



(51) International Patent Classification:

A61B 5/22 (2006.01) G01S 17/88 (2006.01)
A61B 5/11 (2006.01)

(21) International Application Number:

PCT/SG2024/050401

(22) International Filing Date:

14 June 2024 (14.06.2024)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

10202301725Q 16 June 2023 (16.06.2023) SG

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

(54) Title: FRAILITY ASSESSMENT DEVICE AND SYSTEM

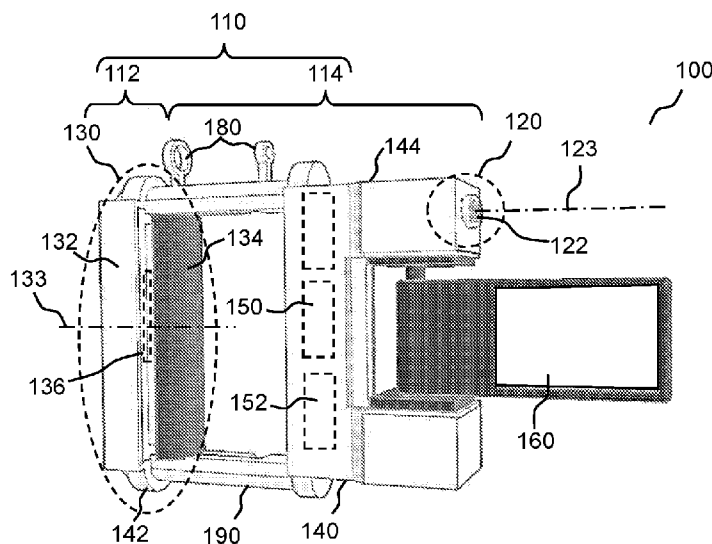


FIG. 1A

(57) Abstract: A frailty assessment device including a strength measurement subunit and a movement measurement subunit. The strength measurement subunit including a first grip member, a second grip member, wherein the first grip member and the second grip member are movable relative to each other, and a force sensing arrangement disposed between the first grip member and the second grip member, wherein the force sensing arrangement is configured to measure a force for urging the first grip member and the second grip member towards each other. The movement measurement subunit including a distance sensing arrangement configured to detect a distance of an external body with respect to the device. The strength measurement subunit and the distance measurement subunit are integrated together in a single device body.

TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, WS,
ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, CV, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SC, SD, SL, ST, SZ, TZ, UG, ZM, ZW), Eurasian (AM, AZ, BY, KG, KZ, RU, TJ, TM), European (AL, AT, BE, BG, CH, CY, CZ, DE, DK, EE, ES, FI, FR, GB, GR, HR, HU, IE, IS, IT, LT, LU, LV, MC, ME, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Published:

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

FRAILITY ASSESSMENT DEVICE AND SYSTEM

Cross References to Related Applications

[0001] The present application claims the benefit of the Singapore Patent Application No. 10202301725Q filed on 16 June 2023, the entire contents of which are incorporated herein by reference for all purposes.

Technical Field

[0002] Embodiments generally relate to a frailty assessment device capable of being used for gait (or walking) speed assessment and grip strength assessment. Embodiments generally also relate to a frailty assessment system.

Background

[0003] Frailty assessment typically involves a questionnaire-based assessment and a physical assessment. The physical assessment may include body functions assessment such as body movement assessment, e.g. gait (or walking) speed assessment, and body strength assessment, e.g. grip strength assessment. Conventionally, such physical assessment is difficult to be conducted in community settings and are prone to errors.

[0004] For example, the conventional method of assessing gait speed is to ask a person to walk along a set distance, with the speed of walking measured using a timer (e.g. stop watch). The minimum recommended distance for walking assessment is 2.4m for the section that is measured, and 2.8m for the acceleration and deceleration component (i.e. a total of 5.2m). This is the absolute minimum recommended, with longer distances providing more accurate measures of true walking speed. Hence the “typical” walking assessment is a 10 metre walk test which has 4m for acceleration and deceleration (14m total). Such distance requirements generally make it difficult/impossible to conduct the assessment in homes and most clinical settings.

[0005] Further, measurement error is high and is directly related to the gait speed assessment method. For instance, measuring the start and stop points for the assessment are highly subjective and influenced by factors such as reaction time. Such errors would have a greater impact on gait speed assessment using shorter distances. This kind of error is also variable between different assessors, as they would have differing perception of when a subject under assessment crosses the start/end points as well as have differing reaction time.

[0006] As another example, conventional devices for grip strength assessment typically uses either spring or hydraulic gauges which have poor precision or accuracy. For example, a difference between true value and the measured value can be around 2kg, which is equivalent to 10% or more of the strength in many older adults. As such large fluctuations in strength are required before changes can be identified.

[0007] Accordingly, there is a need for an improved frailty assessment device or system for conducting frailty assessment.

Summary

[0008] According to various embodiments, there is provided a frailty assessment device including a strength measurement subunit and a movement measurement subunit. The strength measurement subunit including a first grip member, a second grip member, wherein the first grip member and the second grip member are movable relative to each other, and a force sensing arrangement disposed between the first grip member and the second grip member, wherein the force sensing arrangement is configured to measure a force for urging the first grip member and the second grip member towards each other. The movement measurement subunit including a distance sensing arrangement configured to detect a distance of an external body with respect to the device. The strength measurement subunit and the distance measurement subunit are integrated together in a single device body.

[0009] According to various embodiments, there is provided a system for frailty assessment. The system including the frailty assessment device as described herein and an external device in communication with the frailty assessment device.

Brief description of the drawings

[00010] In the drawings, like reference characters generally refer to the same parts throughout the different views. The drawings are not necessarily to scale, emphasis instead generally being placed upon illustrating the principles of the invention. In the following description, various embodiments are described with reference to the following drawings, in which:

FIG. 1A and FIG. 1B show different perspective schematic views of a frailty assessment device according to various embodiments;

FIG. 2A, FIG. 2B, and FIG. 2C show different views of a frailty assessment device according to various embodiments;

FIG. 3A shows an exploded view of a frailty assessment device according to various embodiments;

FIG. 3B, FIG. 3C, and FIG. 3D show different views of the frailty assessment device of FIG. 3A according to various embodiments;

5 FIG. 3E shows a schematic block diagram of the electronic components of the frailty assessment device of FIG. 3A according to various embodiments;

FIG. 4 shows a sample graphic user interface displayed on the touchscreen of the frailty assessment device according to various embodiments; and

10 FIG. 5A, FIG. 5B, and FIG. 5C show different views of the frailty assessment device according to various embodiments.

Detailed description

[00011] Embodiments described below in the context of the apparatus are analogously valid for the respective methods, and vice versa. Furthermore, it will be understood that the
15 embodiments described below may be combined, for example, a part of one embodiment may be combined with a part of another embodiment.

[00012] It should be understood that the terms “on”, “over”, “top”, “bottom”, “down”, “side”, “back”, “left”, “right”, “front”, “lateral”, “side”, “up”, “down” etc., when used in the following
20 description are used for convenience and to aid understanding of relative positions or directions, and not intended to limit the orientation of any device, or structure or any part of any device or structure. In addition, the singular terms “a”, “an”, and “the” include plural references unless context clearly indicates otherwise. Similarly, the word “or” is intended to include “and” unless the context clearly indicates otherwise.

[00013] Various embodiments generally relate to a frailty assessment device. The frailty
25 assessment device may be a device, a tool, an apparatus, or an equipment capable of being used by an assessor to conduct one or both of the physical assessment and the questionnaire-based assessment of a frailty assessment. Accordingly, the frailty assessment device of the various embodiments may be configured for conducting physical assessment including body functions assessment such as body movement assessment (e.g. gait or walking speed assessment) and
30 body strength assessment (e.g. grip strength assessment). Hence, the frailty assessment device of the various embodiments may be configured to measure a body movement (e.g. gait or walking speed) of a subject under assessment (e.g. a patient) and body strength (e.g. grip strength) of the subject under assessment (e.g. the patient). Further, the frailty assessment device of the various embodiments may also be configured for conducting the questionnaire-

based assessment. For instance, the frailty assessment device may be configured to receive inputs from the subject under assessment (e.g. the patient) regarding the questionnaire-based assessment.

[00014] According to various embodiments, the frailty assessment device may include a movement measurement subunit and a strength measurement subunit integrated together in a single device. Accordingly, the same frailty assessment device may be used to conduct both the body movement assessment (e.g. gait or walking speed assessment) and body strength assessment (e.g. grip strength assessment). Hence, the physical assessment portion of a frailty assessment, including body functions assessment such as both the body movement assessment and the body strength assessment, may be conducted using the same frailty assessment device enabling a more streamline frailty assessment procedures, a simpler and hassle-free set-up, and faster and more convenient assessment.

[00015] According to various embodiments, the frailty assessment device may also include a user interface for receiving inputs such that the questionnaire-based portion of the frailty assessment may be conducted with the frailty assessment device. Accordingly, the frailty assessment device may electronically compile or collate the inputs provided by the subject under assessment (e.g. the patient) for subsequent processing.

[00016] According to various embodiments, the frailty assessment device may be configured as an all-in-one device (or a one-stop device), wherein the frailty assessment device may include the movement measurement subunit for body movement assessment (e.g. gait or walking speed assessment), the strength measurement subunit for the body strength assessment (e.g. grip strength assessment), and/or the user interface for the questionnaire-based assessment. Accordingly, the frailty assessment device may be a single device capable of being used to conduct a comprehensive frailty assessment.

[00017] According to various embodiments, the frailty assessment device may be configured to be portable. Accordingly, the frailty assessment device may be carried or moved about between different locations or places. Hence, the frailty assessment device may be deployed to homes, clinics, assessments centers, etc. for conducting frailty assessment.

[00018] FIG. 1A and FIG. 1B show different perspective schematic views of a frailty assessment device 100 according to various embodiments.

[00019] According to various embodiments, the frailty assessment device 100 may include a movement measurement subunit 120 and a strength measurement subunit 130. The movement measurement subunit 120 may be configured to measure a body movement of a subject under assessment (i.e. a patient) and the strength measurement subunit 130 may be configured to

measure a body strength of the subject under assessment (i.e. the patient). According to various embodiments, the body movement of the subject under assessment may be a gait speed or walking speed of the subject under assessment (i.e. the patient) and the body strength of the subject under assessment may be a grip strength of the subject under assessment (i.e. the patient).

[00020] According to various embodiments, the movement measurement subunit 120 and the strength measurement subunit 130 may be integrated into a single device body 110. The single device body 110 may give a concrete physical form to the frailty assessment device 100. With the frailty assessment device 100 being embodied in the single device body 110, the single device body 110 may contain both the movement measurement subunit 120 and the strength measurement subunit 130. Accordingly, each of the movement measurement subunit 120 and the strength measurement subunit 130 may be part of the single device body 110. Thus, the movement measurement subunit 120 and the strength measurement subunit 130 may be incorporated into the single device body 110 to form one unified device serving as the frailty assessment device 100.

[00021] According to various embodiments, the movement measurement subunit 120 may include a distance sensing arrangement 122. The distance sensing arrangement 122 may be configured to detect a distance of an external body with respect to the frailty assessment device 100. Accordingly, the frailty assessment device 100 may serve as a reference point, and the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 100 may measure or determine the distance of the external body from the frailty assessment device 100. Hence, the frailty assessment device 100 may obtain the distance between the external body and the frailty assessment device 100 via the distance sensing arrangement 122 of the movement measurement subunit 120. The data/information relating to the distance between the external body and the frailty assessment device 100 may be processed to determine a speed of the external body relative to the frailty assessment device 100. When the frailty assessment device 100 is kept stationary, an absolute speed of the external body may be determined. When the frailty assessment device 100 is being used to conduct body movement assessment, the external body may be the subject under assessment (e.g. the patient).

[00022] With the movement measurement subunit 120 integrated into the single device body 110 of the frailty assessment device 100, the distance sensing arrangement 122 of the movement measurement subunit 120 may be incorporated into the single device body 110. Accordingly, the distance sensing arrangement 122 may be disposed in/to/at the single device body 110.

[00023] According to various embodiments, the strength measurement subunit 130 may include a first grip member 132, a second grip member 134 and a force sensing arrangement 136. The first grip member 132 and the second grip member 134 may be movable relative to each other. Accordingly, the first grip member 132 and the second grip member 134 may be disposed relative to each other such that they may be movable with respect to each other. According to various embodiments, the first grip member 132 and the second grip member 134 being movable relative to each other may include the first grip member 132 and the second grip member 134 being loosely disposed relative to each other or non-fixedly disposed relative to each other or being disposed in a manner so as to allow some movement leeway relative to each other or being disposed in a manner so as to have some freedom to move relative to each other. According to various embodiments, the relative movement between the first grip member 132 and the second grip member 134 may be a minute or minuscule or fine movement which may be perceivable by a sense of touch and which may be barely perceivable visually. According to some embodiments, the first grip member 132 and the second grip member 134 may be movably coupled with respect to each other such that they may be movable relative to each other.

[00024] Further, the force sensing arrangement 136 may be disposed between the first grip member 132 and the second grip member 134. The force sensing arrangement 136 may be configured to measure a force for urging the first grip member 132 and the second grip member 134 towards each other. Accordingly, with the force sensing arrangement 136 disposed between the first grip member 132 and the second grip member 134, the force sensing arrangement 136 may detect or sense the force being applied to urge the first grip member 132 and the second grip member 134 towards each other so as to measure or quantify said force. According to various embodiments, with the first grip member 132 and the second grip member 134 being movable relative to each other and the force sensing arrangement 136 between the first grip member 132 and the second grip member 134, the force applied to urge the first grip member 132 and the second grip member 134 towards each other may be transmitted to the force sensing arrangement 136 via the first grip member 132 and the second grip member 134. Accordingly, the first grip member 132 and the second grip member 134 may be urged towards each other in a manner so as to impart the force to the force sensing arrangement 136 such that the force may be measured by the force sensing arrangement 136. According to various embodiments, the first grip member 132 and the second grip member 134 being movable relative to each other may enable the force, which is applied to the first grip member 132 and the second grip member 134 towards each other, to be transmitted to the force sensing

arrangement 136. Accordingly, the first grip member 132 and the second grip member 134 may be movable relative to each other to compress the force sensing arrangement 136 such that the force sensing arrangement 136 may measure the force applied thereon. For example, the force, which is applied to urge the first grip member 132 and the second grip member 134 towards each other, may move the first grip member 132 and the second grip member 134 towards each other such that the first grip member 132 and the second grip member 134 may press against the force sensing arrangement 136 from two opposite sides, and further application of the force to the first grip member 132 and the second grip member 134 may impart the force to the force sensing arrangement 136 such that the force sensing arrangement 136 may measure the force.

According to various embodiments, the force applied to urge the first grip member 132 and the second grip member 134 towards each other may be a gripping force applied via a hand gripping the first grip member 132 and the second grip member 134. A subject under assessment (e.g. a patient) applying the gripping force may feel the relative movement between first grip member 132 and the second grip member 134. However, the relative movement between the first grip member 132 and the second grip member 134 may be barely observable visually.

[00025] According to various embodiments, the first grip member 132 and the second grip member 134 of the strength measurement subunit 130 may serve as a handgrip portion 112 of the frailty assessment device 100. Accordingly, the frailty assessment device 100 may include the handgrip portion 112, which may include the first grip member 132 and the second grip member 134. According to various embodiments, the frailty assessment device 100 may include the force sensing arrangement 136 in the handgrip portion 112, wherein the force sensing arrangement 136 may be used to measure grip strength when subject under assessment (e.g. a patient) grips on the handgrip portion 112 (i.e. applies a gripping force on the handgrip portion 112). According to various embodiments, the force sensing arrangement 136 of the strength measurement subunit 130 may include a force sensor with high precision and accuracy. As an example, the force sensor may include, but not limited to, a strain gauge force sensor. According to various embodiment, the frailty assessment device 100 may include a main body portion 114. The distance sensing arrangement 122 of the movement measurement subunit 120 may be in the main body portion 114 of the frailty assessment device 100. According to various embodiments, the distance sensing arrangement 122 may be used to measure a gait or walking speed of the subject under assessment (e.g. a patient) by assessing the change in distance from the device over time when the distance sensing arrangement 122 is pointing to subject under assessment (e.g. a patient). According to various embodiments, the

distance sensing arrangement 122 of the movement measurement subunit 120 may include a distance sensor. For example, the distance sensor may include, but not limited to, a light detection and ranging (Lidar) sensor or a time-of-flight sensor. According to various embodiments, the frailty assessment device 100 may be handheld or placed on a flat surface when being used for conducting body movement assessment, for example when being used to assess gait or walking speed of the subject under assessment (e.g. a patient).

[00026] According to various embodiments, the frailty assessment device 100 may include a device frame 140. The device frame 140 may integrally interconnect the movement measurement subunit 120 and the strength measurement subunit 130. Accordingly, the device frame 140 may serve as a bridging structure to physically integrate the movement measurement subunit 120 and the strength measurement subunit 130 together into the single device. According to various embodiments, the device frame 140 may be a casing, a housing, or an internal frame of the frailty assessment device 100.

[00027] According to various embodiments, the device frame 140 of the frailty assessment device 100 may include a first portion 142 and a second portion 144. The strength measurement subunit 130 may be disposed at the first portion 142 of the device frame and the movement measurement subunit 120 may be disposed at the second portion of the device frame 140. For example, as shown in FIG. 1A, the first portion 142 of the device frame 140 may be at a rear and the second portion 144 of the device frame 140 may be at a front when the frailty assessment device 100 is oriented for conducting body movement assessment.

[00028] According to various embodiments, an axis of relative movement 133 between the first grip member 132 and the second grip member 134 of the strength measurement subunit 130 may be parallel to a measurement axis 123 of the distance sensing arrangement 122 of the movement measurement subunit 120 for measuring the distance of the external body, such as the subject under assessment (e.g. the patient), with respect to the frailty assessment device 100. In the various embodiments, the first grip member 132 and the second grip member 134 of the strength measurement subunit 130 may be movable relative to each other along the axis of relative movement 133. Accordingly, the first grip member 132 and the second grip member 134 may move towards or away from each other along the axis of relative movement 133. In the various embodiments, the distance sensing arrangement 122 of the movement measurement subunit 120 may measure the distance of the external body with respect to the frailty assessment device 100 along the measurement axis 123 of the distance sensing arrangement 122. Accordingly, when using the frailty assessment device 100 to conduct body movement

assessment, the frailty assessment device 100 may be oriented such that the measurement axis 123 of the distance sensing arrangement 122 is pointing towards the external body.

[00029] According to various embodiments, the frailty assessment device 100 may include a processor 150. In various embodiments, a "processor" may be understood as any kind of a logic implementing entity, which may be special purpose circuitry or a processor executing software stored in a memory, firmware, or any combination thereof. Thus, in an embodiment, a "processor" may be a hard-wired logic circuit or a programmable logic circuit such as a programmable processor, e.g. a microprocessor (e.g. a Complex Instruction Set Computer (CISC) processor or a Reduced Instruction Set Computer (RISC) processor). A "processor" may also be a processor executing software, e.g. any kind of computer program, e.g. a computer program using a virtual machine code such as e.g. Java. Any other kind of implementation of the respective functions which will be described in more detail below may also be understood as a "processor" in accordance with various embodiments. In various embodiments, the processor may be part of a computing system or a controller or a microcontroller or any other system providing a processing capability. According to various embodiments, such systems may include a memory which is for example used in the processing carried out by the device. A memory used in the embodiments may be a volatile memory, for example a DRAM (Dynamic Random Access Memory) or a non-volatile memory, for example a PROM (Programmable Read Only Memory), an EPROM (Erasable PROM), EEPROM (Electrically Erasable PROM), or a flash memory, e.g., a floating gate memory, a charge trapping memory, an MRAM (Magnetoresistive Random Access Memory) or a PCRAM (Phase Change Random Access Memory).

[00030] According to various embodiments, the distance sensing arrangement 122 of the movement measurement subunit 120 may be electrically coupled to the processor 150 for communicating a distance output signal (or data) from the distance sensing arrangement 122 to the processor 150. Accordingly, the processor 150 may receive the distance output signal from the distance sensing arrangement 122 of the movement measurement subunit 120. According to various embodiments, the force sensing arrangement 136 of the strength measurement subunit 130 may be electrically coupled to the processor 150 for communicating a force output signal (or data) from the force sensing arrangement 136 to the processor 150. Accordingly, the processor 150 may receive the force output signal from the force sensing arrangement 136 of the strength measurement subunit 130.

[00031] According to various embodiments, the processor 150 may be configured to control the distance sensing arrangement 122 of the movement measurement subunit 120 and/or the

force sensing arrangement 136 of the strength measurement subunit 130. Accordingly, the processor 150 may activate or de-active the distance sensing arrangement 122 of the movement measurement subunit 120 and/or the force sensing arrangement 136 of the strength measurement subunit 130 depending on whether the frailty assessment device 100 is being
5 used for body movement assessment or body strength assessment.

[00032] According to various embodiments, the processor 150 may be configured to determine the distance of the external body with respect to the frailty assessment device 100 based on the distance output signal from the distance sensing arrangement 122 of the movement measurement subunit 120. Accordingly, the processor 150 may process the distance output
10 signal from the distance sensing arrangement 122 of the movement measurement subunit 120 and determine the distance of the external body with respect to the frailty assessment device 100. According to various embodiments, the processor 150 may be configured to determine a speed of the external body based on dividing a difference in distance between two distance measurements detected by the distance sensing arrangement 122 of the movement
15 measurement subunit 120 over a time taken between detecting the two distance measurements. Accordingly, the processor 150 may determine the speed of the external body based on at least two distance measurements taken by the distance sensing arrangement 122 of the movement measurement subunit 120 and the time elapsed for the distance sensing arrangement 122 of the movement measurement subunit 120 to take the at least two distance measurements. For
20 example, when the frailty assessment device 100 is used for body movement assessment (e.g. gait or walking speed assessment), the the subject under assessment (e.g. a patient) may walk towards the frailty assessment device 100. A first distance measurement may be x meters from the frailty assessment device 100 and a second distance measurement may be y meters from the frailty assessment device 100. The processor 150 may then determine the speed of the
25 subject under assessment based on a distance covered from x meters to y meters (i.e. $x - y$ meters) divided by a time taken to travel the distance.

[00033] According to various embodiments, the processor 150 may be configured to determine an amount of force applied to urge the first grip member 132 and the second grip member 134 towards each other based on the force output signal received from the force
30 sensing arrangement 136 of the strength measurement subunit 130. Accordingly, the processor 150 may process the force output signal from the force sensing arrangement 136 of the strength measurement subunit 130 and determine the force applied to urge the first grip member 132 and the second grip member 134 towards each other. According to some embodiments, the force applied may be correlated to the force output signal from the force sensing arrangement

136 of the strength measurement subunit 130. Accordingly, the processor 150 may determine the force applied based on the correlation with the force output signal.

[00034] According to various embodiments, the frailty assessment device 100 may include a visual indication arrangement 160. The visual indication arrangement 160 may be electrically coupled to the processor 150. According to various embodiments, the processor 150 may be configured to control the visual indication arrangement 160 to change between different visual indications. Accordingly, the processor 150 may control the visual indication arrangement 160 to display or provide visual indications based on the usage of the frailty assessment device 100. According to various embodiments, the visual indication arrangement 160 may include a visual display (e.g. a screen, touchscreen, etc.) and/or a light indicator (e.g. a light-emitting-diode, LED). According to various embodiments, when the visual indication arrangement 160 includes the visual display, the visual display may be rotatable relative to the distance sensing arrangement 122 of the movement measurement subunit 120. The visual display may be rotated to face in a direction of sensing of the distance sensing arrangement 122 of the movement measurement subunit 120 or face in an opposite direction with respect to the direction of sensing of the distance sensing arrangement 122 of the movement measurement subunit 120. The direction of sensing of the distance sensing arrangement 122 of the movement measurement subunit 120 may be a direction from the frailty assessment device 100 to the external body (e.g. the subject under assessment, i.e. the patient).

[00035] According to various embodiments, the processor 150 may be configured to control the visual indication arrangement 160 to display a distance-sensing-ready-visual-indication when the processor 150 determines that the external body (e.g. the subject under assessment, i.e. the patient) is within a pre-set range of distances from the frailty assessment device 100 for commencing the body movement assessment. In other words, when the processor 150 determines that the external body (e.g. the subject under assessment, i.e. the patient) is at a required distance (pre-set range of distance) from the frailty assessment device 100 for the body movement assessment, the processor 150 may display the distance-sensing-ready-visual-indication via the visual indication arrangement 160 to indicate that the body movement assessment may commence.

[00036] According to various embodiments, the processor 150 may be configured to control the visual indication arrangement 160 to display the distance-sensing-ready-visual-indication when the processor 150 determines that a set of distances of the external body (e.g. the subject under assessment, i.e. the patient) with respect to the frailty assessment device 100 detected by the distance sensing arrangement 122 of the movement measurement subunit 120 over a

predetermined duration is within a pre-set range of distances. Accordingly, the distance-sensing-ready-visual-indication may be displayed by the visual indication arrangement 160 when the processor 150 determines that the external body (e.g. the subject under assessment, i.e. the patient) is at the required distance (pre-set range of distance) from the frailty assessment device 100 for a minimum period of time (i.e. over the predetermined duration). In other words, the external body (e.g. the subject under assessment, i.e. the patient) may be required to be at the required distance (pre-set range of distance) from the frailty assessment device 100 for the predetermined duration before the processor 150 control the visual indication arrangement 160 to display the distance-sensing-ready-visual-indication.

[00037] According to various embodiments, the processor 150 may be configured to operate the frailty assessment device 100 for body movement assessment (e.g. gait or walking speed assessment) upon displaying the distance-sensing-ready-visual-indication via the visual indication arrangement 160. Accordingly, upon displaying the distance-sensing-ready-visual-indication via the visual indication arrangement 160, the processor 150 may control the distance sensing arrangement 122 of the movement measurement subunit 120 for sensing or detecting a series of distance measurements, and be ready to determine corresponding speeds based on the series of distance measurements.

[00038] According to various embodiments, the processor 150 may be configured to control the visual indication arrangement 160 to display a distance-sensing-completed-visual-indication when the processor 160 determines that the external body (e.g. the subject under assessment, i.e. the patient) has completed the body movement assessment. According to various embodiments, the processor 150 may be configured to control the visual indication arrangement 160 to display the distance-sensing-completed-visual-indication when the processor 160 determines that the distance of the external body (e.g. the subject under assessment, i.e. the patient) with respect to the frailty assessment device 100 detected by the distance sensing arrangement 122 of the movement measurement subunit 120 is less than a predetermined minimum distance threshold from the frailty assessment device 100. Accordingly, when the external body (e.g. the subject under assessment, i.e. the patient) has moved close enough (i.e. predetermined minimum distance threshold) to the frailty assessment device 100, the body movement assessment (e.g. gait or walking speed assessment) is considered to be completed and the processor 150 may be configured to control the visual indication arrangement 160 to display the distance-sensing-completed-visual-indication.

[00039] According to various embodiments, the processor 150 may be configured to control the visual indication arrangement 160 to display a force-sensing-ready-visual-indication when

the frailty assessment device 100 is ready for body strength assessment (e.g. grip strength assessment). According to various embodiments, the processor 150 may be configured to monitor an amount of force applied to urge the first grip member 132 and the second grip member 134 towards each other throughout a predetermined period of time. According to some
5 embodiments, the processor 150 may then determine the grip strength based on a peak amount of force recorded during the predetermined period of time. According to various embodiments, the processor 150 may be configured to control the visual indication arrangement 160 to display a force-sensing-completed-visual-indication at an end of the predetermined period of time.

[00040] According to various embodiments, the frailty assessment device 100 may include
10 an inertial measurement unit 170. The inertial measurement unit 170 may be electrically coupled to the processor 150. According to various embodiments, the processor 150 may be configured to determine an orientation of the frailty assessment device 100 based on output signals (or data) from the inertial measurement unit 170. According to various embodiments, the processor 150 may correct alignment errors of the frailty assessment device 100 using the
15 output signals from the inertial measurement unit 170 and trigonometry.

[00041] According to various embodiments, the frailty assessment device 100 may include an alignment assist arrangement 180 serving as a visual guide capable of being used to aim the distance sensing arrangement 122 of the movement measurement subunit 120 at the external body (e.g. the subject under assessment, i.e. the patient) for detecting the distance of the
20 external body with respect to the frailty assessment device 100. Accordingly, the frailty assessment device 100 may be positioned and/or oriented for body movement assessment by using the alignment assist arrangement 180 to point the distance sensing arrangement 122 of the movement measurement subunit 120 at the external body (e.g. the subject under assessment, i.e. the patient). According to various embodiments, the alignment assist
25 arrangement 180 may include one or a combination of a sight, a laser pointer, or a camera.

[00042] According to various embodiments, the frailty assessment device 100 may include a stand connector 190. The stand connector 190 may be connectable to a stand. With the stand connected to the frailty assessment device 100, the frailty assessment device 100 may be placed on a surface, such as a desk, when conducting the body movement assessment (e.g. gait or
30 walking speed assessment).

[00043] According to various embodiments, the frailty assessment device 100 may include a communication module 152. The communication module may be configured to communicate via a wired or wireless connection with an external electronic device. The wireless connection may include, but not limited to, a wireless fidelity (Wi-Fi) connection, or a Bluetooth

connection, or an infrared connection, or a microwave communication connection, or a mobile communication connection, or a radio frequency communication connection. According to various embodiments, the external electronic device may include, but not limited to, a mobile device, a mobile phone, a tablet, a computer, a laptop, a notebook.

- 5 **[00044]** According to various embodiments, the frailty assessment device 100 may be used for conducting a gait (or walking) speed assessment as an example of the body movement assessment. The procedures for conducting the gait (or walking) speed assessment using the frailty assessment device 100 may be as follows. The subject under assessment (e.g. the patient) may be made to stand still. An assessor may carry the frailty assessment device 100 and move
- 10 to a testing point based on a required test distance (e.g. 3.5m) from the subject under assessment (e.g. the patient). At the testing point, the distance sensing arrangement 122 of the movement measurement subunit 120 (e.g. a lidar sensor) may detect a distance of the subject under assessment (e.g. the patient) from the frailty assessment device 100 and send the distance output signal to the processor 150. The processor 150 may determine that the subject under
- 15 assessment (e.g. the patient) is within the pre-set range of distances from the frailty assessment device 100 for commencing the body movement assessment. Accordingly, the processor 150 may control the visual indication arrangement 160 (e.g. a screen) to display the distance-sensing-ready-visual-indication (e.g. display green colour). With the visual indication arrangement 160 (e.g. the screen) of the frailty assessment device 100 turned green (i.e.
- 20 showing the distance-sensing-ready-visual-indication), the subject under assessment (e.g. the patient) may walk towards the frailty assessment device 100. The frailty assessment device 100 (or the processor 150 of the frailty assessment device 100) may then automatically calculate the gait (or walking) speed. To make sure that an alignment of the frailty assessment device 100 is correct for the gait (or walking) speed assessment, the assessor may line up the alignment
- 25 assist arrangement 180 to a chest of the subject under assessment (e.g. the patient). For example, when the alignment assist arrangement 180 includes two circle sights of different dimensions at a top of the frailty assessment device 100, the smaller circle sight may be lined up with the larger circle sight such that the smaller circle sight is inside the larger circle sight and pointing to the chest of the subject under assessment (e.g. the patient). Further, the visual
- 30 indication arrangement 160 (e.g. the screen) of the frailty assessment device 100 may be facing (or pointing towards) the subject under assessment (e.g. the patient) so that he/she can see the visual indication arrangement 160 (e.g. the screen). In addition, the visual indication arrangement 160 (e.g. the screen) of the frailty assessment device 100 may be controlled to display a distance measurement based on the distance sensing arrangement 122 of the

movement measurement subunit 120 during the gait (or walking) speed assessment for providing feedback on the progress of the gait (or walking) speed assessment to the subject under assessment (e.g. the patient).

[00045] According to various embodiments, the automatic calculation of the gait (or walking) speed performed by the frailty assessment device 100 (or the processor 150 of the frailty assessment device 100) may incorporate error checking. According to various embodiments, the frailty assessment device 100 (or the processor 150 of the frailty assessment device 100) may calculate speed (or velocity) across multiple timepoints in the walking trial of the gait (or walking) speed assessment, and test the consistency of the results to make sure that the results are not affected by artefact and that a steady-state speed (or velocity) was achieved. In doing so, the frailty assessment device 100 (or the processor 150 of the frailty assessment device 100) may ensure that the gait (or walking) speed may be valid. According to various embodiments, the frailty assessment device 100 (or the processor 150 of the frailty assessment device 100) may be configured to extract rolling speed (or velocity) results for pre-defined increments (e.g. 1m) throughout the entire walking trial and examine whether peak velocity was achieved in the middle segment (e.g. after removing the first and last segments to account for acceleration and deceleration respectively), and whether for a continuous stretch (e.g. 1m) of data the variability was less than 0.1m/s as measured using standard deviation. In various embodiments, data may be obtained robustly over very short distances.

[00046] According to some embodiments, an inbuilt, collapsible tripod (serving as the stand) may be provided to the frailty assessment device 100 for allowing the frailty assessment device 100 to be placed on a surface, e.g. a desk, for the gait (or walking) speed assessment. With the frailty assessment device 100 placed on the surface, the assessor may walk with the subject under assessment (e.g. the patient) in instances when the subject under assessment (e.g. the patient) is deemed to be high falls risk.

[00047] According to various embodiments, the frailty assessment device 100 may be used for conducting a grip strength assessment as an example of the body strength assessment. The procedures for conducting the grip strength assessment using the frailty assessment device 100 may be as follows. The assessor may rotate the visual indication arrangement 160 (e.g. the screen) to face in the same direction as that which the distance sensing arrangement 122 of the movement measurement subunit 120 (e.g. the lidar sensor) is pointing. In this arrangement, the frailty assessment device 100 may provide feedback to the assessor during the grip strength assessment. The subject under assessment (e.g. the patient) may then squeeze the handgrip

portion 112 of the frailty assessment device 100 as hard as he/she can. Data from the force sensing arrangement 136 (e.g. an inbuilt load cell) may be recorded.

[00048] According to various embodiments, the frailty assessment device 100 may be configured as a self-contained device including, among others, own power source (e.g. battery pack, rechargeable battery, battery charging, etc.), own analysis capability (e.g. via the processor 150), and own feedback capability (e.g. via the visual indication arrangement 160). According to various embodiments, the frailty assessment device 100 may be wirelessly (e.g. via Wi-Fi or Bluetooth, i.e. the communication module 152) connected to phones, computers etc. if that is deemed useful. According to various embodiments, the communication module 152 may be configured to be normally off (or turned off by default) to ensure data privacy. However, the communication module 152 may be turned on easily when required.

[00049] According to various embodiments, the frailty assessment device 100 may significantly improve the way that frailty may be assessed. It may be far quicker, easier and more accurate than conventional methods. The frailty assessment device 100 may also allow gait speed and grip strength to be assess using a single device, whereby gait speed and grip strength are among the best measures for frailty assessment. The frailty assessment device 100 may be portable, thus enabling testing/assessment to be performed in home and community setting with ease and better accuracy.

[00050] FIG. 2A, FIG. 2B, and FIG. 2C show different views of a frailty assessment device 200 according to various embodiments. According to various embodiments, the frailty assessment device 200 of FIG. 2A to FIG. 2C includes all the features of the frailty assessment device 100 of FIG. 1A and FIG. 1B. Accordingly, all features, changes, modifications, and variations that are applicable to the frailty assessment device 100 of FIG. 1A and FIG. 1B are also applicable to the frailty assessment device 200 of FIG. 2A to FIG. 2C. Therefore, elements which are the same as those described earlier are assigned the same reference numerals, and repetition of their explanations is omitted for brevity. According to various embodiments, the frailty assessment device 200 may, similar to the frailty assessment device 100 of FIG. 1A and FIG. 1B, include the movement measurement subunit 120 including the distance sensing arrangement 122; and the strength measurement subunit 130 including the first grip member 132, the second grip member 134 and the force sensing arrangement 136 therebetween. Further, the frailty assessment device 200 may, similar to the frailty assessment device 100 of FIG. 1A and FIG. 1B, include the device frame 140 integrating the movement measurement subunit 120 and the strength measurement subunit 130 together. Furthermore, the frailty assessment device 200 may, similar to the frailty assessment device 100 of FIG. 1A and FIG. 1B, include the

processor 150, the visual indication arrangement 160, the inertial measurement unit 170, the alignment assist arrangement 180, the stand connector 190 and/or the communication module 152. Additional details of the frailty assessment device 200 are elaborated in the following.

5 [00051] According to various embodiments, the force sensing arrangement 136 of the strength measurement subunit 130 of the frailty assessment device 200 may include a half-bridge strain gauge sensor setup, with two strain gauges mounted to metal frames which allow for detection of force applied to the frailty assessment device 200 whilst providing temperature compensation. Deformation of these gauges may be additive and measured using an amplifier, then converted to a force value via calibration on the processor 150.

10 [00052] According to various embodiments, the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 200 may include a time of flight (ToF) sensor with a narrow focus angle (e.g. $<3^\circ$) that may be pointed at the subject under assessment (e.g. the patient). The ToF sensor may be used to obtain or measure the distance of the subject under assessment (e.g. the patient) from the frailty assessment device
15 200 at high frequency (e.g. 100Hz or more) or high sampling rates controlled by the processor 150 (e.g. a microcontroller). When the change in distance from the frailty assessment device 200 is measured and known as the subject under assessment (e.g. the patient) walks towards it, and the time between samples (e.g. distance measurements) is measured and known (or assumed consistent), the gait (or walking) speed (or velocity) may be calculated or determined
20 as metres per second.

[00053] According to various embodiments, the processor 150 of the frailty assessment device 200 may include a microcontroller, along with battery and charging circuit, that may collect or receive data (or signals) from the half-bridge strain gauge sensor setup (i.e. the force sensing arrangement 136 of the strength measurement subunit 130 of the frailty assessment
25 device 200) and the ToF sensor (i.e. the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 200), perform all calculations (or processing) and/or calibration, and/or report the results via a touchscreen (i.e. the visual indication arrangement 160) mounted into the frailty assessment device 200. According to various embodiments, three buttons may be presented or provided on the touchscreen of the
30 frailty assessment device 200, one to record the grip strength result and one to record the gait (or walking) speed result on completion of the test, and the third to set the calibration/setup of the frailty assessment device 200.

[00054] According to various embodiments, the communication module 152 of the frailty assessment device 200 may include a wireless chip (e.g. for Wi-Fi, radio frequency

communication, and/or Bluetooth) to send these data (or signals) upon a button click in a corresponding web browser/application software that may store the results in a centralised database if desired. As an example, the communication module 152 of the frailty assessment device 200 may include a ESP32 chip.

- 5 **[00055]** According to various embodiments, the frailty assessment device 200 may function according to the following for conducting the gait (or walking) speed assessment and the grip strength assessment in a continuous manner.

- [00056]** According to various embodiments, the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 200 (e.g. a ToF / LIDAR sensor) may detect the distance from the frailty assessment device 200 to a front of the subject under assessment (i.e. the patient) and sends these data to the processor 150 (e.g. the microcontroller). To make sure alignment is correct, the frailty assessment device 200 may be lined up via the alignment assist arrangement 180 of the frailty assessment device 200 (e.g. a cylinder sight at the top of the frailty assessment device 200) with a chest of the subject under assessment (i.e. the patient). Further, the inertial measurement unit 170 of the frailty assessment device 200 may determine whether the frailty assessment device 200 is oriented correctly, and a visual indication via the visual indication arrangement 160 of the frailty assessment device 200 (e.g. the touchscreen) may be provided to indicate when the frailty assessment device 200 is determined to be oriented correctly. According to various embodiments, the inertial measurement unit 170 (or an accelerometer) of the frailty assessment device 200 may be used to determine the orientation relative to the gravity. When the orientation (e.g. a beam or the measurement axis 123 of the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 200, such as the ToF/LIDAR sensor) is determined to be within a predetermined range of distance-sensing-angular-deviations (e.g. ± 5 degrees) off horizontal, the distance value from the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 200 (e.g. the ToF/LIDAR sensor) may be shown on the visual indication arrangement 160 of the frailty assessment device 200 (e.g. the touchscreen). When the processor (e.g. the microcontroller) identifies that that the subject under assessment (i.e. the patient) is within a designated starting boundary (or the pre-set range of distances from the frailty assessment device 200) for commencing the gait (or walking) speed assessment, the distance value displayed or shown on the visual indication arrangement 160 of the frailty assessment device 200 (e.g. the touchscreen) may turn green. The distance value turning green may serve as the distance-sensing-ready-visual-indication to the assessor. As an example, the designated starting boundary (or the pre-set range of distances

from the frailty assessment device 200) may be within $\pm 0.25\text{m}$ of the set starting position (e.g. when the default set starting position is 4.25 metres from the frailty assessment device 200, the designated starting boundary may be 4.00m to 4.5m from frailty assessment device 200).

- [00057]** While the subject under assessment (i.e. the patient) is within the designated starting boundary (or the pre-set range of distances from the frailty assessment device 200), a squeeze of the handgrip portion 112 of the frailty assessment device 200 (e.g. a grip strength attachment) by the assessor (e.g. a person conducting the test/assessment) may add loading (or apply a force) to the force sensing arrangement 136 of the strength measurement subunit 130 (e.g. the strain gauges) embedded in the handgrip portion 112 of the frailty assessment device 200. The loading (or the force) may be converted into a digital force signal by the amplifier (e.g. the load cell amplifier) and converted into a calibrated force measure by the processor 150 (e.g. the microcontroller). According to various embodiments, if this force exceeds a predetermined threshold set for the gait (or walking) speed assessment to start (e.g. the predetermined threshold may be set at 2 kilograms), a green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the touchscreen) may be activated on the patient side of the frailty assessment device 200 which serve to indicate to the subject under assessment (e.g. the patient) to start walking so as to start the gait (or walking) speed assessment. The activation of the green LED light may serve as the distance-sensing-ready-visual-indication for the subject under assessment (i.e. the patient). According to various embodiments, if no force above this predetermined threshold is detected while the patient is within this designated starting boundary, the green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the touchscreen) may be activated, to indicate to the subject under assessment (e.g. the patient) to start walking so as to start the gait (or walking) speed assessment, if the patient stays within this designated starting boundary for a predetermined duration (e.g. 5 consecutive seconds). The activation of the green LED light may serve as the distance-sensing-ready-visual-indication for the subject under assessment (i.e. the patient). This may allow for hands-free assessment of the subject under assessment (e.g. the patient) who may need close supervision during the gait (or walking) speed assessment.
- [00058]** With the green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the touchscreen) activated, the subject under assessment (e.g. the patient) may walk towards the frailty assessment device 200, and when the data (or signal) of distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 200 shows or indicates that the subject under assessment

(e.g. the patient) is less than or equal to the predetermined minimum distance threshold from the frailty assessment device 200 (e.g. 1.25m), the processor 150 (e.g. the microcontroller) may activate a red LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the touchscreen and the green LED light) to indicate to the subject under assessment (e.g. the patient) that they are to stop walking.

[00059] According to various embodiments, the gait (or walking) speed determined may be defined as metres walked divided by time taken. The gait (or walking) speed may be determined by the processor 150 based on utilising the time taken to walk a distance from Distance A (an initial patient starting position when the green light is turned on minus 1.25m to account for acceleration) to Distance B (Distance A minus the predetermined minimum distance threshold). For example, if the patient is at 4.25m from the device when the green light turns on, Distance A = 3m and Distance B = 1.75m. If walking from Distance A to Distance B took 1 second, the gait speed is measured as $1.25 / 1 = 1.25$ metres per second. Additional data may be derived from the device including reaction time, static start, as well as differing distance gait speed.

[00060] After the subject under assessment (e.g. the patient) stops walking, the subject under assessment (e.g. the patient) may grip the hand grip portion 112 of the frailty assessment device 200 in a posture with their elbow by their side to proceed with the grip strength assessment. The subject under assessment (e.g. the patient) may raise the frailty assessment device 200 until their forearm is parallel to the ground. This may be sensed by the inertial measurement unit 170 (or the accelerometer) of the frailty assessment device 200. When the processor 150 (e.g. the microcontroller) detects that the frailty assessment device 200 is within a predetermined range of force-sensing-angular-deviations (e.g. ± 10 degrees off vertical), for example when the forearm of the subject under assessment, e.g. the patient, is substantially perpendicular to the frailty assessment device 200 or substantially parallel to the ground, the green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the touchscreen) may be turned on, indicating that the grip strength assessment has commenced, and the subject under assessment (e.g. the patient) may begin to squeeze the frailty assessment device 200 as hard as they can. The activation of the green LED light may serve as a force-sensing-ready-visual-indication. Squeezing the frailty assessment device 200 may compress the force sensing arrangement 136 of the strength measurement subunit 130 of the frailty assessment device 200 (e.g. the strain gauges or the load cells), which is measured as force by the processor 150 (e.g. the microcontroller) after conversion by the load cell amplifier. Once the force applied on the hand grip portion 112 of the frailty assessment device 200 by the

subject under assessment (e.g. the patient) exceeds a set predetermined minimum force threshold (e.g. 2kg), a timer may commence. After a predetermined period of time (e.g. 5 seconds) measured by the timer, the green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the touchscreen) may be turned off and/or the red LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the touchscreen and the green LED light) may turn on. The changes exhibited by the visual indication arrangement 160 of the frailty assessment device 200 may indicate or signal to the subject under assessment (e.g. the patient) that the grip strength assessment is completed and he/she may stop squeezing the hand grip portion 112 of the frailty assessment device 200. Accordingly, the deactivation of the green LED light and/or the activation of the red LED light may serve as a force-sensing-complete-visual-indication. According to various embodiments, a peak grip force may be calculated on the processor 150 (e.g. the microcontroller) by determining the highest force value achieved between the green LED light turning on and off (i.e. within the predetermined period of time, e.g. 5 seconds, after the force applied on the hand grip portion 112 of the frailty assessment device 200 crosses the predetermined minimum force threshold).

[00061] This completes one round/cycle of assessments, including the gait (or walking) speed assessment and the grip strength assessment. The assessor may then press the buttons for each of the two assessments that are displayed on the touchscreen (i.e. the visual indication arrangement 160 of the frailty assessment device 200) to store the values in the memory of the microcontroller (i.e. the processor 150). The assessments may be repeated, and pressing the buttons on the touchscreen (i.e. the visual indication arrangement 160 of the frailty assessment device 200) may change the stored value. For example, in the event of a higher score is achieved in subsequent assessments, the stored value may be changed accordingly if the goal is to record the highest score of multiple assessments. According to various embodiments, whenever a button is pressed to store the value, the frailty assessment device 200 may also send the current gait speed and grip strength data via the wireless chip (e.g. for Wi-Fi, radio frequency communication, and/or Bluetooth) to a phone application or a computer web browser connected to the frailty assessment device 200. The respective data may be displayed on the phone or the computer, or sent to a centralised database for storage.

[00062] According to various embodiments, the frailty assessment device 100, 200 may synergistically combine the gait (or walking) speed assessment and the grip strength assessment into a single complete device. In the various embodiments, the frailty assessment device 100, 200 may combine the movement measurement subunit 120 for gait (or walking)

speed assessment and the strength measurement subunit 130 for grip strength assessment into the same device with the incorporation of the distance sensing arrangement 122 (e.g. ToF/LIDAR sensors) and the force sensing arrangement 136 (e.g. the strain gauges or load cells). This may allow the subject under assessment (e.g. the patient) to complete multiple objectives of the frailty assessment rapidly using the same device.

[00063] According to various embodiments, the movement measurement subunit 120 and the strength measurement subunit 130 may be integrated together in the frailty assessment device 100, 200 such that both the distance sensing arrangement 122 of the movement measurement subunit 120 and the force sensing arrangement 136 of the strength measurement subunit 130 may cooperatively work together for the gait (or walking) speed assessment and/or the grip strength assessment. For example, according to some embodiments, the force sensing arrangement 136 of the strength measurement subunit 130 may be used to trigger the starting of the gait (or walking) speed assessment. Accordingly, when the distance sensing arrangement 122 of the movement measurement subunit 120 (e.g. ToF/LIDAR sensor) is pointed at the subject under assessment (e.g. patient), and the subject under assessment (i.e. the patient) is within a designated starting boundary (or the pre-set range of distances from the frailty assessment device 100, 200), squeezing the force sensing arrangement 136 of the strength measurement subunit 130 via the handgrip portion 112 of the frailty assessment device 100, 200 may trigger the frailty assessment device 100, 200 to turn on the green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200) to indicate to the subject under assessment (e.g. the patient) to start walking towards the frailty assessment device 100 so as to commence the gait (or walking) speed assessment. Accordingly, this trigger causing the green LED light to light up may serve as a visual indication for commencing the gait (or walking) speed assessment. The activation of the green LED light may serve as a distance-sensing-read-visual-indication. According to various embodiments, this trigger may also serve to acquire reaction time data. These reaction time data may be based on calculating the time between the green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200) being turned on and the subject under assessment (e.g. the patient) starting to walk. As an example, the frailty assessment device 100 may be configured to register that the subject under assessment (e.g. the patient) has started walking after the subject under assessment (e.g. the patient) move a predetermined distance (e.g. 10cm) closer to the frailty assessment device 100 from their position when the trigger was provided (i.e. starting reaction time).

[00064] According to various embodiments, the inertial measurement unit 170 may cooperatively work together with the the movement measurement subunit 120 and/or the strength measurement subunit 130 of the frailty assessment device 100, 200 for the gait (or walking) speed assessment and the grip strength assessment. Firstly, the inclinometer data of the inertial measurement unit 170 may allow detection of whether the frailty assessment device 100, 200 is oriented with the measurement axis 123 of distance sensing arrangement 122 (e.g. the ToF/LIDAR sensor) being horizontal to the ground, which may correspond to a correct alignment of the measurement axis 123 of distance sensing arrangement 122 (e.g. the ToF/LIDAR sensor) with flat ground for the gait (or walking) speed assessment. A (first) threshold range of ± 5 degrees (i.e. the predetermined range of distance-sensing-angular-deviations) may be used as an acceptable range of orientation of the frailty assessment device 100, 200 because this threshold range may reduce the measurement error associated with malalignment to less than or equal to 1.5% over a 4m distance. When the orientation of the frailty assessment device 100, 200 is determined to be within the (first) threshold range, the processor 150 may be configured to display the value measured by the distance sensing arrangement 122 (e.g. the ToF/LIDAR sensor) on the visual indication arrangement 160 (i.e. a screen or a touch screen). This may minimise or reduce measurement error associated with incorrect alignment of the frailty assessment device 100, 200 with the direction of walking. Secondly, the the inertial measurement unit 170 may be used during the grip strength assessment to detect whether the frailty assessment device 100, 200 is being held vertically, which corresponds to the forearm of the subject under assessment (e.g. the patient) being horizontal to the ground and which is the correct angle for the grip strength assessment. Accordingly, when the frailty assessment device 100, 200 is being held correctly, a direction of force application between the first grip member 132 and the second grip member 134 of the frailty assessment device 100, 200 may be aligned to a direction substantially perpendicular to an upright standing posture of the subject under assessment (e.g. the patient). During the grip strength assessment, there may be tremor associated with squeezing of the handgrip portion 112 of the frailty assessment device 100, 200 (in particular when squeezing as hard as possible), and error in the grip strength assessment may not be directly related to misalignment. Therefore a wider (second) threshold range (or a predetermined range of force-sensing-angular-deviations, e.g. of ± 10 degrees) may be used as an acceptable range of orientation of the frailty assessment device 100, 200. When the orientation of the frailty assessment device 100, 200 is determined to be within the wider (second) threshold range, the processor 150 may be configured to display the value for the force sensing arrangement 136 (e.g. the strain gauges or

the load cell sensors) on the visual indication arrangement 160 (i.e. a screen or a touch screen). The displaying of the value for the force sensing arrangement 136 may serve as the force-sensing-ready-visual-indication to indicate to the subject under assessment (e.g. the patient) that he/she can proceed with the grip strength assessment.

- 5 **[00065]** According to various embodiments, the frailty assessment device 100, 200 may be configured to automatically start and end the gait (or walking) speed assessment. An automated “start zone” and an automated “end zone” for the gait (or walking) speed assessment may be provided, whereby the processor 150 of the frailty assessment device 100, 200 may be configured to determine whether the subject under assessment (e.g. the patient) is at the
- 10 **automated “start zone” and an automated “end zone” based on the distance measured by the** distance sensing arrangement 122 of the movement measurement subunit 120. According to various embodiments, the pre-set range of distances (e.g. a 0.5m wide range) may be set at the designated start distance from the frailty assessment device 100, 200, so as to define the **automated “start zone”**. For example, when the designated start distance is 4.25m, the pre-set
- 15 **range of distances defining the automated “start zone” may be 4m to 4.5m.** According to various embodiments, the designated start distance may be set anywhere from 3.5m to 6m. Further, the predetermined minimum distance threshold may be set as the designated end **distance to define the automated “end zone”**. For example, the designated end distance may be set at 1.25m from the frailty assessment device 100, 200. According to various embodiments,
- 20 when the subject under assessment (e.g. the patient) is in the **automated “start zone”** for a predetermined duration, e.g. 2 continuous seconds, the screen (being part of the visual indication arrangement 160 of the frailty assessment device 200) which may be facing (or only visible to) the assessor may change colour to indicate to the assessor that he/she may squeeze the handgrip 112 of the frailty assessment device 100, 200 so as to apply a force on the force
- 25 sensing arrangement 136 of the strength measurement subunit 130 to activate the green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the screen) for indicating to the subject under assessment (e.g. the patient) to start walking towards the frailty assessment device 100, 200 so as to commence the gait (or walking) speed assessment. The change in colour of the screen may serve as the distance-sensing-ready-
- 30 visual-indication. The activation of the green LED light, serving as a visual indication to the subject under assessment (e.g. the patient) to start walking, may be manually activated using the force sensing arrangement 136 of the strength measurement subunit 130 to ensure that false triggering may not occur. The subject under assessment (e.g. the patient) may begin walking towards the frailty assessment device 100, 200, and when he/she crosses the automated “end

zone” (i.e. the predetermined minimum distance threshold), the red LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the screen and the green LED light) may light up so as to indicate to he/she to stop walking. The activation of the red LED light may serve as a distance-sensing-completed-visual-indication.

- 5 According to various embodiments, if the subject under assessment (e.g. the patient) remain in the pre-set range of **distances of the automated “start zone”** for a predetermined duration, e.g. 5 seconds, the green LED light (being part of the visual indication arrangement 160 of the frailty assessment device 200 in addition to the screen) may automatically turn on to indicate to the subject under assessment (e.g. the patient) that he/she may start walking to commence
- 10 the gait (or walking) speed assessment. The activation of the green LED light may serve as the distance-sensing-ready-visual-indication. This may allow the gait (or walking) speed assessment to be completed hands-free, for example if the frailty assessment device 100, 200 is placed on a surface, such as a table, and the assessor may walk next to the subject under assessment (e.g. the patient) to provide assistance if needed for safety reasons.
- 15 **[00066]** According to various embodiments, the frailty assessment device 100, 200 may be configured to include a calibration option for reporting the results of the grip strength assessment so that the results may be compared to other conventional grip strength devices. Currently, there are a few different conventional grip strength devices that have been used to collect normative data. However, the results from the conventional grip strength devices are
- 20 typically not directly comparable between the different conventional grip strength devices. For example, the data from a Jamar hydraulic dynamometer, which is one of the common conventional grip strength devices, are not directly comparable to the data of a Smedley grip dynamometer, which is another one of the common conventional grip strength devices. According to various embodiments, the calibration option provided in the frailty assessment
- 25 device 100, 200 may automatically account for such differences in data. According to various embodiments, the processor 150 of the frailty assessment device 100, 200 may be configured to calibrate the grip strength data based on a relationship defining such differences. For example, when the difference is a consistent difference (e.g. a consistent difference of approximately 3.2kg), the processor 150 may simply add the consistent difference to calibrate
- 30 the data. This may allow the user to select the frailty assessment device 100, 200 to **“replicate”** the data measured so that the values may be reported in a way that allows direct comparison with existing data previously obtained using conventional grip strength devices. This calibration option is advantageous as large normative datasets exist for a number of conventional grip strength devices. According to various embodiments, the frailty assessment

device 100, 200 may be configured with calibration options for comparing with data from the Jamar hydraulic dynamometer and/or the Smedley grip dynamometer. According to various embodiments, the calibration option may be **chosen by touching the “setup” touchscreen** button, then selecting the button that corresponds to the type of conventional grip strength device to replicate the grip strength data.

[00067] According to various embodiments, the frailty assessment device 100, 200 may be configured to provide a **similar “calibration” for the gait** (or walking) speed assessment, allowing the user to compare the results from the frailty assessment device 100, 200 against other gait (or walking) speed assessment methods including the 6 metre walk test and 4 metre walk test from the short physical performance battery. These two methods using short physical performance battery give dissimilar results as the former is only measured while the person is at their normal walking pace whereas the latter includes the start of the walking movement and acceleration phase. However, as the frailty assessment device 100, 200 includes a static start and the walking component, the results from the frailty assessment device 100, 200 may be accurately extrapolated to replicate either method. Similar to the grip strength calibration, this is advantageous because it allows easily comparison of data against established normative data.

[00068] FIG. 3A shows an exploded view of a frailty assessment device 300 according to various embodiments. FIG. 3B, FIG. 3C, and FIG. 3D show different views of the frailty assessment device 300 according to various embodiments. FIG. 3E shows a schematic block diagram of the electronic components of the frailty assessment device 300 according to various embodiments. According to various embodiments, the frailty assessment device 300 of FIG. 3A to FIG. 3E includes all the features of the frailty assessment device 100 of FIG. 1A and FIG. 1B as well as the frailty assessment device 200 of FIG. 2A to FIG. 2C. Accordingly, all features, changes, modifications, and variations that are applicable to the frailty assessment device 100 of FIG. 1A and FIG. 1B as well as the frailty assessment device 200 of FIG. 2A to FIG. 2C are also applicable to the frailty assessment device 300 of FIG. 3A to FIG. 3E. Therefore, elements which are the same as those described earlier are assigned the same reference numerals, and repetition of their explanations is omitted for brevity. According to various embodiments, the frailty assessment device 300 may, similar to the frailty assessment device 100 of FIG. 1A and FIG. 1B and the frailty assessment device 200 of FIG. 2A to FIG. 2C, include the movement measurement subunit 120 including the distance sensing arrangement 122; and the strength measurement subunit 130 including the first grip member 132, the second grip member 134 and the force sensing arrangement 136 therebetween. Further, the frailty assessment device 300 may, similar to the frailty assessment device 100 of FIG. 1A

and FIG. 1B and the frailty assessment device 200 of FIG. 2A to FIG. 2C, include the device frame 140 integrating the movement measurement subunit 120 and the strength measurement subunit 130 together. Furthermore, the frailty assessment device 300 may, similar to the frailty assessment device 100 of FIG. 1A and FIG. 1B and as well as the frailty assessment device 200 of FIG. 2A to FIG. 2C, include the processor 150, the visual indication arrangement 160, the inertial measurement unit 170, the alignment assist arrangement 180, the stand connector 190 and/or the communication module 152. Additional details of the frailty assessment device 300 are elaborated in the following.

[00069] Referring to FIG. 3A, according to various embodiments, the first portion 142 of the device frame 140 of the frailty assessment device 300 may be configured for the first grip member 132, the second grip member 134, and the force sensing arrangement 136 of the strength measurement subunit 130 to be assembled thereto, and the second portion 144 of the device frame 140 of the frailty assessment device 300 may be configured to house or contain the distance sensing arrangement 122 of the movement measurement subunit 120.

[00070] According to various embodiments, the strength measurement subunit 130 may be assembled to the first portion 142 of the device frame 140 of the frailty assessment device 300. Accordingly, the first grip member 132, the second grip member 134, and the force sensing arrangement 136 of the strength measurement subunit 130 may be assembled to the first portion 142 of the device frame 140 of the frailty assessment device 300. According to various embodiments, the first portion 142 of the device frame 140 of the frailty assessment device 300 may include a through-hole 146. The first grip member 132 of the strength measurement subunit 130 may be coupled to the first portion 142 of the device frame 140 to cover a first end of the through-hole 146. The force sensing arrangement 136 of the strength measurement subunit 130 may be disposed in the through-hole 146. An appendage portion 135 of the second grip member 134 of the strength measurement subunit 130 may be fitted into the through-hole 146 from the second end of the through-hole 146 so as to sandwich the force sensing arrangement 136 between the first grip member 132 and the appendage portion 135 of the second grip member 134. According to various embodiments, the second grip member 134 may be assembled to the first portion 142 of the device frame 140 in a manner so as to be movable relative to the first grip member 132. For example, the first grip member 132 may be fixedly coupled to the first portion 142 of the device frame 140, and the second grip member 134 movably coupled to the first portion 142 of the device frame 140 so as to be movable relative to the first grip member 132 and the first portion 142 of the device frame 140. According to some embodiments, the first end of the through-hole 146 of the first portion 142

of the device frame 140 may have a diameter larger than the second end of the through-hole 146 of the first portion 142 of the device frame 140. The appendage portion 135 of the second grip member 134 may have a cross-section diameter smaller than the second end of the through-hole 146 of the first portion 142 of the device frame 140 so as to be capable of being inserted there through. A bolt 137 may be inserted through the appendage portion 135 of the second grip member 134. A washer 138 may be fitted over an end portion of the bolt 137 located within the through-hole 146 of the first portion 142 of the device frame 140 when the appendage portion 135 of the second grip member 134 is inserted into the through-hole 146 of the first portion 142 of the device frame 140 from the second end of the through-hole 146. The washer 138 may have an external diameter that is larger than the second end of the through-hole 146 of the first portion 142 of the device frame 140 and smaller than the first end of the through-hole 146 of the first portion 142 of the device frame 140. A nut 139 may be screwed on the end portion the bolt 137 so as to retain the washer 138 on the bolt 137 such that the second hand grip member 134 may movably coupled to the first portion 142 of the device frame 140 and non-removable from the first portion 142 of the device frame 140.

[00071] According to various embodiments, as shown, the second portion 144 of the device frame 140 may be in the form of an opened-shell or an opened-casing. Accordingly, the distance sensing arrangement 122 of the movement measurement subunit 120 may be housed or contained within the opened-shell or the opened-casing. A cover 148 may be fitted across an opening of the opened-shell or the opened-casing to cover the opening of the opened-shell or the opened-casing. Accordingly, the cover 148 and the second portion 144 of the device frame 140 may together form an enclosure or a complete enclosed casing for housing or containing the distance sensing arrangement 122 of the movement measurement subunit 120 therein. According to some embodiments, the cover 148 may include a window 149. The distance sensing arrangement 122 of the movement measurement subunit 120 may be disposed in the second portion 144 of the device frame 140 in a manner such that the measurement axis 123 of the distance sensing arrangement 122 may extend through the window 149 of the cover 148. The window 149 of the cover 148 may be an aperture or an aperture with a transparent sheet extending across the aperture.

[00072] According to various embodiments, the frailty assessment device 300 may be set up according to the following.

[00073] According to various embodiments, the frailty assessment device 300 may include a power button 102. The power button 102 may be located at the second portion 144 of the device frame 140. The user may turn on the frailty assessment device 300 using the power button 102.

[00074] According to various embodiments, upon starting the frailty assessment device 300, a touchscreen 162 (which is also part of the visual indication arrangement 160) may display an options menu where key demographic data, including but not limited to age, range, weight, ethnicity, etc. of the subject under assessment (e.g. the patient) may be input into the frailty assessment device 300. The key demographic data may allow for normative data comparisons specific to that subject under assessment (e.g. the patient). The normative data may be compiled from existing datasets, for example frailty cutpoints specific to Singaporean males over the age of 65 years from Chinese background may be compared to cutpoints established in a similar cohort. This may be achieved using regression-based algorithms. According to various embodiments, the processor 150 of the frailty assessment device 300 may be configured to perform the data comparison. According to various embodiments, the normative data may be stored in the frailty assessment device 300.

[00075] According to various embodiments, if an external electronic device (or a secondary device) is used for interfacing with the frailty assessment device 300 (or a primary device), an application software may be opened on the external electronic device. The frailty assessment device 300 and the external electronic device may together form a system for frailty assessment. According to various embodiments, the external electronic device may be connected wirelessly to the frailty assessment device 300. For example, the communication module 152 of the frailty assessment device 300 and the external electronic device may be connected via a wireless interface (e.g. Bluetooth, Wi-Fi etc.). According to various embodiments, the external electronic device may interact with the frailty assessment device 300, both as a sender (e.g. triggering events such as automating button pressing, turning on/off the laser pointer) and receiver (e.g. receiving the values from the primary device). According to various embodiments, the external electronic device may be configured as a remote control for remotely controlling the frailty assessment device 300. According to various embodiments, the external electronic device may also be configured to send and update the normative datasets stored in the frailty assessment device 300. According to various embodiments, the external electronic device may also be configured receive data from the frailty assessment device 300 for storage and/or processing. According to various embodiments, the external electronic device may also be configured to upload the data received from the frailty assessment device 300 into the cloud system (for example, for integrating with health records).

[00076] According to various embodiments, the frailty assessment device 300 may function according to the following for conducting the gait (or walking) speed assessment. According to various embodiments, the frailty assessment device 300 may be configured to be handheld

or mounted for conducting the gait (or walking) speed assessment. Conducting the gait (or walking) speed assessment with the frailty assessment device 300 being handheld may be the quickest way, and may be suitable for subject under assessment (e.g. people) deemed to be high risk and those who do not need therapist assistance. This may also be the most convenient way of conducting the gait (or walking) speed assessment with the frailty assessment device 300.

[00077] In preparation to commence the gait (or walking) speed assessment, the frailty assessment device 300 may be positioned to commence the gait (or walking) speed assessment. The assessor may get the subject under assessment (e.g. patient) to stand at one end of an open space (example – dining room, hallway, void deck etc.), which may be of a suitable distance (e.g. 4m long or longer), looking straight forward in the direction of the other end of the open space. The assessor may then stand within the pre-set range of distances (e.g. approximately 4m) from the subject under assessment (e.g. the patient), pointing the distance sensing arrangement 122 (e.g. ToF / LIDAR sensor) of the movement measurement subunit 120 of the frailty assessment device 300 at the subject under assessment (e.g. the patient).

[00078] According to various embodiments, the alignment assist arrangement 180 of the frailty assessment device 300 may include a sight 182, a laser pointer 184, and/or a camera 186. According to various embodiments, when the alignment assist arrangement 180 of the frailty assessment device 300 includes the sight 182, the laser pointer 184, and the camera 186, the frailty assessment device 300 may be aligned with the subject under assessment (e.g. the patient) via three potential methods. First, the sight 182, which is a physical aim sight and which is at a top of the frailty assessment device 300, may be used to aim at the chest of the subject under assessment (e.g. the patient) to align the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 300 with the subject under assessment (e.g. the patient). According to various embodiments, the sight 182 may be disposed relative to the distance sensing arrangement 122 of the movement measurement subunit 120 in a manner such that a line of sight of the sight 182 and the measurement axis 123 of the distance sensing arrangement 122 of the movement measurement subunit 120 may be parallel or converge into a same point within the pre-set range of distances from the frailty assessment device 300. Hence, the sight 182 may be configured for manual alignment of the frailty assessment device 300. Second, the laser pointer 184, which may emit a visible laser beam to project a small visible coloured spot, may be used to aim at the chest of the subject under assessment (e.g. the patient) to align the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 300 with the subject under

assessment (e.g. the patient). According to various embodiments, the laser pointer 184 may be switched on and off using a button on the touchscreen 162 of the frailty assessment device 300 or via the wireless connection using the external electronic device. According to various embodiments, the laser pointer 184 may be disposed relative to the distance sensing arrangement 122 of the movement measurement subunit 120 in a manner such that the visible laser beam of the laser pointer 184 and the measurement axis 123 of the distance sensing arrangement 122 of the movement measurement subunit 120 may be parallel or converge into a same point within the pre-set range of distances from the frailty assessment device 300. Hence, the laser pointer 184 may be configured for laser guided alignment of the frailty assessment device 300. Third, the camera 186 may be used to align the distance sensing arrangement 122 of the movement measurement subunit 120 of the frailty assessment device 300 with the subject under assessment (e.g. the patient) by aligning a crosshairs on the touchscreen 162 based on an image derived from the camera 186 with the chest of the subject under assessment (e.g. the patient). Accordingly, the touchscreen 162 may be configured to display a real-time image captured by the camera 186 with a crosshairs superimposed on the real-time image. According to various embodiments, the camera 186 may be disposed relative to the distance sensing arrangement 122 of the movement measurement subunit 120 in a manner such that a line of sight of the camera 186 and the measurement axis 123 of the distance sensing arrangement 122 of the movement measurement subunit 120 may be parallel or converge into a same point within the pre-set range of distances from the frailty assessment device 300. Hence, the camera 186 may be configured for camera guided alignment of the frailty assessment device 300.

[00079] According to various embodiments, when the distance sensing arrangement 122 of the movement measurement subunit 120 is aligned with the subject under assessment (e.g. the patient), the touchscreen 162 (being part of the visual indication arrangement 160 of the frailty assessment device 300) may display a distance value indicating a distance from the frailty assessment device 300 to the subject under assessment (e.g. patient). Accordingly, the distance value may become visible on the touchscreen 162. Hence, displaying the distance value on the touchscreen 162 may serve as a visual indication that the distance sensing arrangement 122 of the movement measurement subunit 120 is aligned with the subject under assessment (e.g. the patient). According to various embodiments, the distance value displayed on the touchscreen 162 may turn green when the distance measurement of the subject under assessment (e.g. the patient) from the frailty assessment device 300 is within the pre-set range of distances defining the designated starting boundary. The distance value may turn green based on a simple Boolean

yes/no results in determining whether the distance measurements of the subject under assessment (e.g. the patient) from the frailty assessment device 300 are within the designated starting boundary. As an example, the starting boundary may be from 375cm to 425cm from the distance sensing arrangement 122 of the movement measurement subunit 120. If the distance value is displayed in green, this shows that the subject under assessment (e.g. the patient) is in the correct position to commence the gait (or walking) speed assessment. If the subject under assessment (e.g. the patient) is too close/far away, the distance value displayed may be in another colour. Accordingly, the assessor may move backwards/forward until the subject under assessment (e.g. the patient) is in the designated starting boundary, or the assessor may ask the subject under assessment (e.g. the patient) to move backwards/forwards until they are in the designated starting boundary. Accordingly, the distance value turning green may serve as the distance-sensing-ready-visual-indication.

[00080] According to various embodiments, to commence the gait (or walking) speed assessment, the subject under assessment (e.g. the patient) may be instructed to walk towards the frailty assessment device 300. The instruction to start walking may be given verbally. On the other hand, the instruction to start walking may also be provided by change a colour of or turning on a LED light 164. Accordingly, the change in colour or activation of the LED light 164 may serve as the distance-sensing-ready-visual-indication. According to various embodiments, the frailty assessment device 300 may include the LED light 164. The LED light 164 may serve as a part of the visual indication arrangement 160 in addition to the touchscreen 162.

[00081] According to various embodiments, when the subject under assessment (e.g. the patient) is identified to be in the starting position (i.e. within the pre-set range of distances defining the designated starting boundary e.g. between 375cm and 425cm from the frailty device 300) the processor 150 (e.g. a microcontroller) may further analyse the distance data (or distance measurements) to make sure that the subject under assessment (e.g. the patient) is stationary before changing the colour of or activating the LED light 164 (i.e. displaying the distance-sensing-ready-visual-indication) to alert he/she to start walking. The distance of the subject under assessment (e.g. the patient) from the frailty device 300 may be measured using the distance sensing arrangement 122 (e.g. ToF / LIDAR sensor) and the distance data (or distance measurements) may be used to determine if the subject under assessment (e.g. the patient) is standing still. According to various embodiments, upon detect that the subject under assessment (e.g. the patient) is within the pre-set range of distances defining the designated starting boundary (e.g. between 375cm and 425cm) from the distance sensing arrangement 122,

the processor 150 may create an array, and examines whether a new distance value is within a deviation range, e.g. by $>+-2\text{cm}$, from the previous values in the array. The array is reset if the subject under assessment (e.g. the patient) moves outside this deviation range or if the $+2\text{cm}$ threshold is exceeded. The LED light 164 may change colour or be active (i.e. to display the distance-sensing-ready-visual-indication) only after the array is equal to or greater than a predetermined duration, e.g. 2 seconds in duration (e.g. at 100Hz the array would be 200 samples long or longer). According to various embodiments, the average position of the subject under assessment (e.g. the patient) in the 2s array of data may be treated as the starting position.

[00082] According to various embodiments, if there is an interest in obtaining additional information about reaction time, the subject under assessment (e.g. the patient) may be instructed to react to the change in colour of the LED light 164 on the frailty assessment device 300. The LED light 164 may only change colour once the subject under assessment (e.g. the patient) has been standing relatively still (for example, the set of distances from the frailty assessment device 300 has not changed or deviate, e.g. by $>+-2\text{cm}$) for a predetermined duration. The predetermined duration may be a relatively short, bounded randomised time (for example, randomised between 3 and 5 seconds). The predetermined duration may be randomised (e.g. via the processor 150) by randomly selecting between at least two different time durations as the predetermined duration to prevent prompting and starting anticipation. Accordingly, the LED light 164 (being part of the visual indication arrangement 160) may display the change in colour (i.e. the distance-sensing-ready-visual-indication) when it is determined (e.g. via the processor 150) that the set of distances with respect to the frailty device 300 detected (e.g. by the distance sensing arrangement 122) over the predetermined duration is within the pre-set range of distances, as well as within the deviation range.

[00083] According to various embodiments, the reaction time may be measured as the time it takes for the subject under assessment (e.g. the patient) to move a predetermined distance (e.g. 10cm) towards the frailty assessment device 300 from the starting position after the LED light 164 is triggered or activated. Accordingly, a time elapsed (may be determined by the processor 150) between the LED light 164 being triggered or activated (i.e. the distance-sensing-ready-visual-indication being displayed) and the subject under assessment (e.g. the patient) being detected (e.g. by the distance sensing arrangement 122) to have moved the predetermined distance relative to the frailty device 300 (e.g. as determined via the processor 150). The time elapsed determined may be the reaction time. According to various embodiments, a determination of the subject under assessment (e.g. the patient) moving the

predetermined distance (e.g. 10cm) relative to the frailty device 300 may trigger the reaction time analysis.

[00084] According to various embodiments, the starting position of the subject under assessment (e.g. the patient) to be used for subsequent determination of the gait (or walking) speed, via the processor 150, may be defined as the average distance from the distance sensing arrangement 122 of the movement measurement subunit 120 over a sampling duration (e.g. the 2s array of data) prior to the light changing colour or activation of light (i.e. the displaying of the distance-sensing-ready-visual-indication) to indicate to the subject under assessment (e.g. the patient) to start walking. Once signalled to walk, the subject under assessment (e.g. the patient) may walk directly to the frailty assessment device 300 and stops in front of it.

[00085] According to various embodiments, the LED light 164 may change colour or turns on when the person reaches a predetermined minimum distance threshold, e.g. a distance of 100cm, from the frailty assessment device 300, providing a further signal to stop. The further signal may serve as the distance-sensing-completed-visual-indication. Accordingly, the LED light 164 (being part of the visual indication arrangement 160) may display the distance-sensing-completed-visual-indication when it is determined that the distance from the frailty assessment device 300 detected (e.g. by the distance sensing arrangement 122) is less than or equal to the predetermined minimum distance threshold.

[00086] According to various embodiments, the processor 150 may determine a gait (or walking) speed. According to various embodiments, the gait (or walking) speed may be measured using a custom algorithm that filters random error. According to various embodiments the custom algorithm may include following.

[00087] According to various embodiments a time point and a distance measurement (i.e. distance from the distance sensing arrangement 122) may be recorded (e.g. by the processor 150) when the subject under assessment (e.g. the patient) crosses every distance interval, e.g. 10cm, within a predetermined range of distances (e.g. from <370cm to <120cm) from the frailty assessment device 300 or the distance sensing arrangement 122 of the frailty assessment device 300. For example, if the subject under assessment (e.g. the patient) is stationary at 395cm from the frailty assessment device 300, the time point and the distance from the sensor (i.e. the distance measurement) are recorded when the subject under assessment (e.g. the patient) first progresses past a series of distance-points within the predetermined range of distances (e.g. the thresholds of 370cm, 360cm, 350cm etc.) until they pass a last distance-point (e.g. the 120cm threshold). Hence, the true value of the time point and the distance measurement may always be less than that at the exact threshold point as recording occur after the threshold is crossed.

Therefore, according to various embodiments, the processor 150 may be configured to record the time point and the distance measurement detected by the distance sensing arrangement 122 when the distance measurement crosses below a predetermined distance-point within the predetermined range of distances from the frailty assessment device 300, wherein the predetermined range of distances comprises a series of predetermined distance-points equally distributed within the predetermined range of distances. The series of predetermined distance-points being at an equal distance interval along the predetermined range of distances. According to various embodiments, the time points and the distance measurements for the series of predetermined distance-points within the predetermined range of distances may be compiled into a dataset by the processor 150.

[00088] A calculated speed (e.g. calculated walking speed) of each pair of distance-points being of a predetermined distance-points apart (e.g. over each 50cm threshold distance) may be determined or calculated using the simple equation $\frac{\Delta Distance}{\Delta Time}$ (i.e. dividing a difference in distance between two distance measurements of the pair of distance-points within the predetermined range of distances over a difference in time between two time points of the pair of distance-point within the predetermined range of distances). For example, if an initial distance-point (e.g. initial distance threshold of <370cm from the frailty assessment device 300) crossing was recorded at 1000 milliseconds (initial time point) and 368cm (initial distance measurement) from the frailty assessment device 300, it may be compared to the crossing at a subsequent distance-point (e.g. subsequent distance threshold of <320cm the frailty assessment device 300) that is of the predetermined distance-points apart (e.g. 50cm threshold distance apart) whereby 2000 milliseconds (subsequent time point) and 319cm (subsequent distance measurements) were recorded. The calculated speed for said pair of distance-points may then be

$$\frac{368 - 319}{1000 - 2000}$$

[00089] This results in the calculated speed (e.g. calculated walking speed) of 0.049 cm per millisecond over this interval, or 0.49 metres/second when converted to standard units.

[00090] A series of calculated speeds may be determined when the calculated speed of each pair of distance-points (being of the predetermined distance-points apart) are determined. For example, based on the predetermined range of distances from <370cm to <120cm and the predetermined distance-points apart of 50 cm, a series of 21 calculated speeds (or 21 measures of walking speed, i.e. from thresholds 370cm to 320cm, 360cm to 310cm....., 170cm to

120cm) may be obtained. These values (e.g. series of calculated speeds) may then be filtered to remove noise. This may be done using a variety of filtering methods including finite impulse response (e.g. averaging filters such as median, mean) or infinite impulse response (e.g. Butterworth, Chebyshev) and wavelet techniques (such as discrete wavelet transform). This filter may be applied across the series of calculated speeds (or the calculated walking speeds). Accordingly, a filtered series of speeds may be determined (via the processor 150) based on applying a filtering algorithm across the series of calculated speeds. The filtering algorithm may include any one of an infinite impulse response filtering algorithm, a finite impulse response filtering algorithm, a discrete wavelet transform filtering algorithm etc. For example, a 5-point moving median filter may be applied across the series of 21 calculated speeds (or the 21 measures of walking speed), with only results with 5 samples included. As such, this may result in a filtered series of 17 speeds (or 17 filtered walking speeds), with each one encompassing approximately 90cm (i.e. the first approximately 50cm measurement in the series, and the next 4x50cm measurements). From these filtered series of 17 speeds (or 17 filtered walking speeds), a maximum speed (or maximum value) may be obtained and deemed to be the gait (or walking) speed of the subject under assessment (e.g. the patient). Accordingly, the processor 150 may be configured to determine a series of median speeds based on applying a moving median filter across the series of calculated speeds, and select a maximum median speed from the series of median speeds as a speed output to be the gait (or walking) speed of the subject under assessment (e.g. the patient). Therefore, the processor 150 may be configured to select the maximum speed from the filtered series of speeds as the speed output representing as the gait (or walking) speed of the subject under assessment (e.g. the patient). In the various embodiments, the above is performed to overcome measurement error associated with factors such as jerkiness in forward progression, which is common in some clinical populations, and would result in high variability of measurement. This method of data analysis may result in a data analysis window small enough that it may obtain true steady-state walking speed without acceleration and deceleration effects, but large enough to minimise error.

[00091] According to various embodiments, the gait (or walking) speed result may be displayed immediately on the frailty assessment device 300, e.g. the touchscreen 162, and an external electronic device, e.g. a mobile device, if connected. A touchscreen button may be pressed to store this gait (or walking) speed result before the frailty assessment device 300 is turned off, or the gait (or walking) speed assessment may be repeated and overwritten.

[00092] According to various embodiments, the protocol for conducting the gait (or walking) speed assessment with the frailty assessment device 300 being mounted may be identical to

that when the frailty assessment device 300 is being handheld, except that the frailty assessment device 300 may be placed into a stand 192 and the assessor may walk with the subject under assessment (e.g. the patient). Further, alignment of the frailty assessment device 300 to the subject under assessment (e.g. the patient) may be achieved manually or using the laser pointer 184, which may be controlled using a portable external electronic device, e.g. the mobile device (or a touchscreen button on the mobile device), connected to the frailty assessment device 300 wirelessly. In addition, the distance may also be shown on the external electronic device (e.g. the mobile device), with the colour set to green if they are in the correct position as described previously. The assessor may mount the external electronic device (e.g. the mobile device) so that it is clearly visible in the line of sight of when walking, or may hold it in his/her hand if required for vision impairment.

[00093] According to various embodiments, the frailty assessment device 300 may function according to the following for conducting the grip strength assessment.

[00094] After the subject under assessment (e.g. the patient) completes the gait (or walking) speed assessment, the assessor may pass the frailty assessment device 300 to the subject under assessment (e.g. the patient). The subject under assessment (e.g. the patient) may hold the frailty assessment device 300 by gripping the handgrip portion 112 of the frailty assessment device 300. According to various embodiments, the inertial measurement unit 170 of the frailty assessment device may sense or detect the orientation of the frailty assessment device 300 held by the subject under assessment (e.g. the patient). When the inertial measurement unit 170 detects that the direction of force application between the first grip member 132 and the second grip member 134 is aligned, within the predetermined range of force-sensing-angular-deviations (e.g. ± 10 degrees), to the direction perpendicular to an upright standing posture of the subject under assessment (e.g. the patient), the force value displayed on the screen may turn green indicating that the frailty assessment device 300 is held in an acceptable orientation for the grip strength assessment. The force value turning green may serve as the force-sensing-ready-visual-indication. Accordingly, the inertial measurement unit 170 in the frailty assessment device 300 may determine whether the frailty assessment device 300 is being held with a pitch and roll within ± 10 degrees orthogonal to the ground plane so as to guide and ensure that the subject under assessment (e.g. the patient) is holding the frailty assessment device 300 correctly before proceeding with the grip strength assessment. The subject under assessment (e.g. the patient) may proceed to squeeze the handgrip portion 112 of the frailty assessment device 300 as hard as he/she can, with the frailty assessment device 300 providing a countdown of a predetermined period of time (e.g. a 5 second countdown) once the force

applied exceeds a predetermined minimum force threshold (or a baseline threshold level, e.g. 2kg). The force may be measured by the force sensing arrangement 136 between the first grip member 132 and the second grip member 134 of the handgrip portion 112. The force sensing arrangement 136 may be two strain-gauge based force sensors with Wheatstone bridge completed using an amplifier. The countdown and/or the force may be presented on the touchscreen 162, and the assessor may tell the subject under assessment (e.g. the patient) when the grip strength assessment is completed. Alternatively, at completion of the grip strength assessment, a visual indication may be provided via the LED lighting up, or an indicator on the external electronic device, e.g. the mobile device, alerting the subject under assessment (e.g. the patient) and assessor that the grip strength assessment is completed.

[00095] According to various embodiments, the frailty assessment device 300 may be configured such that the grip strength assessment may be performed at any time, either before or after the gait (or walking) speed assessment or even without the gait (or walking) speed assessment.

[00096] According to various embodiments, in addition to the gait (or walking) speed assessment and the grip strength assessment, the frailty assessment device 300 may be configured to be used for one or more additional assessments. One of the additional assessments may be height (or vertical distance) measurement. According to various embodiments, the frailty assessment device 300 may function according to the following for conducting a height measurement.

[00097] For most accurate assessment, the subject under assessment (e.g. the patient) may be required to stand upright, preferably with his/her back against a wall. The frailty assessment device 300 may be placed lightly touching the top of his/her head, with a longitudinal axis of the frailty assessment device 300 parallel to the ground and the distance sensing arrangement 122 (e.g. distance sensor such as ToF/LIDAR sensor) pointing at the ground. When the subject under assessment (e.g. the patient) is standing against the wall, a flat base of a stand of the frailty assessment device 300 may be used to ensure that the longitudinal axis of the frailty assessment device 300 is parallel to the ground (i.e. if the flat base is flat against the wall, the frailty assessment device 300 ought to be orthogonal to the wall and therefore parallel to the ground) such that the distance sensing arrangement 122 (e.g. distance sensor such as ToF/LIDAR sensor) may be pointing to the ground. The inertial measurement unit 170 may detect the orientation of the frailty assessment device 300. When it is detected that the frailty assessment device 300 is oriented in a manner such that the measurement axis 123 of the distance sensing arrangement 122 is aligned, within a predetermined range of vertical-distance-

sensing-angular-deviations (e.g. ± 5 degrees), to a direction of acceleration of gravity, the LED light 164 on the frailty assessment device 300 may turn green and/or an indicator on the external electronic device, e.g. the mobile phone (connected via the wireless protocol), may be turned on to provide visual indication that the positioning is correct. The activation of the LED light 164 may serve as a vertical-distance-sensing-ready-visual-indication. Accordingly, the inertial measurement unit 170 may detect whether the frailty assessment device 300 is within ± 5 degrees off horizontal (pitch and roll) or whether the measurement axis 123 of the distance sensing arrangement 122 of the frailty assessment device 300 is within ± 5 degrees off vertical so as to guide and ensure that the frailty assessment device 300 is correctly positioned before proceeding with the height measurement. According to various embodiments, the inertial measurement unit 170 may be used to determine whether the longitudinal axis of the frailty assessment device 300 is vertical during the gait (or walking) speed assessment and the grip strength assessment, while the inertial measurement unit 170 may be used to determine whether the same longitudinal axis of the frailty assessment device 300 is horizontal during the height measurement assessment.

[00098] After the assessor is satisfied with the positioning of the frailty assessment device 300, the subject under assessment (e.g. the patient) may be asked to step away from the wall. A height (or vertical distance) of the frailty assessment device 300 from the ground may be measured using the distance sensing arrangement 122 (e.g. distance sensor such as ToF/LIDAR sensor), with any offset from the distance sensing arrangement 122 to an external surface and/or external edge of the frailty assessment device 300 (i.e. the flat side) that was touching the head of the subject under assessment (e.g. the patient) being added to/subtracted from a distance measured from the frailty assessment device 300 to the ground so as to obtain the height of the subject under assessment (e.g. the patient). When the frailty assessment device 300 is used for height measurement, the vertical distance sensed or detected or measured may fit within standard ranges of height (based on Singaporean data and normalised to gender). Accordingly, when the vertical distance sensed or detected or measured is within such standard ranges (or a predetermined range of distances), the frailty assessment device 300 may determine that it is being used for height measurement. Further, when the frailty assessment device 300 is being used for height measurement and when the vertical distance sensed or detected or measured is within such standard ranges (or the predetermined range of distances), it may be assumed that the subject under assessment (e.g. the patient) has stepped away and the vertical distances measured may be recorded to determine the height of the subject under assessment (e.g. the patient). When the frailty assessment device 300 starts recording the distance data for height

measurement, the LED light 162 may change colour (e.g. turn orange) to indicate that data are being recorded. The changing of colour may serve as a vertical-distance-sensing-in-progress-visual-indication. Accordingly, the vertical-distance-sensing-in-progress-visual-indication may be displayed when the distance sensing arrangement 122 detects that the vertical distance is within the predetermined range of vertical distances.

[00099] After a predetermined length of time (e.g. 1 continuous second) of the recorded distance data not exceeding a predetermined variance (e.g. a 5% variance), the LED light 162 (i.e. the orange light) may turn off or change colour indicating that the height measurement assessment is completed. The turning off or changing of colour of the light may serve as a vertical-distance-sensing-completed-visual-indication. Accordingly, in response to the predetermined length of time of detecting the vertical distance is within a predetermined variance, the vertical-distance-sensing-completed-visual-indication may be displayed to indicate that the height measurement assessment is completed. According to various embodiments, the frailty assessment device 300 may include a sound generating arrangement and may be configured to generate a sound to indicate commencement and completion of the height measurement assessment.

[000100] According to various embodiments, the height may be determined or calculated using a simple median distance algorithm for the height data recorded (i.e. a series of vertical distances measured) within the predetermined length of time (e.g. the 1 continuous second). Accordingly, the height result (or a vertical distance output) may be determined based on applying a simple median algorithm to the series of vertical distances measured during the predetermined length of time. The height result may be shown or display on the touchscreen 162, and transmitted to the external electronic device, e.g. via the wireless connection if required. The height result may be verified with the subject under assessment (e.g. the patient), for example by subjectively estimating if the height result is correct or asking the subject under assessment (e.g. the patient) if the height result is close to their known height (if they know it). Upon verifying the height result, the height result may be stored into the database.

[000101] Referring to FIG. 3E, the processor 150 may be electrically coupled to the distance sensing arrangement 122 of the movement measurement subunit 120. Accordingly, the processor 150 may be in communication with the distance sensing arrangement 122 of the movement measurement subunit 120 such that a distance output signal from the distance sensing arrangement 122 may be sent to the processor 150 and the processor 150 may send control instructions to the distance sensing arrangement 122. The distance sensing arrangement 122 may include, but not limited to, a ToF sensor or a LIDAR sensor. Hence, the processor

150 may determine a distance based on the distance output signal, as well as process the distance output signal to obtain a speed based on the distance and time. Further, the processor 150 may be electrically coupled to the force sensing arrangement 136 of the strength measurement subunit 130. Accordingly, the processor 150 may be in communication with the
5 force sensing arrangement 136 of the strength measurement subunit 130 such that a force output signal from the force sensing arrangement 136 may be sent to the processor 150 and the processor 150 may send control instructions to the force sensing arrangement 136. The force sensing arrangement 136 may include two strain gauges 136a and a Wheatstone bridge 136b. Hence, the processor 150 may determine a force based on the force output signal.

10 **[000102]** According to various embodiments, the processor 150 may be electrically coupled to the visual indication arrangement 160. The visual indication arrangement 160 may include the touchscreen 162 (or a screen) and/or the LED light 164 (or a light source). Accordingly, the processor 150 may control the visual indication arrangement 160 (e.g. control the touchscreen 162 and/or the LED light 164) to display various types of visual indications. The
15 visual indications may include, but not limited to, the distance-sensing-ready-visual-indication, distance-sensing-completed-visual-indication, the force-sensing-ready-visual-indication, force-sensing-completed-visual-indication, the vertical-distance-sensing-ready-visual-indication, the vertical-distance-sensing-in-progress-visual-indication, and the vertical-distance-sensing-completed-visual-indication as previously described with reference to the
20 various embodiments.

[000103] According to various embodiments, the processor 150 may be electrically coupled to the inertial measurement unit 170. Accordingly, the processor 150 may receive output signal from the inertial measurement unit, whereby the output signal is indicative of the orientation of the frailty assessment device 100, 200, 300.

25 **[000104]** According to various embodiments, the processor 150 may control the visual indication arrangement 160 to display the various types of visual indications based on the output signal from the inertial measurement unit 170, and/or the distance output signal from the distance sensing arrangement 122, and/or the force output signal from the force sensing arrangement 136. The visual indications for the various combinations of the output signal from
30 the inertial measurement unit, and/or the distance output signal from the distance sensing arrangement 122, and/or the force output signal from the force sensing arrangement 136 are described previously with reference to the various embodiments.

[000105] According to various embodiments, the processor 150 may be electrically coupled to the alignment assist arrangement 180 in the form of the laser pointer 184 and/or the camera

186. Accordingly, the processor 150 may control the laser pointer 184 and/or the camera 186 to serve as visual guide for aiming the distance sensing arrangement 122 at the external body (i.e. the subject under assessment, e.g. the patient).

[000106] According to various embodiments, the processor 150 may be electrically coupled to the communication module 152. Accordingly, the processor 150 may transmit/send data or instructions to the external electronic device via the communication module 152. The processor 150 may also receive data and instructions from the external electronic device via the communication module 152. For example, the processor 150 may send measured data or calculated data, via the communication module 152, to the external electronic device for storage. The processor 150 may also send instructions, via the communication module 152, to the external electronic device to control the display of the external electronic device to display various results as well as to display various visual indications. Further, the processor 150 may receive normative data from the external electronic device, or instructions for operating the frailty assessment device 100, 200, 300 when the external electronic device is being used as a remote control. According to various embodiments, the frailty assessment device 100, 200, 300 and the external electronic device may together form the frailty assessment system.

[000107] FIG. 4 shows a sample graphic user interface displayed on the touchscreen 162 of the frailty assessment device 100, 200, 300. Accordingly, the graphic user interface may display a gait (or walking) speed assessment icon 162a, a grip strength assessment icon 162b, a gait (or walking) speed 162c, and a grip strength 162d. According to various embodiments, the gait (or walking) speed 162c may be saved by touching the gait (or walking) speed assessment icon 162a, and the grip strength 162d may be saved by touching the grip strength assessment icon 162b.

[000108] FIG. 5A, FIG. 5B, and FIG. 5C show different views of the frailty assessment device 500 according to various embodiments. According to various embodiments, the frailty assessment device 500 of FIG. 5A to FIG. 5C includes all the features of the frailty assessment device 100 of FIG. 1A and FIG. 1B, the frailty assessment device 200 of FIG. 2A to FIG. 2C and the frailty assessment device 300 of FIG. 3A to FIG. 3E. Accordingly, all features, changes, modifications, and variations that are applicable to the frailty assessment device 100 of FIG. 1A and FIG. 1B, the frailty assessment device 200 of FIG. 2A to FIG. 2C and the frailty assessment device 300 of FIG. 3A to FIG. 3E are also applicable to the frailty assessment device 500 of FIG. 5A to FIG. 5C. Therefore, elements which are the same as those described earlier are assigned the same reference numerals, and repetition of their explanations is omitted for brevity. According to various embodiments, the frailty assessment device 500 may, similar

to the frailty assessment device 100 of FIG. 1A and FIG. 1B as well as the frailty assessment device 200 of FIG. 2A to FIG. 2C and the frailty assessment device 300 of FIG. 3A to FIG. 3E, include the movement measurement subunit 120 including the distance sensing arrangement 122; and the strength measurement subunit 130 including the first grip member 132, the second grip member 134 and the force sensing arrangement 136 therebetween. Further, the frailty assessment device 500 may, similar to the frailty assessment device 100 of FIG. 1A and FIG. 1B as well as the frailty assessment device 200 of FIG. 2A to FIG. 2C and the frailty assessment device 300 of FIG. 3A to FIG. 3E, include the device frame 140 integrating the movement measurement subunit 120 and the strength measurement subunit 130 together. Furthermore, the frailty assessment device 500 may, similar to the frailty assessment device 100 of FIG. 1A and FIG. 1B as well as the frailty assessment device 200 of FIG. 2A to FIG. 2C and the frailty assessment device 300 of FIG. 3A to FIG. 3E, include the processor 150, the visual indication arrangement 160, the inertial measurement unit 170, the alignment assist arrangement 180, the stand connector 190 and/or the communication module 152.

[000109] Various embodiments have provided a frailty assessment device capable of being used to conduct a comprehensive frailty assessment, in particular a gait (or walking) speed assessment and a grip strength assessment, in a single device. Accordingly, the frailty assessment device of the various embodiments may be an all-in-one device (or a one-stop device). In addition, the frailty assessment device of the various embodiments may be portable so as to be deployable to different locations for conducting frailty assessment.

[000110] While the invention has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes, modification, variation in form and detail may be made therein without departing from the scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

Claims

1. A frailty assessment device comprising
a strength measurement subunit comprising
a first grip member,
a second grip member, wherein the first grip member and the second grip member are movable relative to each other, and
a force sensing arrangement disposed between the first grip member and the second grip member, wherein the force sensing arrangement is configured to measure a force for urging the first grip member and the second grip member towards each other; and
a movement measurement subunit comprising
a distance sensing arrangement configured to detect a distance of an external body with respect to the device,
wherein the strength measurement subunit and the distance measurement subunit are integrated together in a single device body.
2. The device according to claim 1, further comprising a device frame integrally interconnecting the strength measurement subunit and the distance measurement subunit.
3. The device according to claim 2, wherein the device frame has a first portion and a second portion, wherein the strength measurement subunit is disposed at the first portion of the device frame and the distance measurement subunit is disposed at the second portion of the device frame.
4. The device according to claim 3,
wherein the strength measurement subunit is assembled to the first portion of the device frame,
wherein the first portion of the device frame has a through-hole,
wherein the first grip member is coupled to the first portion of the device frame to cover a first end of the through-hole,
wherein the force sensing arrangement is disposed in the through-hole,

wherein an appendage portion of the second grip member is fitted into the through-hole from the second end thereof so as to sandwich the force sensing arrangement between the first grip member and the appendage portion of the second grip member, and

wherein the second grip member is movable minutely relative to the first grip member and the first portion of the device frame.

5. The device according to any one of claims 1 to 4, wherein an axis of relative movement between the first grip member and the second grip member is parallel to a measurement axis of the distance sensing arrangement for measuring the distance of the external body with respect to the device.

6. The device according to any one of claims 1 to 5, further comprising a processor, wherein the force sensing arrangement is electrically coupled to the processor for communicating a force output signal from the force sensing arrangement to the processor, and

wherein the distance sensing arrangement is electrically coupled to the processor for communicating a distance output signal from the distance sensing arrangement to the processor.

7. The device according to claim 6, wherein the processor is configured to determine an amount of force applied to urge the first grip member and the second grip member towards each other based on the force output signal received from the force sensing arrangement, and

wherein the processor is configured to determine the distance of the external body with respect to the device based on the distance output signal from the distance sensing arrangement.

8. The device according to claim 7, wherein the processor is configured to determine a speed of the external body based on dividing a difference in distance between two distance measurements detected by the distance sensing arrangement over a time taken between detecting the two distance measurements.

9. The device according to claim 7 or 8,

wherein the processor is configured to record a time point and a distance measurement detected by the distance sensing arrangement when the distance measurement crosses below a predetermined distance-point within a predetermined range of distances from the device, wherein the predetermined range of distances comprises a series of predetermined distance-points equally distributed within the predetermined range of distances.

10. The device according to claim 9,
wherein the processor is configured to
 - compile a dataset of time points and distance measurements for the series of predetermined distance-points within the predetermined range of distances, and
 - determine a series of calculated speeds, wherein each calculated speed is based on dividing a difference in distance between two distance measurements of a pair of distance-points within the predetermined range of distances over a difference in time between two time points of the pair of distance-points within the predetermined range of distances, wherein each pair of distance-points are of a predetermined distance-points apart.
11. The device according to claim 10, wherein the processor is configured to determine a filtered series of speeds based on applying a filtering algorithm across the series of calculated speeds.
12. The device according to claim 11, wherein the filtering algorithm comprises any one of an infinite impulse response filtering algorithm, a finite impulse response filtering algorithm, and a discrete wavelet transform filtering algorithm.
13. The device according to claim 11 or 12, wherein the processor is configured to select a maximum speed from the filtered series of speeds as a speed output.
14. The device according to claim 10, wherein the processor is configured to determine a series of median speeds based on applying a moving median filter across the series of calculated speeds, and select a maximum median speed from the series of median speeds as a speed output.

15. The device according to any one of claims 7 to 14, wherein in response to the processor determining the amount of force applied is above a predetermined minimum force threshold, the processor monitors the amount of force applied to urge the first grip member and the second grip member towards each other throughout a predetermined period of time and determines a peak amount of force during the predetermined period of time as a force output.

16. The device according to any one of claims 6 to 15, further comprising a visual indication arrangement electrically coupled to the processor, wherein the processor is configured to control the visual indication arrangement to change between different visual indications.

17. The device according to claim 16, wherein the processor is configured to control the visual indication arrangement to display a distance-sensing-ready-visual-indication when the processor determines that a set of distances of the external body with respect to the device detected by the distance sensing arrangement over a predetermined duration is within a pre-set range of distances.

18. The device according to claim 17, wherein the processor is configured to randomise the predetermined duration by randomly selecting between at least two different time durations as the predetermined duration.

19. The device according to claim 18, wherein the processor is configured to determine a time elapsed between the visual indication arrangement displaying the distance-sensing-ready-visual-indication and the processor determines that the external object is detected, by the distance sensing arrangement, to have moved a predetermined distance relative to the device.

20. The device according to any one of claims 17 to 19, wherein the processor is configured to operate according to claims 8 to 14 when the visual indication arrangement is displaying the distance-sensing-ready-visual-indication.

21. The device according to claim 20, wherein the processor is configured to control the visual indication arrangement to display a distance-sensing-completed-visual-indication when

the processor determines that the distance of the external body with respect to the device detected by the distance sensing arrangement is less than or equal to a predetermined minimum distance threshold.

22. The device according to any one of claims 16 to 21, wherein in response to the processor determining the amount of force applied is above a predetermined force threshold when the visual indication arrangement is displaying a force-sensing-ready-visual-indication, the processor monitors the amount of force applied to urge the first grip member and the second grip member towards each other throughout a predetermined period of time, determines a peak amount of force during the predetermined period of time as a force output, and controls the visual indication arrangement to change to a force-sensing-completed-visual-indication at an end of the predetermined period of time.

23. The device according to any one of claims 16 to 22, further comprising an inertial measurement unit electrically coupled to the processor, wherein the processor is configured to determine an orientation of the device based on output signals from the inertial measurement unit.

24. The device according to claim 23 in combination with claim 17, wherein the processor controls the visual indication arrangement to display the distance-sensing-ready-visual-indication when the processor determines based on the output signal from the inertial measurement unit that the device is oriented in a manner such that the distance sensing arrangement is aligned, within a predetermined range of distance-sensing-angular-deviations, to a direction parallel to a ground for detecting the distance of the external body from the device and the set of distances of the external body with respect to the device detected by the distance sensing arrangement over the predetermined duration is within the pre-set range of distances.

25. The device according to claim 23 or 24 in combination with claim 22, wherein the processor is configured to control the visual indication arrangement to display the force-sensing-ready-visual-indication when the processor determines based on the output signal from the inertial measurement unit that the device is oriented in a manner such that a direction of force application between the first grip member and the second grip member is

aligned, within a predetermined range of force-sensing-angular-deviations, to a direction perpendicular to an upright standing posture of a user.

26. The device according to anyone of claims 23 to 25, wherein the processor is configured to control the visual indication arrangement to display a vertical-distance-sensing-ready-visual-indication when the processor determines based on the output signal from the inertial measurement unit that the device is oriented in a manner such that the measurement axis of the distance sensing arrangement is aligned, within a predetermined range of vertical-distance-sensing-angular-deviations, to a direction of acceleration of gravity.

27. The device according to claim 26, wherein the processor is configured to control the visual indication arrangement to display a vertical-distance-sensing-in-progress-visual-indication when the distance sensing arrangement detects a vertical distance within a predetermined range of vertical distances.

28. The device according to claim 27, wherein, in response to a predetermined length of time of detecting the vertical distance being within a predetermined variance, the processor controls the visual indication arrangement to display a vertical-distance-sensing-completed-visual-indication.

29. The device according to claim 28, wherein the processor is configured to determine a vertical distance output based on applying a simple median algorithm to a series of vertical distances measured during the predetermined length of time.

30. The device according to any one of claims 16 to 29, wherein the visual indication arrangement comprises a visual display and/or a light indicator.

31. The device according to claim 30, wherein, when the visual indication arrangement comprises the visual display, the visual display is rotatable relative to the distance sensing arrangement for the visual display to face in a direction of sensing of the distance sensing arrangement or face in an opposite direction with respect to the direction of sensing of the distance sensing arrangement.

32. The device according to any one of claims 1 to 31, further comprising an alignment assist arrangement serving as a visual guide to aim the distance sensing arrangement at the external body for detecting the distance of the external body with respect to the device.
33. The device according to claim 32, wherein the alignment assist arrangement comprises one or a combination of a sight, a laser pointer, or a camera.
34. The device according to any one of claims 1 to 33, further comprising a stand connector connectable to a stand.
35. The device according to any one of claims 1 to 34, further comprising a communication module configured to communicate via wired or wireless connections with an external electronic device.
36. A system for frailty assessment, the system comprising
the frailty assessment device according to claim 35; and
the external electronic device.

1 / 9

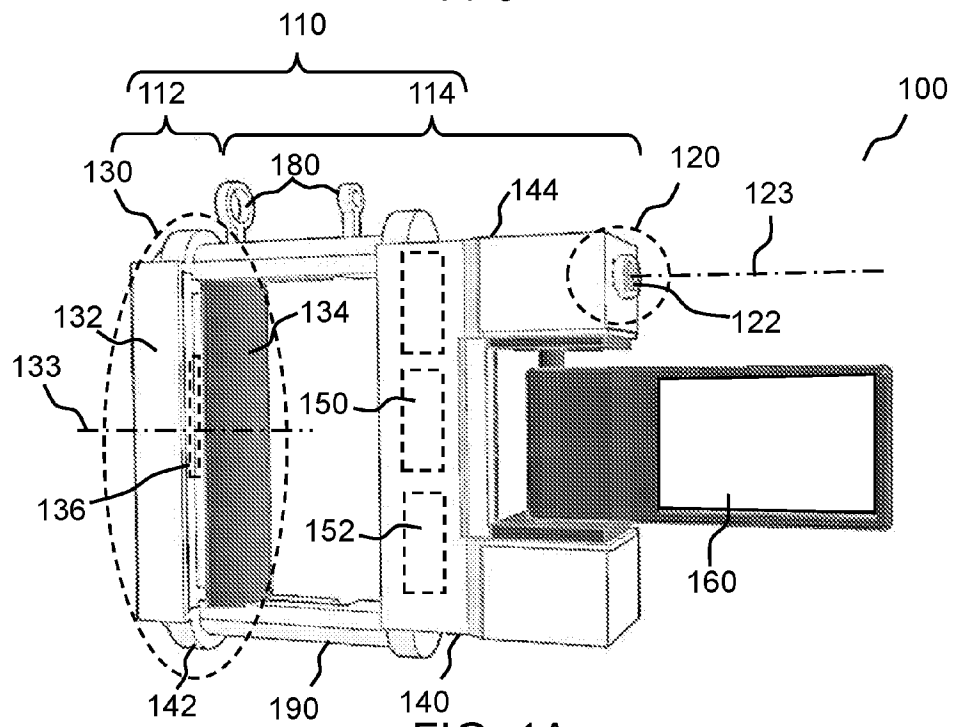


FIG. 1A

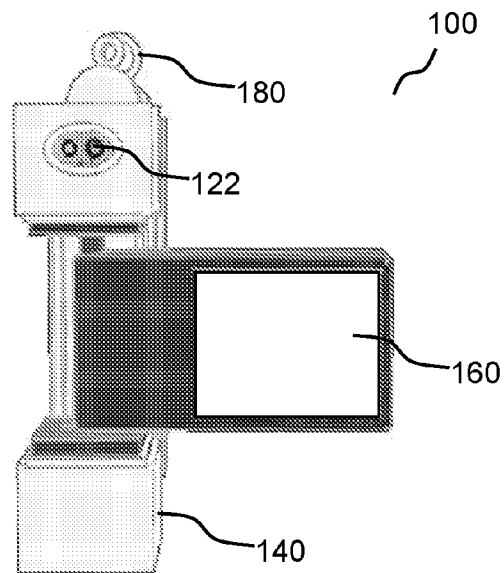


FIG. 1B

2 / 9

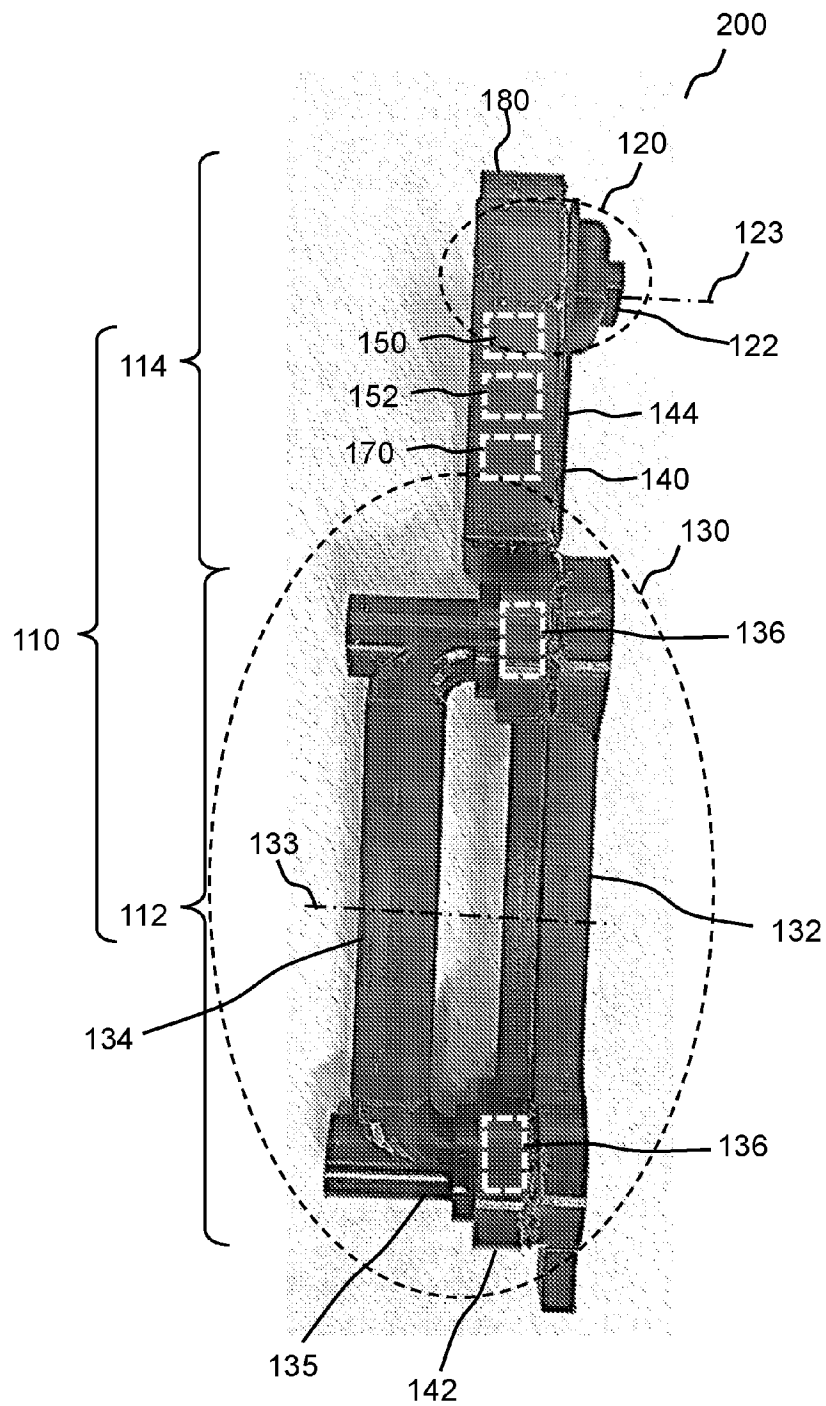


FIG. 2A

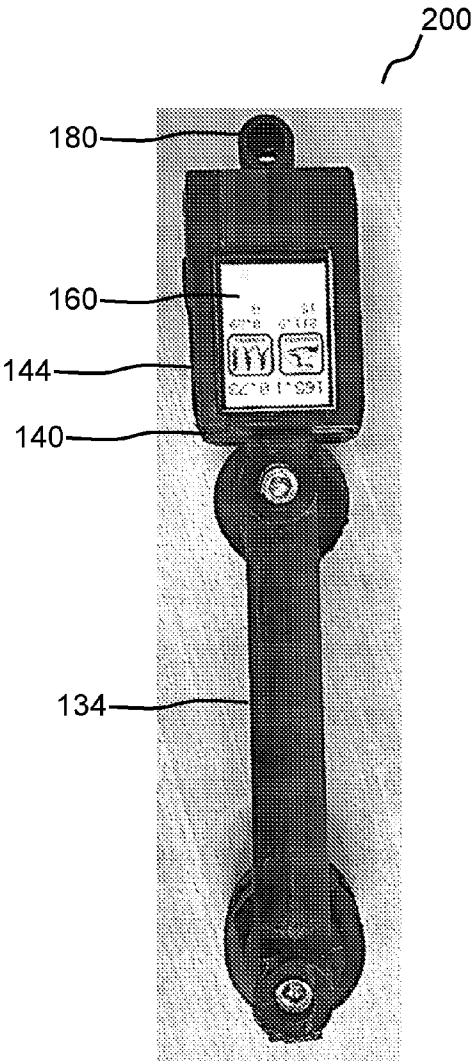


FIG. 2B

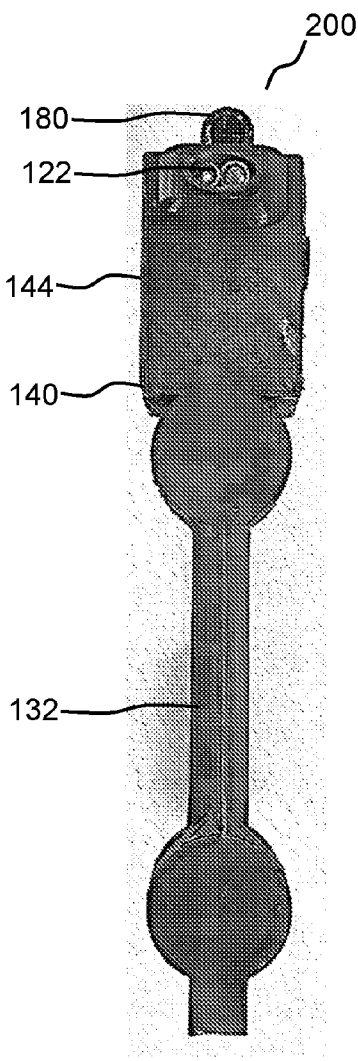


FIG. 2C

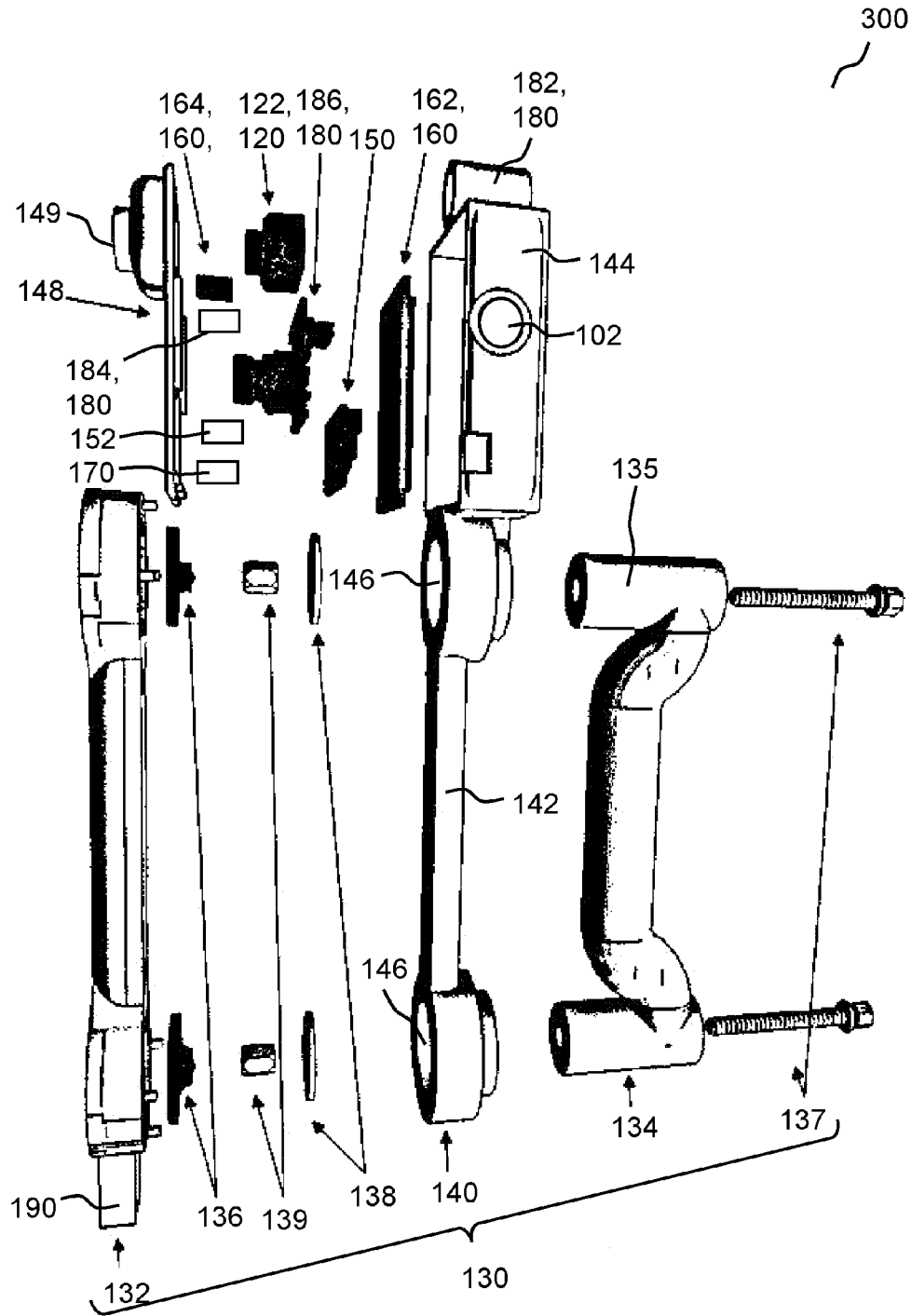


FIG. 3A

5 / 9

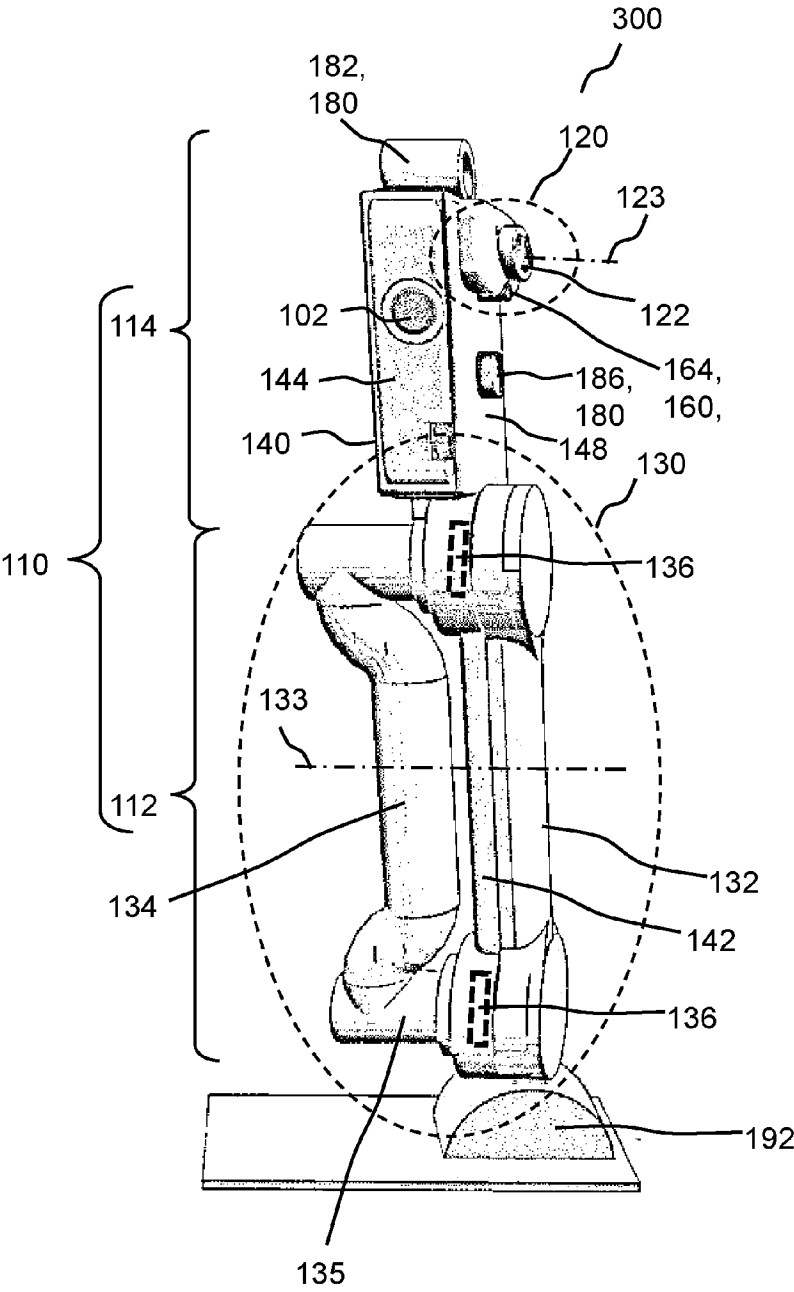


FIG. 3B

6 / 9

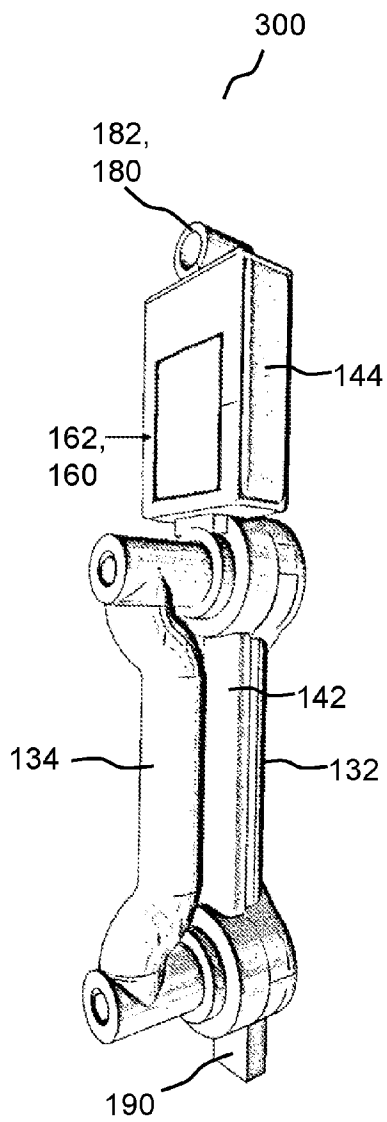


FIG. 3C

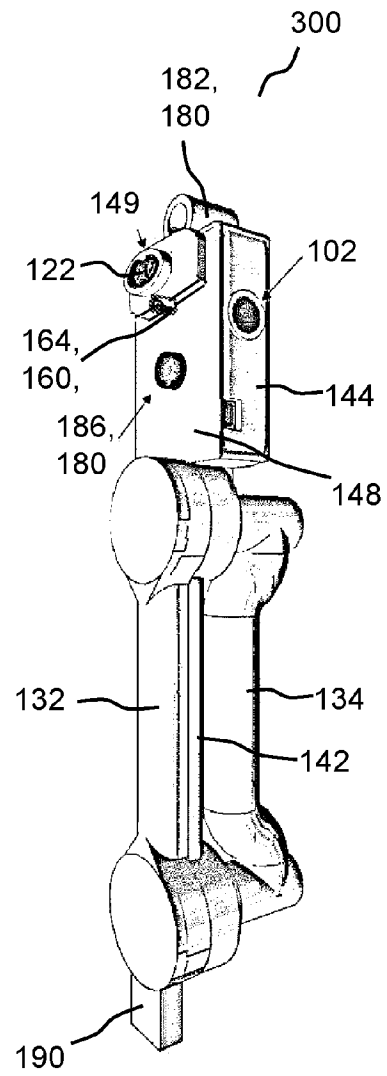


FIG. 3D

7 / 9

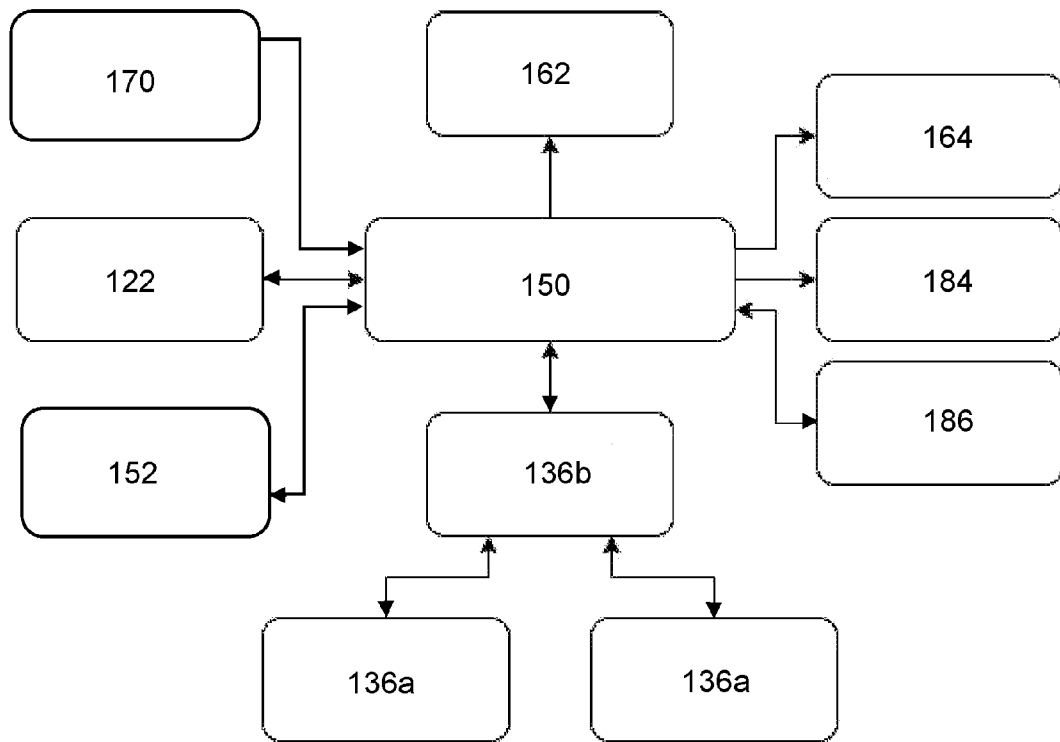


FIG. 3E

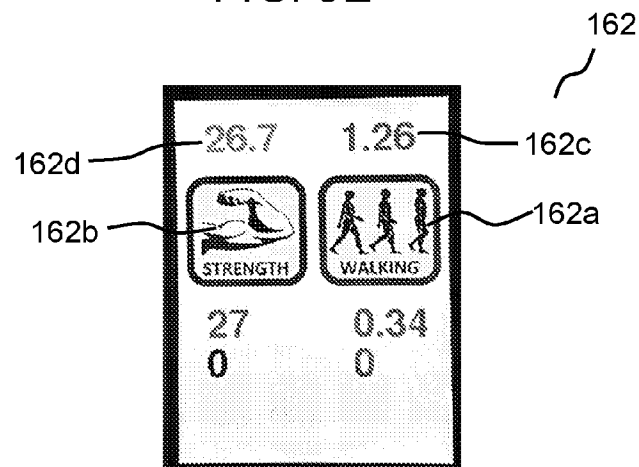


FIG. 4

8 / 9

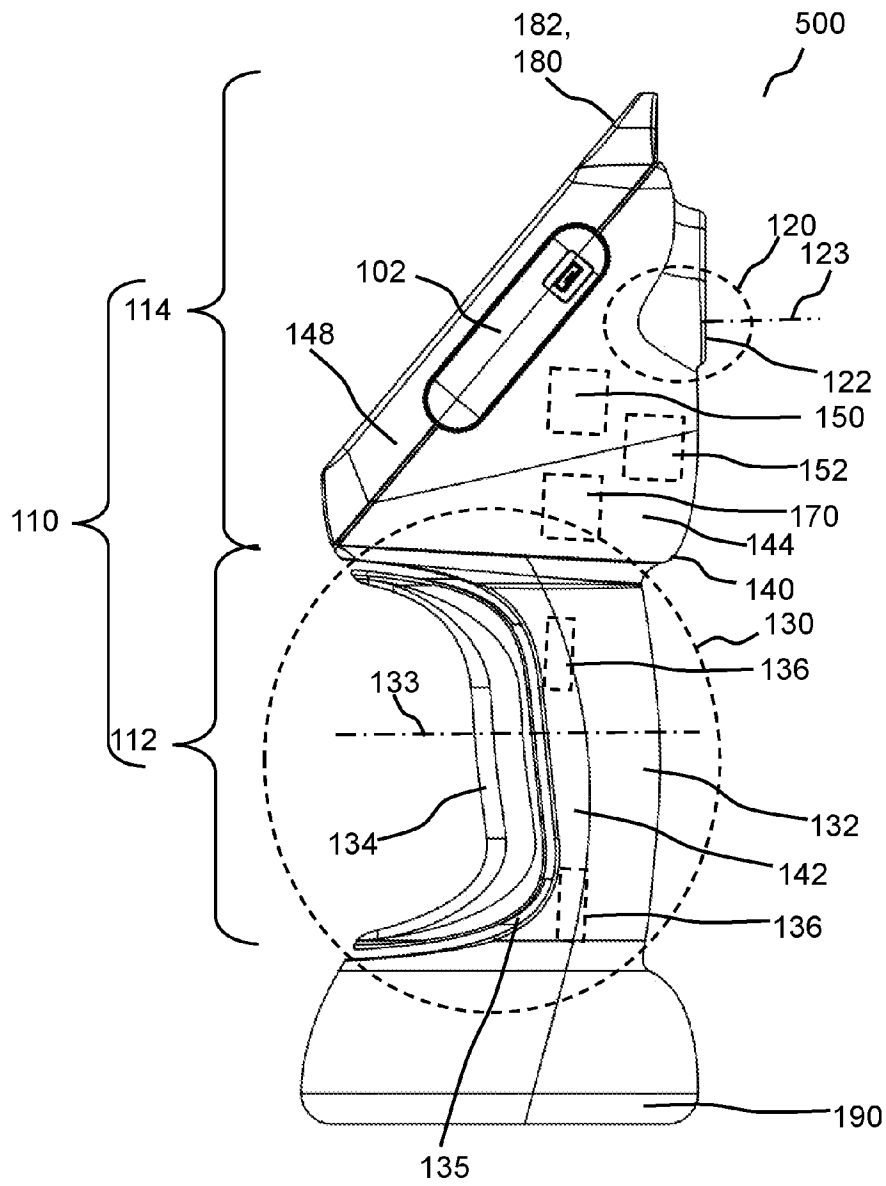


FIG. 5A

9 / 9

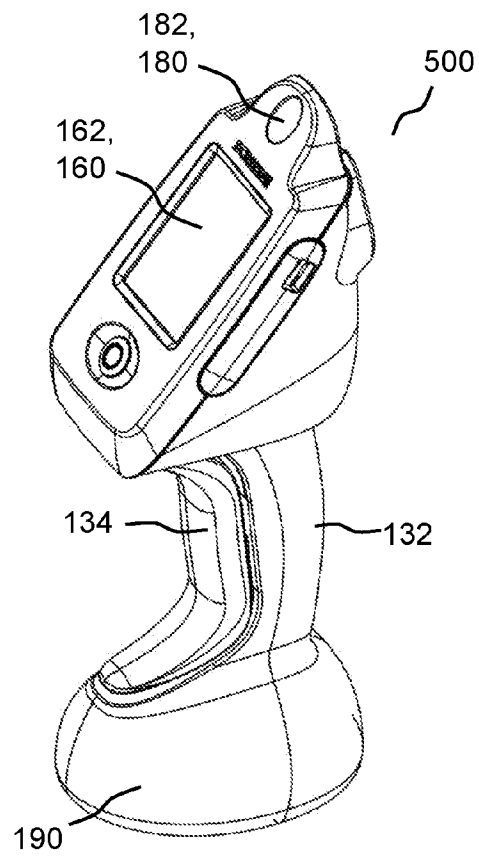


FIG. 5B

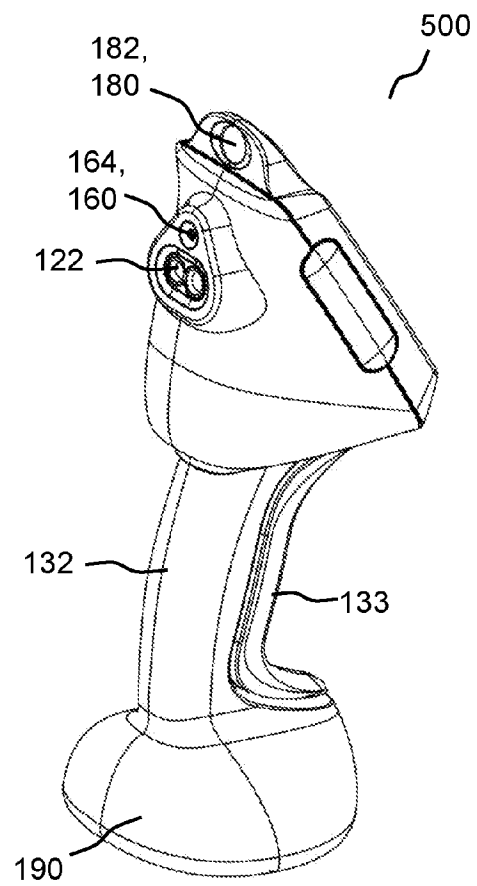


FIG. 5C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2024/050401

A. CLASSIFICATION OF SUBJECT MATTER**A61B 5/22 (2006.01) A61B 5/11 (2006.01) G01S 17/88 (2006.01)**

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

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 practicable, search terms used)

FAMPAT/research gateway: frailty, gait, walking speed, grip strength, height, strain, dynamometer and like terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 213155934 U (ZHONGSHAN HOSPITAL FUDAN UNIV) 11 May 2021 abstract; para. [n0017]-[n0021]; fig. 2, 3 of the machine translation	1-36
X	CN 114469101 A (UNIV ZHENGZHOU) 13 May 2022 abstract; para. [n0014]-[n0015], [n0019], [n0021], [n0025], [n0027]; fig. 1, 2, 4, 5 of the machine translation	1-36
X	CN 115530833 A (UNIV CENTRAL SOUTH; BEIJING YOUXIN TECH CO LTD) 30 December 2022 abstract; para. [n0068]-[n0070], [n0097], [n0163]-[n0169]; fig. 1-4, 12 of the machine translation	1-36
A	HUANG L. ET AL., Reliability and validity of two hand dynamometers when used by community-dwelling adults aged over 50 years. <i>BMC Geriatrics</i> , 15 July 2022, Vol. 22, No. 1, pages 580:1-8 [Retrieved on 2024-08-26] <DOI: 10.1186/S12877-022-03270-6> pg. 2, left col., para. 2	-

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

*Special categories of cited documents:

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

“D” document cited by the applicant in the international application

“E” earlier application or patent but published on or after the
international filing date“L” document which may throw doubts on priority claim(s) or
which is cited to establish the publication date of another
citation or other special reason (as specified)“O” document referring to an oral disclosure, use, exhibition or
other means“P” document published prior to the international filing date but
later than the priority date claimed“T” later document published after the international filing date or
priority date and not in conflict with the application but cited to
understand the principle or theory underlying the invention“X” document of particular relevance; the claimed invention
cannot be considered novel or cannot be considered to
involve an inventive step when the document is taken alone“Y” document of particular relevance; the claimed invention
cannot be considered to involve an inventive step when the
document is combined with one or more other such
documents, such combination being obvious to a person
skilled in the art

“&” document member of the same patent family

Date of the actual completion of the international search

26/08/2024

(day/month/year)

Date of mailing of the international search report

27/08/2024

(day/month/year)

Name and mailing address of the ISA/SG

**Intellectual Property Office of Singapore**1 Paya Lebar Link, #11-03
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Authorized officer

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2024/050401

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	BOHANNON R.W. ET AL., Accuracy of Spring and Strain Gauge Hand-held Dynamometers. <i>J Orthop Sports Phys Ther.</i> , February 1989, Vol. 10, No. 8, pages 323-325 [Retrieved on 2024-08-26] <DOI: 10.2519/JOSPT.1989.10.8.323> whole document, particularly abstract; results; discussion	-
A	US 10568547 B1 (JOHANNING J.M.) 25 February 2020 col. 4 lines 7-12; col. 6 lines 1-8	-

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2024/050401

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

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