

DESCRIPTION

Title of Invention:

WALKING MEASUREMENT SYSTEM, WALKING MEASUREMENT PROGRAM, AND
WALKING MEASUREMENT METHOD

[0001] The present invention relates to a gait measurement system, a gait measurement program, and a gait measurement method. Specifically, the present invention relates to a gait measurement system, a gait measurement program, and a gait measurement method which enable accurately grasping a gait state of a subject and efficiently guiding the subject to his/her objective gait motion.

Background Art

[0002] For subjects with impaired gait function caused by a decline in leg strength with the recent increases in an aging society, illness, accidents, and the like, the necessity for training to improve, recover, and maintain gait function has increased. The training for such subjects to recover gait function includes gait training.

[0003] Conventionally, in gait training, a method of causing a subject to walk while assisting his/her gait posture by an attendant, training in which a subject walks on his/her own between two hand rails extending in parallel (which are called parallel bars) while grasping the hand rails, etc., have

generally been performed.

[0004] However, in such gait training that is performed with assistance by an attendant and such gait training using parallel bars, medical staff such as a physical therapist or a doctor who assesses the training and gives instructions has calculated gait parameters such as a rough walking speed and stride by use of a stopwatch, a scale, a pedometer, or the like to perform assessment. In such conventional methods, the subject's gait parameters that change moment by moment could not be measured directly and accurately in real time, so that the medical staff could not grasp an accurate gait state of the subject or could not obtain effective information to be used for diagnosis of therapeutic effect.

[0005] Therefore, in, for example, Patent Literature 1, a measurement device capable of measuring an accurate walking speed or walking distance according to actual walking of a subject is disclosed. Specifically, the measurement device is configured to make it possible to measure a person's walking speed in real time by attaching a magnetic field generating means on one foot of the subject and attaching a detecting means that detects a magnetic field from the magnetic field generating means on the other foot to calculate a crossing speed when both feet cross based on that detection data.

[0006] Further, in Patent Literature 2, disclosed is an arithmetic device with which an acceleration sensor is attached to a foot portion of a subject and which calculates a walking speed, a walking time, and a walking distance based on an acceleration measured by the acceleration sensor. Specifically, whether or not an acceleration measured by a triaxial acceleration sensor attached to a foot portion of a subject has changed is measured, and detection time when it is detected that the acceleration has changed is estimated as a walking time. By then multiplying the estimated walking time and a walking speed calculated from the acceleration sensor together to calculate a walking distance, it becomes possible to measure the walking speed, walking time, and walking distance of the subject in real time.

Citation List

Patent Literatures

[0007]

Patent Literature 1: Japanese Published Unexamined Patent Application No. 2004-69468

Patent Literature 2: Japanese Published Unexamined Patent Application No. 2005-49202

Summary of Invention

Technical Problem

[0008] However, in the measurement device disclosed in Patent Literature 1 described above, although it is provided that a walking speed that changes moment by moment can be measured, the speed calculated in Patent Literature 1 is a crossing speed of both foot portions. Normally, the crossing speed of both feet and the subject's walking speed are different speeds, however, in Patent Literature 1, both are considered to be the same speed, and the crossing speed of both foot portions is estimated as the subject's walking speed, and therefore, an accurate walking speed of the subject is not necessarily calculated.

[0009] Further, in the arithmetic device disclosed in Patent Literature 2 described above, for example, the walking speed is calculated by time integration of an acceleration measured by the acceleration sensor, but in an integral calculation process of the acceleration, an integration error inevitably occurs. Therefore, also in Patent Literature 2 described above, an accurate walking speed of the subject is not necessarily calculated.

[0010] The present invention has been devised in view of the above problems, and an object of the present invention is to provide a gait measurement system, a gait measurement program, and a gait measurement method which enable accurately

grasping a gait state of a subject and efficiently guiding the subject to his/her objective gait motion.

Solution to Problem

[0011] In order to achieve the above-described object, a gait measurement system of the present invention includes a foot pressure sensor which measures a foot pressure of a subject and outputs measured foot pressure data, a foot position sensor which measures a foot position of the subject based on a reflection state of a detection wave that is horizontally irradiated at a predetermined pitch angle and outputs measured foot pressure data, and a gait analysis device having a filter processing unit which removes noise data included in the foot position data and outputs processed foot position data obtained by removing the noise data, a storage unit which stores the foot pressure data output from the foot pressure sensor and the processed foot position data in association with measurement time, and an arithmetic unit which calculates a predetermined gait parameter of the subject based on the foot pressure data and the processed foot position data.

[0012] Here, by including the foot pressure sensor that measures a foot pressure of a subject and outputs measured foot pressure data, a contact state of a foot portion and a separation state of the foot portion of the subject when walking

can be determined based on the measured foot pressure data, so that a gait state of the subject can be grasped in detail.

[0013] Further, by including the foot position sensor that measures a foot position of the subject based on a reflection state of a detection wave horizontally irradiated at a predetermined pitch angle and outputs measured foot pressure data, a foot position of the subject when walking can be accurately grasped by an inexpensive system.

[0014] Further, by including the gait analysis device that analyzes a gait state of the subject based on the foot pressure data and the foot position data, the gait state of the subject that changes moment by moment can be accurately analyzed based on the foot pressure data and the foot position data.

[0015] Further, by the gait analysis device including the filter processing unit that removes noise data included in the foot position data and outputs processed foot position data obtained by removing the noise data, an accurate foot position of the subject can be detected by detecting and removing noise data that is irrelevant to the measurement target (subject) included in the foot position data measured by the foot position sensor.

[0016] Further, by the gait analysis device including the storage unit that stores the foot pressure data output from

the foot pressure sensor and the processed foot position data in association with measurement time, the contact state of a foot portion with a floor surface of the subject when walking based on the foot pressure data and the foot position of the subject when walking based on the processed foot position data can be associated with each other, so that a gait state of the foot portion of the subject when walking can be accurately grasped.

[0017] Further, by the gait analysis device including the arithmetic unit that calculates a predetermined gait parameter of the subject based on the foot pressure data and the processed foot position data, gait parameters indicating a gait state of the subject can be easily and accurately calculated based on the foot pressure data and the processed foot position data associated with measurement time.

[0018] Further, when the filter processing unit includes a coordinate conversion section that converts the foot position data to coordinate data in an orthogonal coordinate system, the foot position data measured by the foot position sensor, which is output as distance data between the foot position sensor and the subject, can be converted to orthogonal coordinate data by coordinate conversion.

[0019] Further, when the filter processing unit includes

a data approximation section that approximates the coordinate data to a predetermined number of significant digits, coordinate data converted to the orthogonal coordinate data by the coordinate conversion section can be approximated to a predetermined number of significant digits.

[0020] Further, when the filter processing unit includes a data integration section that integrates into a group of data the coordinate data that becomes the same coordinate value through the approximation by the data approximation section, coordinate data having been approximated by the data approximation section to have the same coordinate value can be integrated and made into one coherent group of data.

[0021] Further, when the filter processing unit includes a coordinate data counting section that counts the number of coordinate data consisting of the same coordinates that compose a group of data, by counting the number of data of coordinate data consisting of the same coordinates that compose a group of data, the size of the group of data can be grasped.

[0022] Further, when the filter processing unit includes a first determination section that determines a group of data as noise when the number of coordinate data composing the group of data is less than a predetermined threshold set according to a distance from the foot position sensor to a subject's foot

portion as the measurement target, whether there is minute noise data irrelevant to the foot portion of the subject in the foot position data measured by the foot position sensor can be determined based on the number of coordinate data included in a group of data counted by the coordinate data counting section.

[0023] At this time, the threshold is set to a value according to the distance between the foot position sensor and the measurement target. Specifically, the detection wave is irradiated at a predetermined pitch angle by the foot position sensor, and therefore has characteristics such that the interval of adjacent detection waves irradiated from the foot position sensor increases with the increase in irradiation distance of detection waves to a measurement target. Therefore, for example, by setting a small value as the threshold when the distance from the foot position sensor to the measurement target is short and setting a large value as the threshold when the distance from the foot position sensor to the measurement target is long, a detection error based on a difference in the distance between the foot position sensor and the measurement object can be prevented.

[0024] Further, when the filter processing unit includes a detection point coordinate setting section which sets, as

detection point coordinates, the coordinate data composing a group of data determined to be not less than the threshold by the first determination section, the coordinate data composing the group of data determined not to be noise data by the first determination section can be set as detection point coordinates for detection of the foot portion of the subject.

[0025] Further, when the filter processing unit includes a specific detection point coordinate setting section which selects specified detection point coordinates as specific detection point coordinates from among the detection point coordinates, for example, detection point coordinates that serve as center coordinates for detection of the foot portion of the subject can be set as specific detection point coordinates.

[0026] Further, when the filter processing unit includes an area setting section which sets a predetermined determination area centered on the specific detection point coordinates, for example, a determination area can be set based on the size around a general subject's foot portion as the determination area.

[0027] Further, when the filter processing unit includes a second determination section which determines the specific detection point coordinates to be a part of the measurement

target when a predetermined number of the detection point coordinates exist around the specific detection point coordinates in the determination area, by considering that a data group having a certain spread exists based on existence of a predetermined number of the detection point coordinates around the specific detection point coordinates, the data group can be determined to be a part of the foot portion of the subject.

[0028] Further, when the gait measurement system includes a waist position sensor which measures a waist position of the subject based on a reflection state of a detection wave horizontally irradiated at a predetermined pitch angle and outputs measured waist position data, and the filter processing unit specifies noise data included in the foot position data based on noise data included in the waist position data, noise data existing around the measurement target can be detected based on both of the foot position data and waist position data, so that a detection accuracy of the noise data can be increased.

[0029] Further, when the arithmetic unit includes a step length measurement section which measures a step length of the subject based on the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an n-th step (n is a natural number) of one

foot portion of both left and right feet of the subject when walking is determined based on the foot pressure data and the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an $(n+1)$ -th step of the other foot portion of the subject when walking is determined based on the foot pressure data, a step length is measured based on the foot pressure data and the processed foot position data, so that a more accurate step length can be measured.

[0030] Further, when the arithmetic unit includes a stride measurement section which measures a stride of the subject based on the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an n -th step (n is a natural number) of one foot portion of the subject when walking is determined based on the foot pressure data, the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an $(n+1)$ -th step of the other foot portion of the subject when walking is determined based on the foot pressure data, and the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an $(n+2)$ -th step of the one foot portion of the subject when walking is determined based on the foot

pressure data, a stride is measured based on the foot pressure data and the processed foot position data, so that a more accurate stride can be measured.

[0031] Further, when the arithmetic unit includes a step width measurement section which measures a step width of the subject based on the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an n -th step (n is a natural number) of one foot portion of the subject when walking is determined based on the foot pressure data and the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an $(n+1)$ -th step of the other foot portion of the subject when walking is determined based on the foot pressure data, a contact status with a floor surface of the foot portion of the subject when walking can be grasped from the foot pressure data measured by the foot pressure sensor, and a step width is measured based on the processed foot position data based on the contact status of the foot portion with the floor surface, so that a more accurate step width can be measured.

[0032] Further, when the arithmetic unit includes a step measurement section which calculates the number of steps in a measurement target area based on a contact or separation state

of one and the other of the left and right feet of the subject when walking, based on the foot pressure data, the number of steps of the subject can be accurately calculated based on a contact or separation state with a floor surface of a foot portion of the subject based on the foot pressure data measured by the foot pressure sensor.

[0033] In order to achieve the above-described object, a gait measurement program and a gait measurement method of the present invention include a foot pressure data receiving step of receiving foot pressure data indicating a foot pressure of a subject measured in a measurement target area, a foot position data receiving step of receiving foot position data indicating a foot position of the subject measured in the measurement target area, a noise detecting step of detecting noise data included in the foot position data, a storage step of storing the foot pressure data and processed foot position data obtained by removing the detected noise data in association with measurement time, and a calculation step of calculating a predetermined gait parameter of the subject based on the foot pressure data and the processed foot position data.

[0034] Here, by including the foot pressure data receiving step of receiving foot pressure data indicating a foot pressure of a subject measured in a measurement target area, a contact

state of a foot portion and a separation state of the foot portion of the subject when walking can be determined based on the received foot pressure data, so that a gait state of the subject can be accurately grasped.

[0035] Further, by including the foot position data receiving step of receiving foot position data indicating a foot position of the subject measured in the measurement target area, a foot position of the subject when walking can be determined based on the received foot position data, so that a gait state of the subject can be accurately grasped.

[0036] Further, by including the noise detecting step of detecting noise data included in the foot position data, the calculation accuracy of gait parameters can be increased by detecting noise data included in the foot position data and removing the noise data that is irrelevant to a measurement target.

[0037] By including the storage step of storing the foot pressure data and processed foot position data obtained by removing the noise data in association with measurement time, the foot pressure data and the processed foot position data can be stored as paired data in association with measurement time.

[0038] Further, by including the calculation step of

calculating a predetermined gait parameter of the subject based on the foot pressure data and the processed foot position data, the calculation accuracy for calculating gait parameters indicating a gait state of the subject can be increased based on the foot pressure data and the processed foot position data stored in the storage unit in association with measurement time.

[0039] Further, when the noise detecting step includes a coordinate converting step of converting the foot position data to coordinate data in an orthogonal coordinate system, for example, the foot position data received as distance data can be converted to orthogonal coordinate data by coordinate conversion.

[0040] Further, when the noise detecting step includes an approximation step of approximating the coordinate data to a predetermined number of significant digits, coordinate data converted to orthogonal coordinate data by the coordinate conversion step can be approximated to a predetermined number of significant digits.

[0041] Further, when the noise detecting step includes an integration step of integrating into a group of data the coordinate data that becomes the same coordinate value through the approximation by the approximation step, coordinate data

having been approximated by the approximation step to have the same coordinate value can be integrated and made into one coherent group of data.

[0042] Further, when the noise detecting step includes a counting step of counting the number of coordinate data consisting of the same coordinates that compose a group of data, by counting the number of data of coordinate data consisting of the same coordinates that compose a group of data, the size of the group of data can be grasped.

[0043] Further, when the noise detecting step includes a first determination step of determining a group of data as noise when the number of coordinate data composing the group of data is less than a predetermined threshold, whether there is minute noise data irrelevant to the measurement target can be determined by comparing the number of coordinate data consisting of the same coordinates included in a group of data with a predetermined threshold.

[0044] Further, when the noise detecting step includes a detection point coordinate setting step of setting, as detection point coordinates, the coordinate data composing a group of data determined to be not less than the threshold by the first determination step, the coordinate data consisting of the same coordinate value that compose a group of data having

been determined not to be noise data by the first determination step can be set as detection point coordinates for detection of the foot portion of the subject.

[0045] Further, when the noise detecting step includes a specific detection point coordinate setting step of selecting specified detection point coordinates as specific detection point coordinates from among the detection point coordinates, for example, detection point coordinates that serve as center coordinates of the measurement target can be set as specific detection point coordinates.

[0046] Further, when the noise detecting step includes an area setting step of setting a predetermined determination area centered on the specific detection point coordinates, for example, a determination area can be set based on the size around a general subject's foot portion as the determination area.

[0047] Further, when the noise detecting step includes a second determination step of determining the specific detection point coordinates to be a measurement target when a predetermined number of the detection point coordinates exist around the specific detection point coordinates in the determination area, by considering that a data group having a certain spread exists based on existence of a predetermined

number of the detection point coordinates around the specific detection point coordinates, the data group can be determined to be a part of the foot portion of the subject.

Advantageous Effects of Invention

[0048] The gait measurement system, the gait measurement program, and the gait measurement method according to the present invention enable accurately grasping a gait state of a subject and efficiently guiding the subject to his/her objective gait motion.

Brief Description of Drawings

[0049] FIG. 1 is an overall block diagram of a gait measurement system according to an embodiment of the present invention.

FIGS. 2 are views showing a foot pressure sensor to be fitted to foot portions of a subject in the gait measurement system according to the embodiment of the present invention.

FIGS. 3 are views showing a housing unit according to the embodiment of the present invention, where FIG. 3(a) is a complete view, and FIG. 3(b) is an exploded view.

FIG. 4 is a conceptual view showing a measurement area for which the gait measurement system according to the embodiment of the present invention is used.

FIGS. 5 are views illustrating gait parameters.

FIG. 6 is a block diagram of a filter processing unit according to the embodiment of the present invention.

FIG. 7 is a block diagram of an arithmetic unit according to the embodiment of the present invention.

FIG. 8 is a diagram showing a process flow of a gait analysis device.

FIG. 9 is a diagram showing a process flow of the filter processing unit in the gait analysis device.

FIG. 10 is a conceptual view showing the content of processing in the filter processing unit.

Description of Embodiments

[0050] Hereinafter, description will be given of an embodiment of the present invention relating to a gait measurement system, a gait measurement program, and a gait measurement method with reference to the drawings to provide an understanding of the present invention.

[0051] [Gait Measurement System]

First, a block diagram showing an entire configuration of a gait measurement system 1 according to the present invention will be described with reference to FIG. 1. As shown in FIG. 1, the gait measurement system 1 is composed mainly of a foot pressure sensor 2 that is attached to foot portions of a subject S to measure a foot pressure when walking, a foot

position sensor 3 that measures a position of the foot portion of the subject S based on a reflection state of a detection wave irradiated at a predetermined pitch angle, a waist position sensor 4 that measures a position of a waist portion, a wireless communication unit 5 that transmits and receives foot pressure data measured by the foot pressure sensor 2, foot position data measured by the foot position sensor 3, and waist position data measured by the waist position sensor 4 individually, a gait analysis device 6 that calculates and outputs a predetermined gait parameter of the subject S, and a display unit 7 for displaying calculation results by the gait analysis device 6.

[0052] [Foot Pressure Sensor]

As shown in FIG. 2, the foot pressure sensor 2 is composed of insoles 21 that are worn in shoes to be used by the subject S when walking, load sensors 22 that are disposed in a distributed manner in a range from a heel portion to a toe portion of each of the insoles 21, wearing devices 23 that are worn on ankles of the subject S, and electrical equipment portions 24 that convert load signals output from the load sensors 22 to transmission signals for wireless transmission and transmit the transmission signals toward the wireless communication unit 5, and configured to make it possible to

measure in real time a gait state such as a stance, a swing, and the like, based on the pressure data of the subject S when walking. A further detailed description of the foot pressure sensor 2 will be omitted here because it has been described in Japanese Published Unexamined Patent Application No. 2014-45885 filed by the applicant in the past.

[0053] Here, the foot pressure sensor 2 does not necessarily need to be in the form shown in FIG. 2. For example, the foot pressure sensor 2 and the gait analysis device 6 may be connected not wirelessly but via a wire. Further, the foot pressure sensor 2 does not need to be attached to a subject's shoes, but may be configured such that walking and measurement are performed in a state where the foot portions of the subject S are placed on the insoles 21.

[0054] [Housing Unit]

The foot position sensor 3, the waist position sensor 4, the wireless communication unit 5, the gait analysis device 6, etc., according to the embodiment of the present invention are built in a housing unit 8, as shown in FIG. 3. The housing unit 8 is composed mainly of a base portion 81 and a pole portion 82 that extends vertically upward from substantially the center of the base portion 81, and the base portion 81 and the pole portion 82 are covered by a cover portion 83.

[0055] On the pole portion 82, the foot position sensor 3, the waist position sensor 4, and an imaging device 9 for video-shooting a gait state of the subject S are fixed at predetermined height positions of the pole portion 82 by adjusting mechanisms capable of position adjustment in the up and down direction. Accordingly, the foot position sensor 3, the waist position sensor 4, and the imaging device 9 can be adjusted to appropriate measuring positions and used according to the physical build of a subject. On the other hand, the base portion 81 has a power supply section 84 that supplies power to the housing unit 8, the gait analysis device 6, and the wireless communication unit 5 that receives data measured by the respective sensors and outputs the calculation results by the gait analysis device 6 to the display unit 7.

[0056] The cover portion 83 has transparent sensor windows 83a and 83b in a manner corresponding to the height positions of the foot position sensor 3 and the waist position sensor 4, and the detection wave can be irradiated through the sensor windows 83a and 83b toward the inside of a measurement area M. Further, at the height position of the imaging device 9, a circular imaging window 83c is attached, and the imaging device 9 is capable of imaging a gait state of the subject S through the imaging window 83c.

[0057] Here, the foot position sensor 3, the waist position sensor 4, and the gait analysis device 6, etc., do not necessarily need to be integrated in the housing unit 8. For example, the foot position sensor 3, the waist position sensor 4, and the gait analysis device 6 may individually be configured as separate bodies. However, by the integration of the foot position sensor 3, the waist position sensor 4, and the gait analysis device 6, only installing the housing unit 8 in a predetermined place for performing measurement makes it possible to start the measurement, and therefore, preparation steps for the measurement can be reduced.

[0058] Further, the waist position sensor 4 does not necessarily need to be provided. Since it suffices that a foot position of the subject S when walking can be grasped, only the foot position sensor 3 may be provided. However, the provision of the waist position sensor 4 makes it possible to detect noise data based on both of the foot position sensor 3 and the waist position sensor 4 in filter processing by a filter processing unit 61 to be described later. Therefore, from the viewpoint of increasing reliability of the foot position data of the subject S detected by the foot position sensor 3, it is preferable that the waist position sensor 4 is provided.

[0059] Further, the measurement data measured by the respective sensors and the calculation results by the gait analysis device 6 do not necessarily need to be transmitted and received through wireless communications by the wireless communication unit 5. For example, the transmission and reception can be achieved through wired communications in place of the wireless communications.

[0060] Further, the imaging device 9 for video-shooting a gait state of the subject S does not necessarily need to be provided. However, the provision of the imaging device 9 makes it possible to confirm the gait state of the subject S by a video image, and therefore, feedback during rehabilitation can be efficiently provided.

[0061] [Foot Position Sensor, Waist Position Sensor]

For the foot position sensor 3 and the waist position sensor 4, at each height position thereof, a laser range finder (hereinafter, referred to as "LRF") that irradiates the subject S with a detection wave (laser) along the horizontal direction with respect to a floor surface and measures a distance between the foot position sensor 3 or the waist position sensor 4 and the subject S based on reflection time of the irradiated detection wave from the subject S is used.

[0062] A schematic view of the measurement area M for which

the LRFs are used is shown in FIG. 4. The LRFs used in the embodiment of the present invention have a range scanning angle (viewing angle) of 240 deg and an angular resolution of 0.36 deg, and is capable of measuring within a range of a radius (R) of approximately 3.5 m. Height positions of the foot position sensor 3 and the waist position sensor 4 from the floor surface are appropriately set according to the physical build of the subject S as described above, however, for example, in the embodiment of the present invention, the foot position sensor 3 is installed at a height position of approximately 18 cm from the floor surface so that the detection wave is irradiated from the ankles to the vicinity of a part below the knees of the subject S, and the waist position sensor 4 was installed at a height position of approximately 80 cm from the floor surface so that the detection wave is irradiated on a waist position part of the subject S.

[0063] Here, the LRFs are not necessarily limited to the specifications described above, and those with various specifications can be used according to the measuring environment.

[0064] Further, the detection wave does not necessarily need to be irradiated from the ankles to the part below the knees of the subject S as an irradiation range of the foot

position sensor 3, and on the waist position part of the subject as an irradiation range of the waist position sensor 4. For example, as the detection wave irradiation range of the foot position sensor 3, it may be irradiated on any part as long as both left and right foot portions of the subject S can be distinguished at that part. Also, as the detection wave irradiation range of the waist position sensor 4, it may be irradiated on any part as long as a trunk portion of the subject S can be distinguished at that part.

[0065] Further, the LRFs do not necessarily need to be used as the sensors, and any type of measuring device may be used as long as the device is capable of measuring the foot position and waist position of the subject S.

[0066] When performing measurement, when the subject S starts to walk from the "START" position, a measurement of the foot pressure by the foot pressure sensor 2 is started, and foot pressure data is transmitted to the wireless communication unit 5 via a radio signal. When the subject S enters the measurement area M, a measurement of the foot position and a measurement of the waist position by the foot position sensor 3 and the waist position sensor 4 are started, and foot position data and waist position data are transmitted to the wireless communication unit 5 via radio signals. When the subject S

withdraws from the measurement area M, the measurements by the foot position sensor 3 and the waist position sensor 4 are ended, however, the measurement by the foot pressure sensor 2 is continuously performed. When the subject S then reaches the position of "FINISH," all measurements end.

[0067] [Gait Analysis Device]

The gait analysis device 6 is a general purpose computer that calculates gait parameters indicating a gait state of the subject S based on the foot pressure data measured by the foot pressure sensor 2, the foot position data measured by the foot position sensor 3, and the waist position data measured by the waist position sensor 4, and is composed mainly of, as shown in the block diagram of FIG. 1, the filter processing unit 61, a storage unit 62, and an arithmetic unit 63, and these units are connected so as to communicate with each other through an internal bus.

[0068] [Filter Processing Unit]

The filter processing unit 61 detects noise data (for example, a walking stick, minute noise data, etc.) which is not relevant to the subject S who is walking out of the foot position data and the waist position data measured by the foot position sensor 3 and the waist position sensor 4 and received by the wireless communication unit 5, and removes the noise

data, and as shown in FIG. 6, is composed of a coordinate conversion section 61a, a data approximation section 61b, a data integration section 61c, a coordinate data counting section 61d, a first determination section 61e, a detection point coordinate setting section 61f, a specific detection point coordinate setting section 61g, an area setting section 61h, and a second determination section 61i. A process flow of the filter processing unit 61 will be described later.

[0069] [Storage Unit]

The storage unit 62 stores the foot pressure data measured by the foot pressure sensor 2 and the foot position data measured by the foot position sensor 3 and subjected to filter processing by the filter processing unit 61 described above (hereinafter, referred to as "processed foot position data") in correlation with measurement time, and is composed of a publicly known storage device such as a hard disk drive, a nonvolatile memory, or the like. The waist position data measured by the waist position sensor 4 is used only in the foregoing process for removing noise data in the filter processing unit 61, and is not stored in the storage unit 62.

[0070] [Arithmetic Unit]

In the arithmetic unit 63, a gait state calculation section 63a, a step length calculation section 63b, a stride

calculation section 63c, a step width calculation section 63d, a step calculation section 63e, a gait cycle calculation section 63f, a gait velocity calculation section 63g, and a cadence calculation section 63h are housed as programs for calculating the respective parameters indicating a gait state of the subject S based on the foot pressure data and the processed foot position data stored in the storage unit 62, as shown in FIG. 7. General definitions of a step length L1, a stride L2, and a step width W which are representative parameters to be calculated by the arithmetic unit 63 are as described in FIG. 5(a).

[0071] [Gait State Calculation Section]

The gait state calculation section 63a determines timings of contact with or separation from the floor surface of one and the other of the left and right foot portions of the subject S based on the foot pressure data stored in the storage unit 62. That is, in the gait state calculation section 63, information on each of heel contact time when a heel makes contact, full contact time when the entirety of a sole surface makes contact, and separation time when a toe separates from the floor surface of the subject S when walking are acquired based on the foot pressure data, and a stance phase P1, a double support phase P2, and a swing phase P3 (FIG. 5(b))

of the subject S when walking can be determined.

[0072] [Step Length Calculation Section]

In the step length calculation section 63b, the step length L1 which is a distance in a forward walking direction from contact of one of the left and right heels until the other heel makes contact is calculated based on contact or separation states of the foot portions of the subject S calculated by the gait state calculation section 63a and the processed foot position data. That is, the step length L1 is calculated based on a heel contact state of an n-th step (n is a natural number) of one of the feet of the subject S walking inside the measurement area M and the processed foot position data corresponding to that time and a heel contact state of an (n+1)-th step of the other foot and the processed foot position data corresponding to that time.

[0073] [Stride Calculation Section]

In the stride calculation section 63c, the stride L2 which is a distance from contact of one of the left and right heels until the one heel again makes contact is calculated based on contact or separation states of the foot portions of the subject S calculated by the gait state calculation section 63a and the processed foot position data. That is, the stride L2 is calculated based on the heel contact state of the n-th step

of one of the feet of the subject S walking inside the measurement area M and the processed foot position data corresponding to that time, the heel contact state of the (n+1)-th step of the other foot and the processed foot position data corresponding to that time, and further, a heel contact state of an (n+2)-th step of the one foot and the processed foot position data corresponding to that time.

[0074] [Step Width Calculation Section]

In the step width calculation section 63d, the step width W which is a distance in a width direction of a contact position of one of the left and right heels and a contact position of the other heel is calculated based on contact or separation states of the foot portions of the subject S calculated by the gait state calculation section 63a and the processed foot position data. That is, the step width W is calculated based on the heel contact state of the n-th step of one of the feet of the subject S walking inside the measurement area M and the processed foot position data corresponding to that time and the heel contact state of the (n+1)-th step of the other foot and the processed foot position data corresponding to that time.

[0075] Here, as the foot pressure data and the processed foot position data to be used in the step length calculation

section 63b, the stride calculation section 63c, and the step width calculation section 63d, data in heel contact states of the subject S does not necessarily need to be used, and any data may be used as long as it is in a predetermined contact state of the foot portions. For example, it is also possible to perform the calculation based on foot pressure data in a full contact state where the entirety of a sole is in contact and processed foot position data temporally corresponding to the foot pressure data.

[0076] [Step Calculation Section]

In the step calculation section 63e, the number of steps N in the measurement area M is calculated based on contact and separation states of one and the other of the left and right feet of the subject S calculated by the gait state calculation section 63a. When performing the calculation of the number of steps N, the number of steps N may be calculated based on a temporal change in the foot position of the subject S based on the processed foot position data, for example.

[0077] [Gait Cycle Calculation Section]

The gait cycle calculation section 63f calculates one gait cycle C1 which is the time required for one stride, and the one gait cycle C1 can be calculated based on the stride L2 calculated by the stride calculation section 63c and

measurement time.

[0078] Here, the one gait cycle C1 does not necessarily need to be calculated based on the stride L2 calculated by the stride calculation section 63c and measurement time. For example, the one gait cycle C1 may be calculated based on the results of determination of the stance phase P1 and the swing phase P3 of the subject S when walking by the gait state calculation section 63a and time data associated therewith.

[0079] [Gait velocity calculation section]

In the gait velocity calculation section 63g, a gait velocity V is calculated based on the stride L2 calculated by the stride calculation section 63c and the one gait cycle C1 calculated by the gait cycle calculation section 63f.

[0080] Here, the gait velocity V does not necessarily need to be calculated based on the stride L2 and the one gait cycle C1, and may be calculated from a relationship of the step length L1 and time required for the step length L1.

[0081] [Cadence Calculation Section]

The cadence calculation section 63h calculates a cadence C2 which indicates the number of steps N per minute, and the cadence C2 is calculated based on the number of steps N calculated by the step calculation section 63e and measurement time.

[0082] The above are representative parameters to be calculated by the arithmetic unit 63 of the embodiment of the present invention, however, the gait parameters to be calculated by the arithmetic unit 63 are not necessarily limited to these. As other gait parameters, it is also possible to calculate, for example, a foot movement direction indicating the direction of movement of a foot portion of the subject S when walking, a foot angle indicating the direction in which a foot portion points when it contacts the floor surface, and the like. Further, out of the gait parameters described above, only parameters necessary for the subject S may be specified and calculated.

[0083] [Display Unit]

The display unit 7 displays the calculation results of gait parameters by the arithmetic unit 63, and is configured from, for example, a personal computer or a tablet terminal, and for example, the calculation results can be stored in a memory inside the personal computer or tablet terminal to facilitate data management of each subject S.

[0084] [Gait Analysis Program]

Next, an overall process flow in the gait measurement system 1 will be described with reference to FIG. 8.

[0085] <STEP 1: Determination of Subject's Walking>

When the gait measurement system 1 is started, the system as a whole is first initialized, and then it is determined whether or not the subject S is walking inside the measurement area M.

[0086] <STEP 2: Start of Measurement>

When the subject S enters the measurement area M, measurements of a gait state of the subjects S are started by the foot pressure sensor 2, the foot position sensor 3, and the waist position sensor 4. As described above, the measurement by the foot pressure sensor 2 is continuously performed before and after the measurement area M, and the video shooting by the imaging device 9 may also be started irrespective of whether or not the subject S is walking inside the measurement area M.

[0087] <STEP 3: Reception of Data>

Once the measurement of the subject S in the walking state is started, the foot pressure data measured by the foot pressure sensor 2, the foot position data measured by the foot position sensor 3, and the waist position data measured by the waist position sensor 4 are individually transmitted to the wireless communication unit 5 by radio signals.

[0088] <STEP 4: Filter Processing>

Of the measurement data received by the wireless

communication unit 5, the foot position data and the waist position data pass through the filter processing unit 61, in which a processing to detect and remove noise data included in the data is performed.

[0089] <STEP 5: Storage of Data>

The foot pressure data measured by the foot pressure sensor 2 and the processed foot position data obtained by removing the noise data by the filter processing unit 61 are stored in the storage unit 62 in association with measurement time.

[0090] <STEP 6: Arithmetic Processing>

Based on the foot pressure data and the processed foot position data stored in the storage unit 62, various gait parameters are calculated by the arithmetic unit 63 as described above.

[0091] <STEP 7: Output of Calculation Results>

The calculation results of gait parameters by the arithmetic unit 63 are displayed via the display unit 7 such as a personal computer or a tablet terminal, and the calculation results are managed in the memory of the personal computer or tablet terminal.

[0092] [Filter Processing Program]

Next, a filter process flow in the filter processing unit

61 will be described with reference to FIG. 9. Because the foot position data and waist position data have the same process flow, filter processing of the foot position data will be mainly described in the following process flow.

[0093] <STEP 411: Reception of Foot Position Data>

The foot position data measured by one time of scanning with the foot position sensor 3 is transmitted to the filter processing unit 61 through the wireless communication unit 5. As described above, the LRF used in the embodiment of the present invention has a range scanning angle (viewing angle) of 240 deg and an angular resolution of 0.36 deg, so that 667 sets ($= 240 \text{ deg} / 0.36 \text{ deg}$) of foot position data are acquired by one time of scanning with the foot position sensor 3. On the other hand, necessary field-of-view data out of the acquired data is data within the measurement area M where the subject S walks, and therefore, it suffices to set only foot position data in a region of a range scanning angle of 180 deg with reference to the foot position sensor 3 as targets. Accordingly, 500 sets of foot position data are the targets of foot position data that are actually used for the filter processing by the filter processing unit 61.

[0094] <STEP 412: Coordinate Conversion of Foot Position Data into Orthogonal Coordinate System>

The foot position data measured by the foot position sensor 3 is distance data between the foot position sensor 3 and the subject S, and this data is converted to coordinate data in an x-y orthogonal coordinate system by trigonometric function processing in the coordinate conversion section 61a to obtain coordinate data according to each set of foot position data.

[0095] <STEP 413: Approximation of Coordinate Data>

For respective sets of the coordinate-converted coordinate data, coordinate data approximation is performed by data approximation section 61b. Specifically, coordinate data having been unit-converted into [units of cm] by subtracting respective sets of coordinate data in [units of mm] is subjected to an approximation processing to a predetermined number of significant digits (which is, for example, two significant figures, but is not limited to this number).

[0096] <STEP 414: Integration of Coordinate Data>

Coordinate data that becomes the same coordinate value in a predetermined region (for example, in a coordinate region of 10 mm × 10 mm) through the approximation of coordinate data is integrated as a group of data by the data integration section 61c.

[0097] <STEP 415: Counting of Coordinate Data>

The number of coordinate data composing each group of data is calculated by the coordinate data counting section 61d.

[0098] <STEP 416: Setting of Threshold>

As shown in FIG. 4, with the foot position sensor 3 from which a detection wave is irradiated at a predetermined pitch angle, an interval between adjacent detection waves increases with the distance away from the foot position sensor 3. Therefore, even when the number of coordinate data composing each group of data is the same, their data densities are different according to the distance from the foot position sensor 3, and it is hence necessary to consider the distance between the coordinate data and the foot position sensor 3. Therefore, here, a threshold for a noise determination is set according to the distance between the coordinate data and the foot position sensor 3.

[0099] Specifically, when coordinate data composing a group of data are at predetermined close distances from the foot position sensor 3, a small value may be set as a threshold T1a, and when they are at predetermined far distances from the foot position sensor 3, a large value may be set as a threshold T1c, and further, when they are at predetermined intermediate distances from the foot position sensor 3, an intermediate

value may be set between the threshold T1a and the threshold T1c as a threshold T1b.

[0100] <STEP 417: Noise Determination>

Based on the number of coordinate data composing each group of data counted by the coordinate data counting section 61d and the threshold T1a, T1b, or T1c determined according to the distance from the coordinate data to the foot position sensor 3, a determination whether or not the group of data is minute noise data is performed by the first determination section 61e. When the number of coordinate data composing the group of data is less than the threshold T1a, T1b, or T1c, the group of data is determined to be minute noise that is irrelevant to the measurement target (subject S), and the coordinate data is deleted (STEP 418), and is not used for the subsequent arithmetic processing.

[0101] On the other hand, when the number of coordinate data composing the group of data is not less than the threshold T1a, T1b, or T1c, it can be judged that the group of data has a certain size and is highly likely to be a foot portion of the subject S. Then, the coordinate data determined to be not less than the threshold T1a, T1b, or T1c is used for a subsequent arithmetic processing in detection of a foot portion of the subject S by the second determination section 61i.

[0102] Here, the threshold does not necessarily need to be set at three levels like T1a, T1b, and T1c according to the distance of separation from the foot position sensor 3, and it may be set to be, for example, at two levels or four levels or more, and its range can be appropriately changed.

[0103] <STEP 421: Setting of Detection Point Coordinates>

For a group of data determined to be not less than a predetermined threshold by the first determination section 61e, coordinate data consisting of the same coordinates that compose the group of data are set as detection point coordinates by the detection point coordinate setting section 61f.

[0104] <STEP 422: Setting of Specific Detection Point Coordinates>

From among the detection point coordinates set by the detection point coordinate setting section 61f, specific detection point coordinates that are specified detection point coordinates are selected by the specific detection point coordinate setting section 61g.

[0105] <STEP 423: Setting of Determination Area centered on Specific Detection Point Coordinates>

A predetermined determination area is set by the area setting section 61h centered on the specific detection point coordinates selected by the specific detection point

coordinate setting section 61g. Specifically, as shown in FIG. 10, coordinates (x_i+a, y_i) , (x_i-a, y_i) , (x_i, y_i+a) , and (x_i, y_i-a) are defined (a is a constant) as a peripheral region centered on specific detection point coordinates (x_i, y_i) in a predetermined region on an orthogonal coordinate system with the detection point coordinates plotted.

[0106] The " a " can be set to a predetermined value as the size of an average ankle circumference of the subject S to be a detection target, and is set to " $a = 5 \text{ cm}$ " in the embodiment of the present invention, however, it is not necessarily limited to this value, and can be appropriately changed according to the size of the subject S 's ankles. When detection of noise data around the waist position is performed by the waist position sensor 4, a value on the order of, for example, " $a = 40 \text{ cm}$ " is set.

[0107] <STEP 424: Foot Portion Determination>

On the coordinates (x_i+a, y_i) , (x_i-a, y_i) , (x_i, y_i+a) , and (x_i, y_i-a) set by the area setting section 61h, whether or not the detection point coordinates exist is confirmed, and when a predetermined threshold T_2 or more (for example, three or more) detection point coordinates exist, the second determination section 61i determines them as aggregated data having a certain spread centered on the specific detection

point coordinates and that the specific detection point coordinate data is a foot portion of the subject S.

[0108] On the other hand, when detection point coordinates are less than a predetermined number, the second determination section 61i determines them as data not having a certain spread centered on the specific detection point coordinates and that the specific detection point coordinate data is an object smaller by one size than a foot portion of the subject S (for example, a walking stick which the subject S carries with him/her when walking) and is thus of a detection object other than a foot portion of the subject S.

[0109] The specific detection point coordinates determined to be a part of the foot portion of the subject S by the second determination section 61i are transmitted to the storage unit 62 as processed foot position data together with foot pressure data in correlation with processing time, and used for the calculation of gait parameters by the arithmetic unit 63. On the other hand, when the data is determined to be an object other than a foot portion of the subject S by the second determination section 61i, it is data unrelated to the calculation of gait parameters and is therefore deleted (STEP 425), or transmission to the storage unit 62 is not performed.

[0110] As above, although a description has been given of

a noise process flow of the foot position data, for the waist position data acquired by the waist position sensor 4, processing is also performed by a similar process flow, and from the waist position data measured by the waist position sensor 4, extraction and removal of unnecessary noise data existing around the waist position are performed. As described above, the waist position data is not directly used for the calculation of gait parameters, and is used for increasing reliability of the foot position data in the filter processing flow by the filter processing unit 61.

[0111] As above, a gait measurement system, a gait measurement program, and a gait measurement method according to the present invention enable accurately grasping a gait state of a subject and efficiently guiding the subject to his/her objective gait motion.

Reference Signs List

- [0112] 1 Gait measurement system
- 2 Foot pressure sensor
- 3 Foot position sensor
- 4 Waist position sensor
- 5 Wireless communication unit
- 6 Gait analysis device
- 61 Filter processing unit

- 61a Coordinate conversion section
- 61b Data approximation section
- 61c Data integration section
- 61d Coordinate data counting section
- 61e First determination section
- 61f Detection point coordinate setting section
- 61g Specific detection point coordinate setting section
- 61h Area setting section
- 61i Second determination section
- 62 Storage unit
- 63 Arithmetic unit
- 63a Gait state calculation section
- 63b Step length calculation section
- 63c Stride calculation section
- 63d Step width calculation section
- 63e Step calculation section
- 63f Gait cycle calculation section
- 63g Gait velocity calculation section
- 63h Cadence calculation section
- 7 Display unit
- 8 Housing unit
- 81 Base portion
- 82 Pole portion

83 Cover portion
83a, 83b Sensor window
83c Imaging window
84 Power supply section
9 Imaging device
S Subject

CLAIMS

[Claim 1] A gait measurement system comprising:

- a foot pressure sensor which measures a foot pressure of a subject and outputs measured foot pressure data;

- a foot position sensor which measures a foot position of the subject based on a reflection state of a detection wave that is horizontally irradiated at a predetermined pitch angle and outputs measured foot position data; and

- a gait analysis device having a filter processing unit which removes noise data included in the foot position data and outputs processed foot position data obtained by removing the noise data, a storage unit which stores the foot pressure data output from the foot pressure sensor and the processed foot position data in association with measurement time, and an arithmetic unit which calculates a predetermined gait parameter of the subject based on the foot pressure data and the processed foot position data.

[Claim 2] The gait measurement system according to claim 1, wherein

- the filter processing unit has:

- a coordinate conversion section which converts the foot position data to coordinate data in an orthogonal coordinate system;

a data approximation section which approximates the coordinate data to a predetermined number of significant digits;

a data integration section which integrates into a group of data the coordinate data that becomes the same coordinate value through the approximation by the data approximation section;

a coordinate data counting section which counts the coordinate data composing the group of data; and

a first determination section which determines the group of data as noise when the number of the coordinate data composing the group of data is less than a predetermined threshold set according to a distance from the foot position sensor to a measurement target.

[Claim 3] The gait measurement system according to claim 2, wherein the filter processing unit has:

a detection point coordinate setting section which sets, as detection point coordinates, the coordinate data composing a group of data determined to be not less than the threshold by the first determination section;

a specific detection point coordinate setting section which selects specified detection point coordinates as specific detection point coordinates from among the detection

point coordinates;

an area setting section which sets a predetermined determination area centered on the specific detection point coordinates; and

a second determination section which determines the specific detection point coordinates to be a measurement target when a predetermined number of the detection point coordinates exist around the specific detection point coordinates in the determination area.

[Claim 4] The gait measurement system according to claim 1, wherein

the gait measurement system comprises a waist position sensor which measures a waist position of the subject based on a reflection state of a detection wave horizontally irradiated at a predetermined pitch angle and outputs measured waist position data, and

the filter processing unit specifies noise data included in the foot position data based on noise data included in the waist position data.

[Claim 5] The gait measurement system according to claim 1, wherein

the arithmetic unit includes

a step length measurement section which measures a step

length of the subject based on the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an n -th step (n is a natural number) of one of the left and right feet of the subject when walking is determined based on the foot pressure data and the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an $(n+1)$ -th step of the other of the left and right feet of the subject when walking is determined based on the foot pressure data.

[Claim 6] The gait measurement system according to claim 1, wherein

the arithmetic unit includes

a stride measurement section which measures a stride of the subject based on the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an n -th step (n is a natural number) of one of the left and right feet of the subject when walking is determined based on the foot pressure data, the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an $(n+1)$ -th step of the other of the left and right feet of the subject when walking is determined based on the foot

pressure data, and the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an $(n+2)$ -th step of the one of the left and right feet of the subject when walking is determined based on the foot pressure data.

[Claim 7] The gait measurement system according to claim 1, wherein

the arithmetic unit includes

a step width measurement section which measures a step width of the subject based on the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an n -th step (n is a natural number) of one of the left and right feet of the subject when walking is determined based on the foot pressure data and the processed foot position data stored in the storage unit corresponding to time at which a predetermined contact state of an $(n+1)$ -th step of the other of the left and right feet of the subject when walking is determined based on the foot pressure data.

[Claim 8] The gait measurement system according to claim 1, wherein

the arithmetic unit includes

a step measurement section which calculates the number

of steps in a measurement target area based on a contact or separation state of one and the other of the left and right feet of the subject when walking, based on the foot pressure data.

[Claim 9] A gait measurement program that causes a computer to execute:

- a foot pressure receiving step of receiving foot pressure data indicating a foot pressure of a subject measured in a measurement target area;

- a foot position data receiving step of receiving foot position data indicating a foot position of the subject measured in the measurement target area;

- a noise detecting step of detecting noise data included in a foot position data;

- a storage step of storing the foot pressure data and processed foot position data obtained by removing the detected noise data in association with measurement time; and

- a calculation step of calculating a predetermined gait parameter of the subject based on the foot pressure data and the processed foot position data.

[Claim 10] The gait measurement program according to claim 9, wherein

- the noise detecting step has:

a coordinate converting step of converting the foot position data to coordinate data in an orthogonal coordinate system;

an approximation step of approximating the coordinate data to a predetermined number of significant digits;

an integration step of integrating into a group of data the coordinate data that becomes the same coordinate value;

a counting step of counting the coordinate data composing the group of data;

a first determination step of determining the group of data as noise when the number of the coordinate data composing the group of data is less than a predetermined threshold.

[Claim 11] The gait measurement program according to claim 9, wherein

a step of removing noise data included in the foot position data has:

a detection point coordinate setting step of setting, as detection point coordinates, the coordinate data composing the group of data determined to be not less than the threshold by the first determination step;

a specific detection point coordinate setting step of selecting specific coordinates as specific detection point coordinates from among the detection point coordinates;

an area setting step of setting a predetermined determination area centered on the specific detection point coordinates; and

a second determination step of determining the specific detection point coordinates to be a measurement target when a predetermined number of the detection point coordinates exist around the specific detection point coordinates in the determination area.

[Claim 12] A gait measurement method comprising:

a foot pressure receiving step of receiving foot pressure data indicating a foot pressure of a subject measured in a measurement target area;

a foot position data receiving step of receiving first foot position data indicating a foot position of the subject measured in the measurement target area;

a noise removing step of removing noise data included in the foot position data;

a storage step of storing the foot pressure data and processed foot position data obtained by removing the noise data, in association with measurement time; and

a calculation step of calculating a predetermined gait parameter of the subject based on the foot pressure data and the processed foot position data.