

Claims

1. A system for motion analysis of a subject, including:
two or more sensor units that are attachable at respective attachment points
5 of the subject to detect motion of the attachment points relative to each other, each
sensor unit including a time-of-flight (TOF) ranging sensor in communication with at
least one processor;
wherein the at least one processor is configured to:
cause the sensor units to execute a two-way ranging protocol at a
10 succession of times, said two-way ranging protocol including transmission of
one or more signals from, and reception of one or more signals at, said TOF
ranging sensors, to determine TOF distance data indicative of one or more
respective distances between the sensor units at respective times; and
determine, from at least the TOF distance data, one or more motion
15 metrics.
2. A system according to claim 1, wherein the sensor units include:
a first sensor unit and a second sensor unit for placement in spaced arrangement at
a first spacing on a first foot of the subject; and
20 a third sensor unit and a fourth sensor unit for placement in spaced arrangement at
a second spacing on a second foot of the subject.
3. A system according to claim 1 or claim 2, wherein the two-way ranging protocol is a
single-sided two-way ranging protocol that includes:
25 a, or the, first sensor unit transmitting a first poll signal to each other sensor
unit;
one or more of the other sensor units transmitting a response signal, or
response signals, to the first sensor unit, each said response signal including a
difference between a time of receipt of the first poll signal at the respective other
30 sensor unit and a time of transmission of the response signal.
4. A system according to claim 2, wherein the two-way ranging protocol is a single-
sided two-way ranging protocol that includes:
the first sensor unit transmitting a first poll signal to the second, third and
35 fourth sensor units;

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the second sensor unit transmitting a second poll signal to the third and fourth sensor units;

5 the third sensor unit transmitting a first response signal to the first and second sensor units, the first response signal including a difference between a time of receipt of the first poll signal at the third sensor unit and a time of transmission of the first response signal, and a difference between a time of receipt of the second poll signal at the third sensor unit and the time of transmission of the first response signal; and

10 the fourth sensor unit transmitting a second response signal to the first and second sensor units, the second response signal including a difference between a time of receipt of the first poll signal at the fourth sensor unit and a time of transmission of the second response signal, and a difference between a time of receipt of the second poll signal at the fourth sensor unit and a time of transmission of the second response signal.

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5. A system according to claim 3 or claim 4, wherein the first poll signal includes a beacon time.
6. A system according to any one of claims 3 to 5, wherein the one or more respective distances are determined only by the processor of the first sensor unit and, if applicable, the processor of the second sensor unit.
7. A system according to any one of claims 1 to 6, wherein each sensor unit is configured to record a respective sensor temperature; and wherein the at least one processor is configured to adjust the respective distances using the respective sensor temperatures and a temperature calibration model.
8. A system according to any one of claims 1 to 7, wherein at least one of the sensor units further includes an inertial sensor in communication with the at least one processor, each said inertial sensor being configured to measure inertial sensor data including at least accelerometer data and gyroscope data.
9. A system according to claim 8, wherein the at least one processor is configured to determine the one or more motion metrics by a sensor fusion process that combines the TOF distance data and the inertial sensor data.

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10. A system according to any one of claims 1 to 9, wherein the one or more motion metrics include one or more gait metrics.
11. A system according to any one of claims 1 to 10, wherein the at least one processor
5 is configured to determine one or more stationary points of a curve defined at least partly by the TOF distance data and/or the inertial sensor data, or a smoothed version thereof; and wherein at least one of said motion metrics is computed based on the one or more stationary points.
- 10 12. A method of motion analysis of a subject, including:
attaching two or more sensor units at respective attachment points of the subject to detect motion of the attachment points relative to each other, each sensor unit including a time-of-flight (TOF) ranging sensor in communication with at least one processor;
15 executing, by the at least one processor, a two-way ranging protocol at a succession of times, said two-way ranging protocol including transmission of one or more signals from, and reception of one or more signals at, said TOF ranging sensors, to determine TOF distance data indicative of one or more respective distances between the sensor units at respective times; and
20 determining, from at least the TOF distance data, one or more motion metrics.
13. A method according to claim 12, wherein the two-way ranging protocol is a single-sided two-way ranging protocol that includes:
a, or the, first sensor unit transmitting a first poll signal to each other sensor
25 unit;
one or more of the other sensor units transmitting a response signal, or response signals, to the first sensor unit, each said response signal including a difference between a time of receipt of the first poll signal at the respective other sensor unit and a time of transmission of the response signal.
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14. A method according to claim 12, comprising attaching a first sensor unit and a second sensor unit at a first spacing from each other on a first foot of the subject; and attaching a third sensor unit and a fourth sensor unit at a second spacing from each other on a second foot of the subject; wherein the two-way ranging protocol is a
35 single-sided two-way ranging protocol that includes:

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the first sensor unit transmitting a first poll signal to the second, third and fourth sensor units;

the second sensor unit transmitting a second poll signal to the third and fourth sensor units;

5 the third sensor unit transmitting a first response signal to the first and second sensor units, the first response signal including a difference between a time of receipt of the first poll signal at the third sensor unit and a time of transmission of the first response signal, and a difference between a time of receipt of the second poll signal at the third sensor unit and the time of transmission of the first response
10 signal; and

 the fourth sensor unit transmitting a second response signal to the first and second sensor units, the second response signal including a difference between a time of receipt of the first poll signal at the fourth sensor unit and a time of transmission of the second response signal, and a difference between a time of receipt of the second poll signal at the fourth sensor unit and a time of transmission
15 of the second response signal.

15. A method according to claim 13 or claim 14, wherein the first poll signal includes a beacon time.

20 16. A method according to any one of claims 12 to 15, including recording, by each of said sensor units, a respective sensor temperature; and adjusting the respective distances using the respective sensor temperatures and a temperature calibration model.

25 17. A method according to any one of claims 12 to 16, wherein at least one of the sensor units further includes an inertial sensor in communication with the at least one processor, and wherein the method includes measuring, by said inertial sensor, inertial sensor data including at least accelerometer data and gyroscope data.

30 18. A method according to claim 17, including determining the one or more motion metrics by a sensor fusion process that combines the TOF distance data and the inertial sensor data.

35 19. A method according to any one of claims 12 to 18, wherein the one or more motion metrics include one or more gait metrics.

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20. A method according to any one of claims 12 to 19, including determining one or more stationary points of a curve defined at least partly by the TOF distance data and/or the inertial sensor data, or a smoothed version thereof; and computing at least one of said motion metrics based on the one or more stationary points.
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