the required additional search fees were timely paid by the applicant, this International Search Report covers only those claims for which fees were paid, specifically claims Nos.:
4. No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- The additional search fees were accompanied by the applicant's protest.
- No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

PCT/JP2004/007402

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
US 5919149	A	06-07-1999	NONE	
EP 1195139	A	10-04-2002	EP 1195139 A1	10-04-2002
			AU 8946601 A	15-04-2002
			WO 0228282 A1	11-04-2002
			EP 1322227 A1	02-07-2003
			US 2004015103 A1	22-01-2004