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(54) TRACKING CALORIC EXPENDITURE USING A CAMERA

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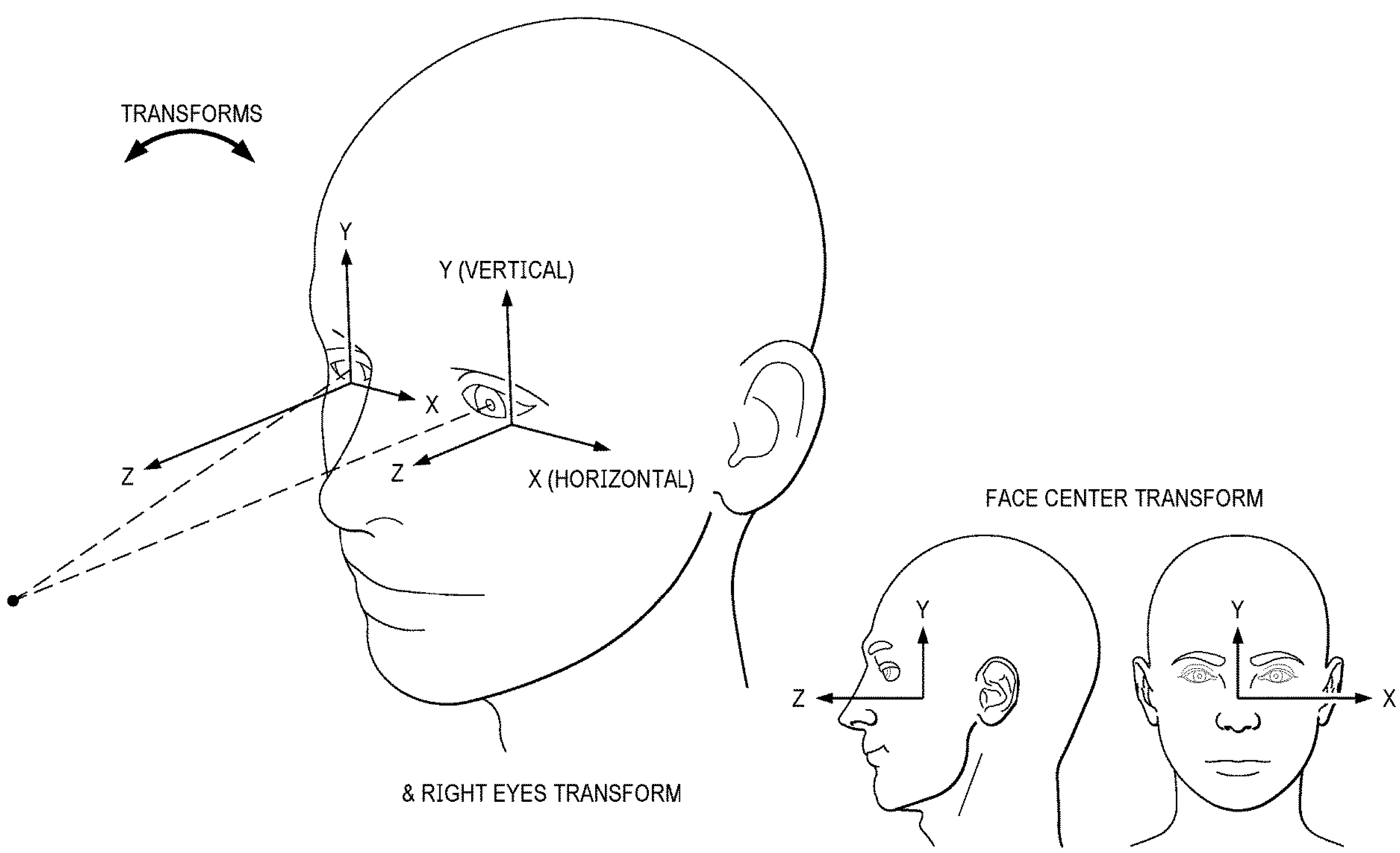
(57) **ABSTRACT**

The enclosed embodiments are directed to tracking caloric expenditure using a camera. In an embodiment, a method comprises: obtaining face tracking data associated with a user; determining a step cadence of the user based on the face tracking data; determining a speed of the user based on the step cadence and a stride length of the user; obtaining device motion data from at least one motion sensor of the device; determining a grade of a surface on which the user is walking or running based on at least one of the device motion data or the face tracking data; and determining an energy expenditure of the user based on the estimated speed, the estimated grade and a caloric expenditure model.



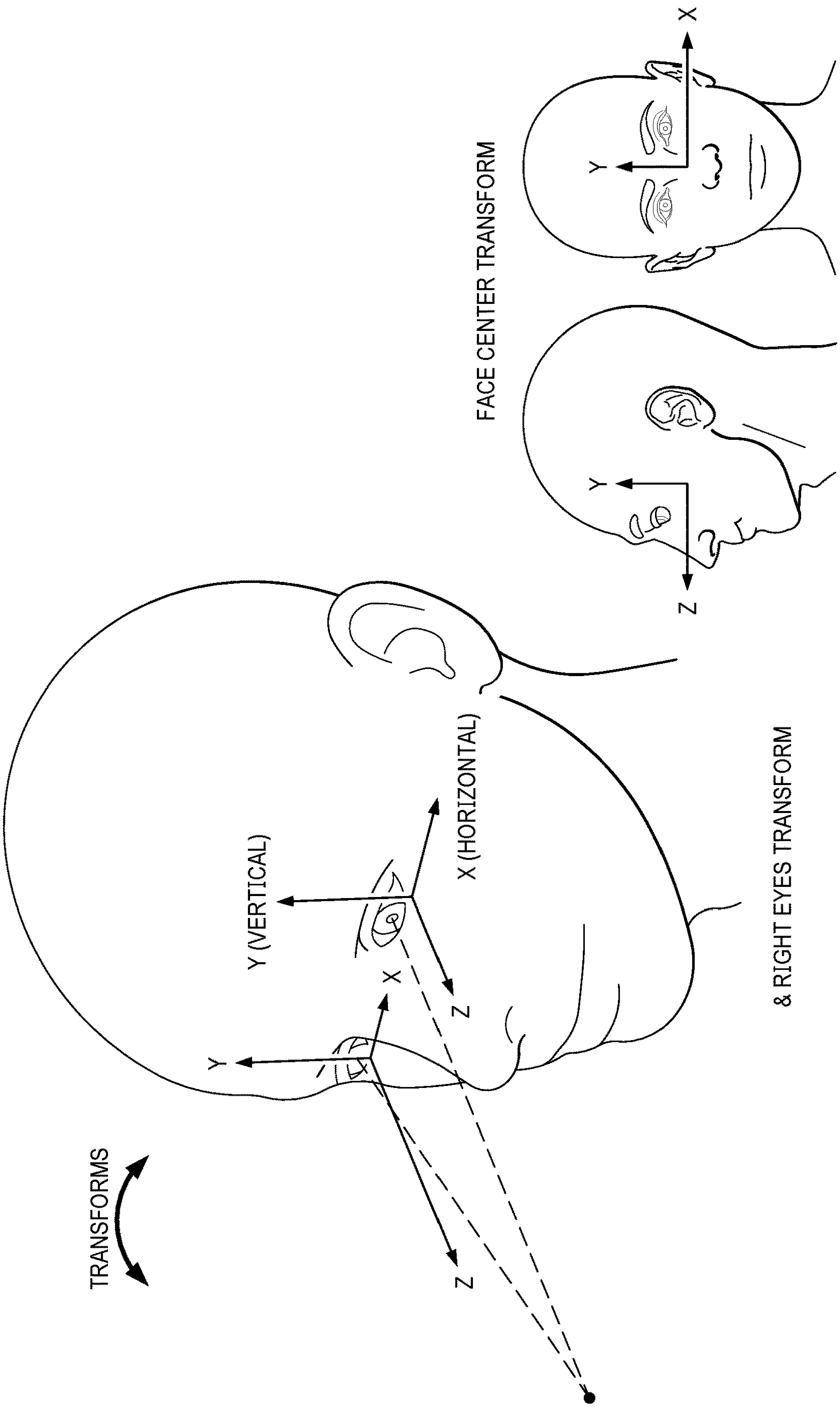

FACE CENTER TRANSFORM
X
Y
Z
Y (VERTICAL)
X (HORIZONTAL)
& RIGHT EYES TRANSFORM
TRANSFORMS

FIG. 1A

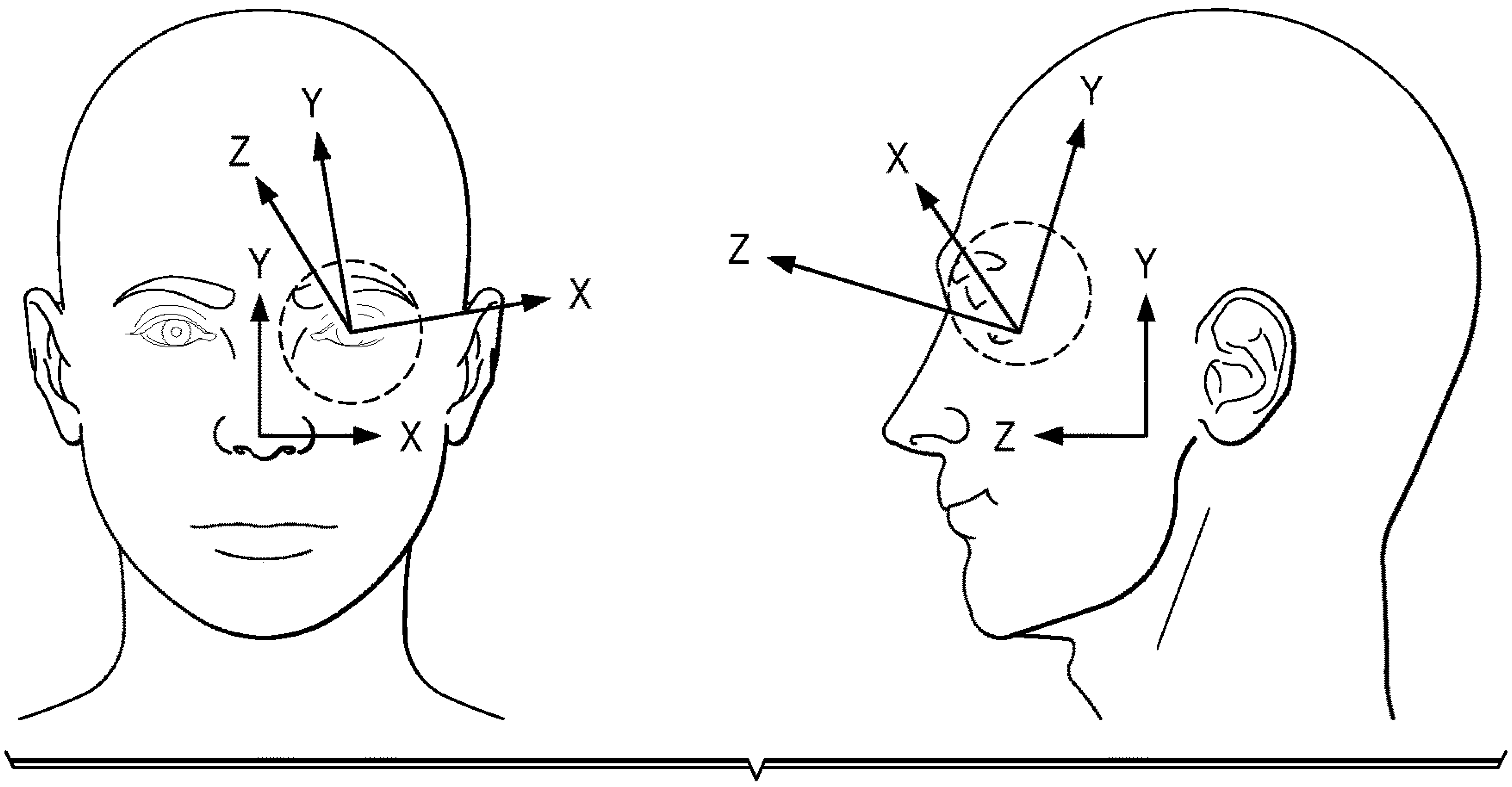


FIG. 1B

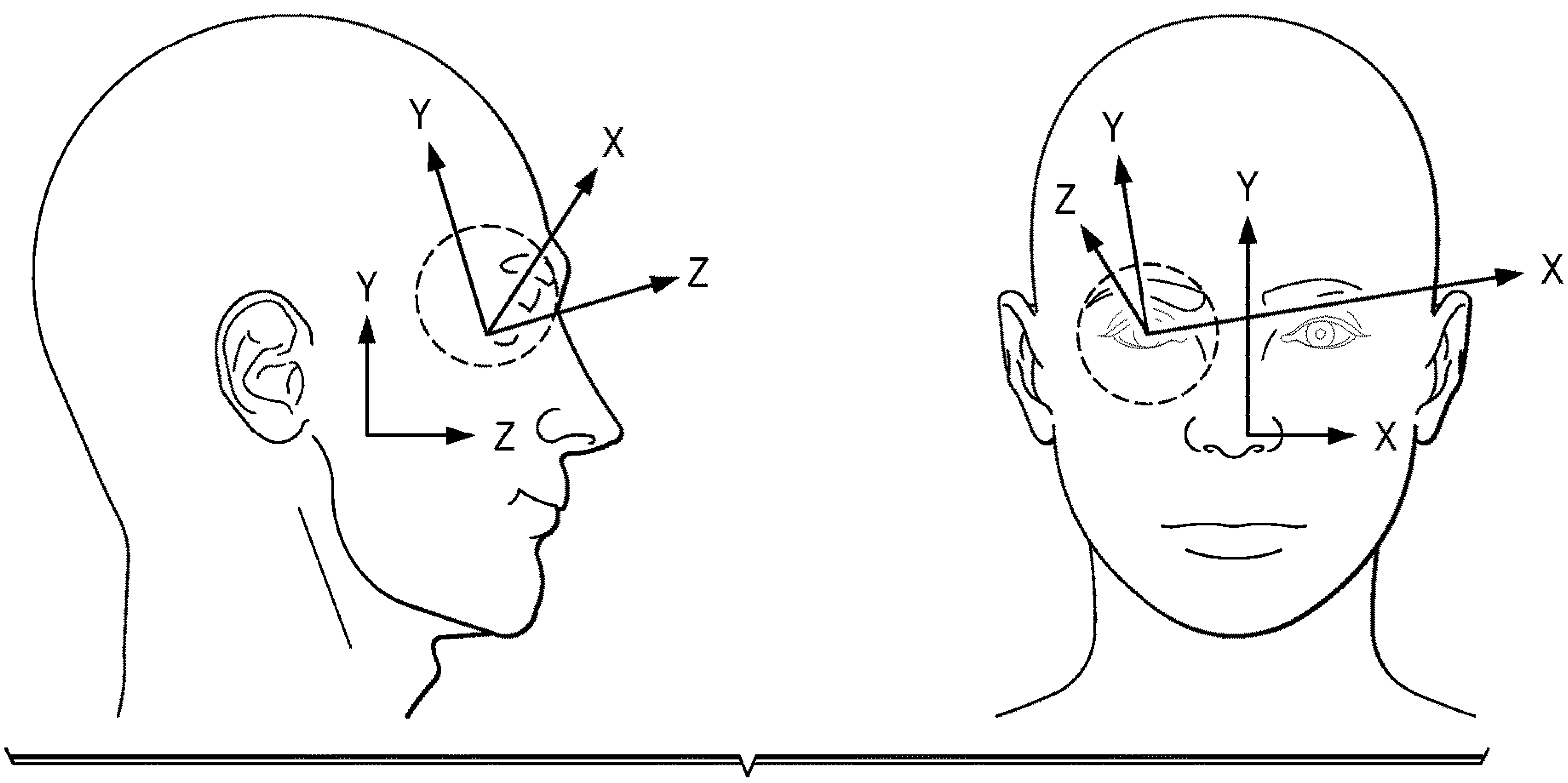


FIG. 1C

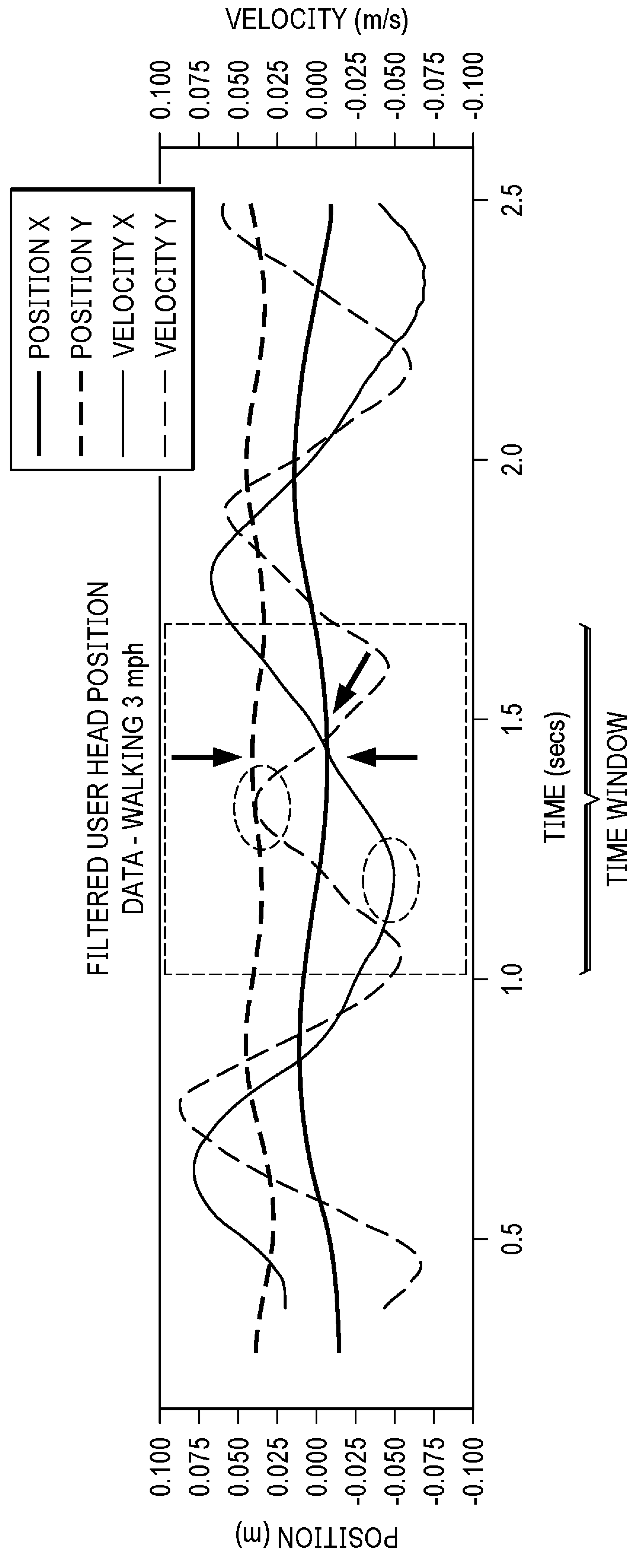

FILTERED USER HEAD POSITION
DATA - WALKING 3 mph
POSITION X
POSITION Y
VELOCITY X
VELOCITY Y
VELOCITY (m/s)
0.100
0.075
0.050
0.025
0.000
-0.025
-0.050
-0.075
-0.100
POSITION (m)
0.100
0.075
0.050
0.025
0.000
-0.025
-0.050
-0.075
-0.100
0.5
1.0
1.5
2.0
2.5
TIME (secs)
TIME WINDOW

FIG. 2

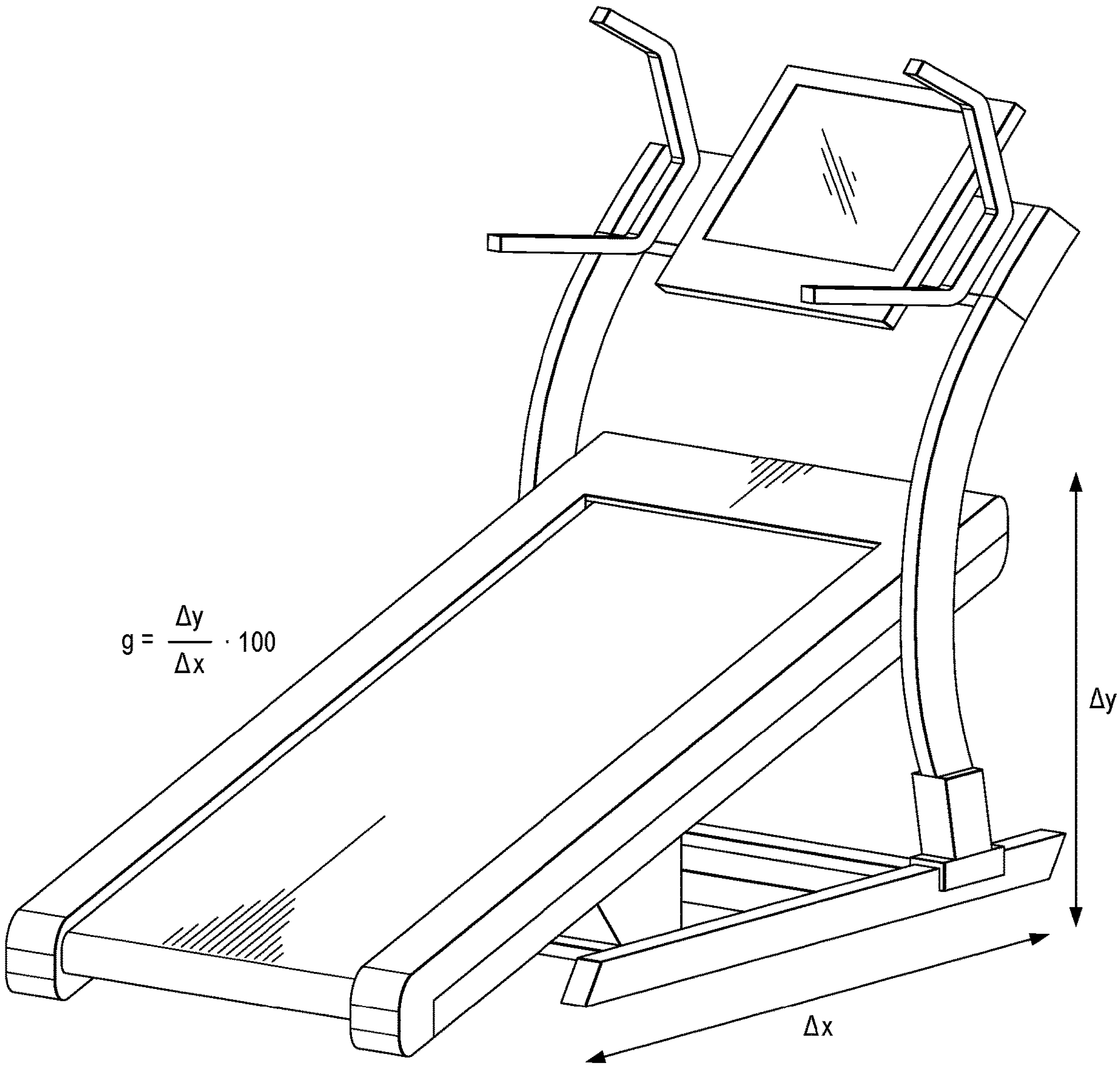


FIG. 3A

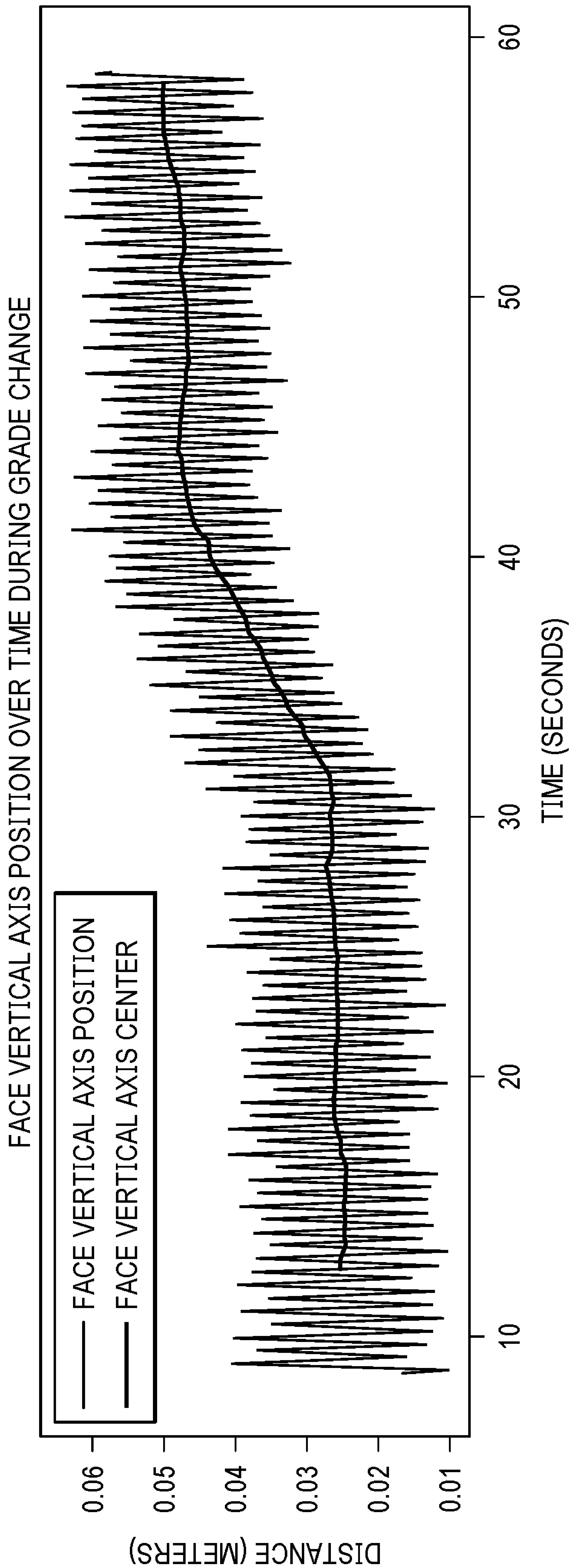

FACE VERTICAL AXIS POSITION OVER TIME DURING GRADE CHANGE
FACE VERTICAL AXIS POSITION
FACE VERTICAL AXIS CENTER
DISTANCE (METERS)
0.06
0.05
0.04
0.03
0.02
0.01
TIME (SECONDS)
10
20
30
40
50
60

FIG. 3B

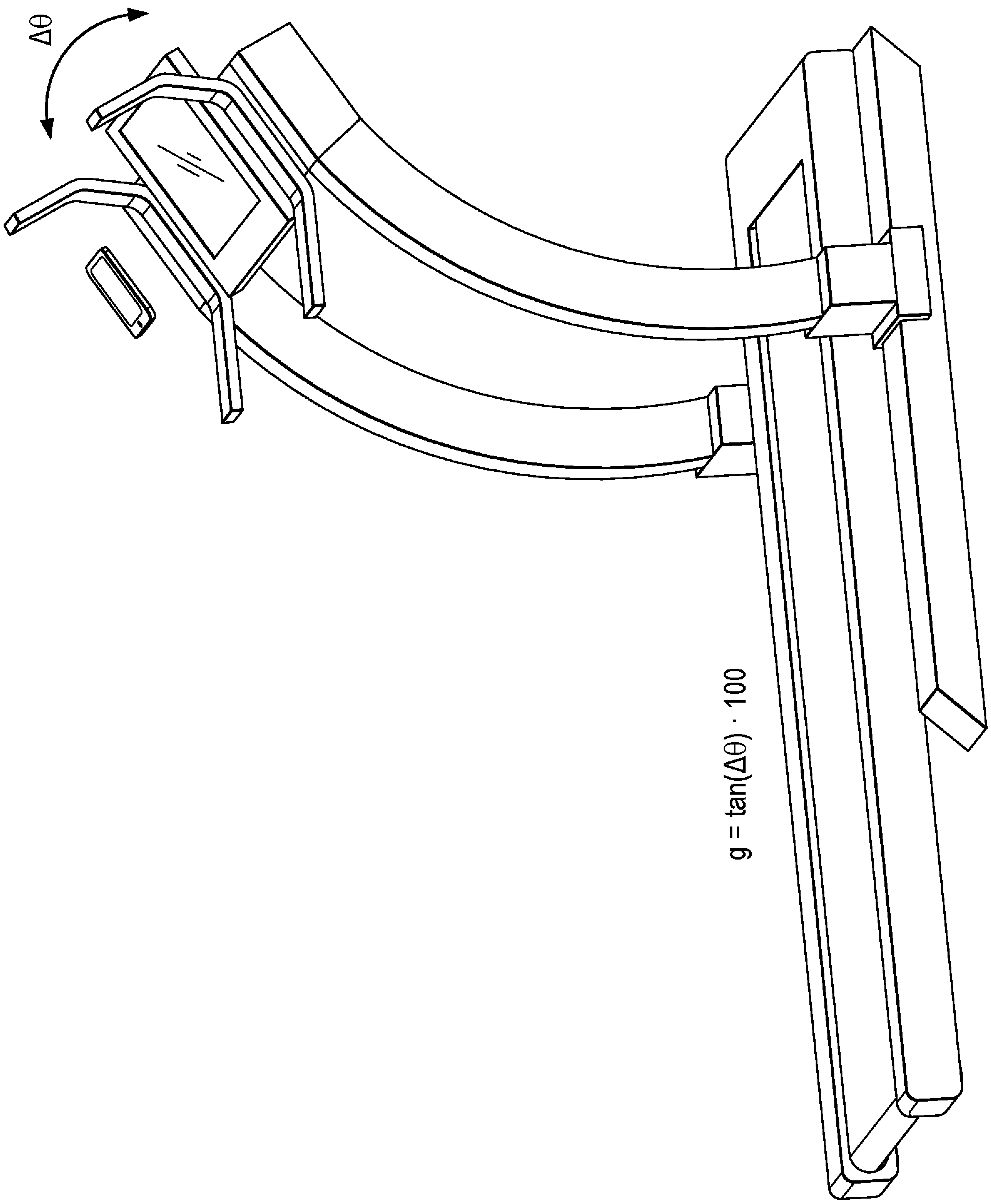


FIG. 3C

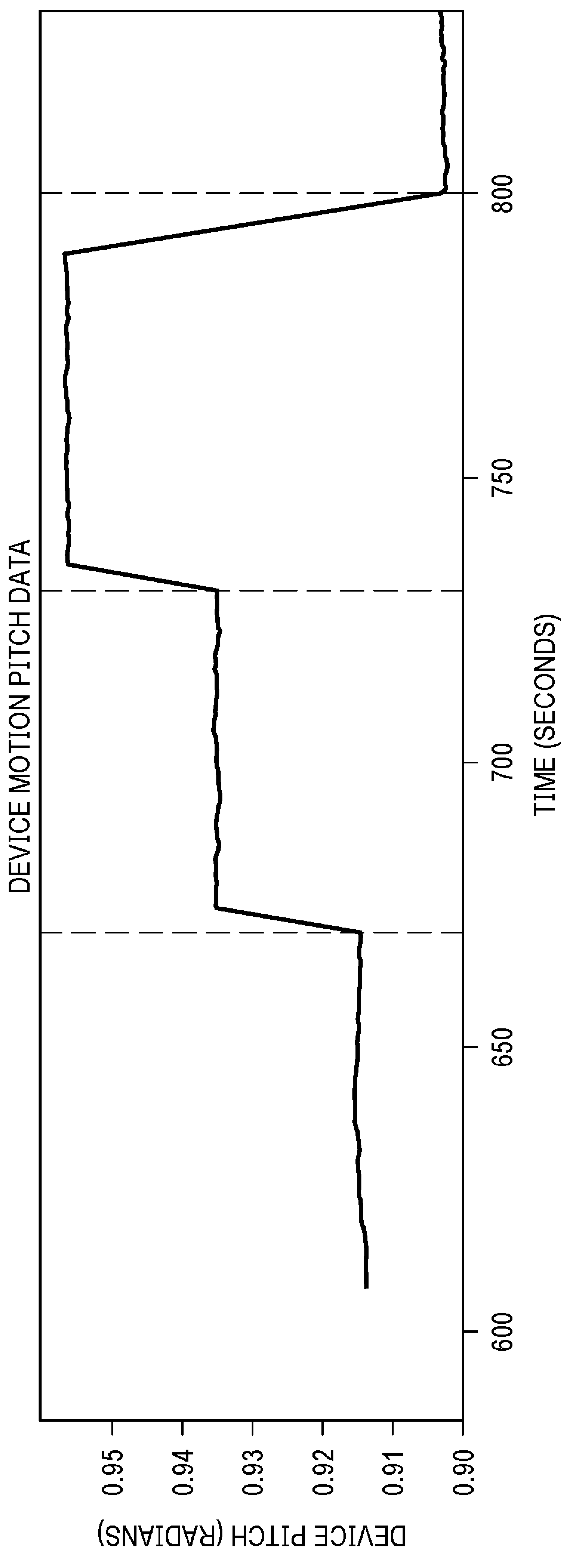

DEVICE MOTION PITCH DATA
DEVICE PITCH (RADIANS)
0.95
0.94
0.93
0.92
0.91
0.90
TIME (SECONDS)
600
650
700
750
800

FIG. 3D

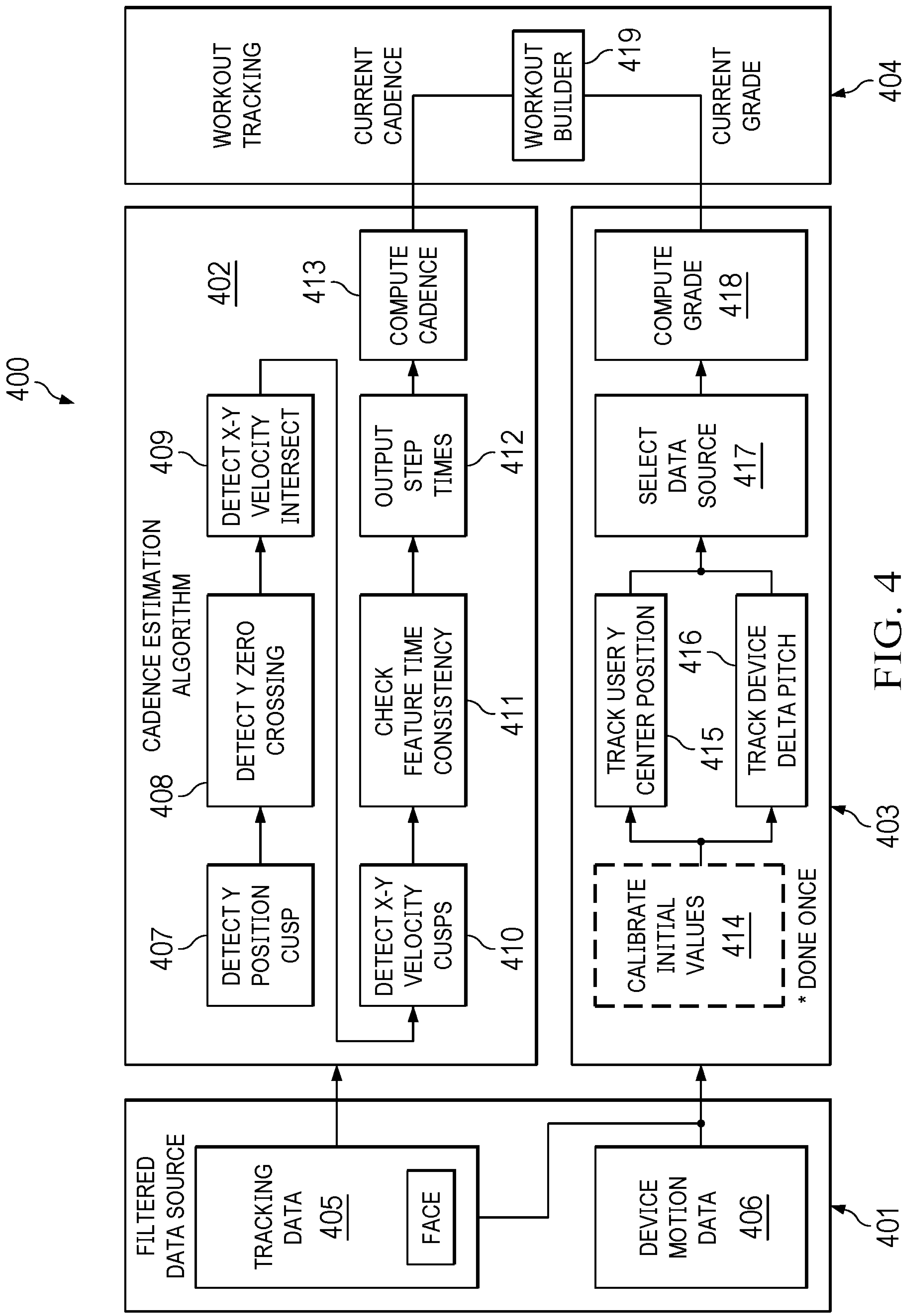

400
FILTERED DATA SOURCE
TRACKING DATA 405
FACE
DEVICE MOTION DATA 406
401
CADENCE ESTIMATION ALGORITHM
402
DETECT Y POSITION CUSP
407
DETECT Y ZERO CROSSING
408
DETECT X-Y VELOCITY INTERSECT
409
DETECT X-Y VELOCITY CUSPS
410
CHECK FEATURE TIME CONSISTENCY
411
OUTPUT STEP TIMES
412
COMPUTE CADENCE
413
CALIBRATE INITIAL VALUES 414
* DONE ONCE
TRACK USER Y CENTER POSITION
415
TRACK DEVICE DELTA PITCH
416
SELECT DATA SOURCE 417
COMPUTE GRADE 418
403
WORKOUT TRACKING
CURRENT CADENCE
WORKOUT BUILDER
419
CURRENT GRADE
404

FIG. 4

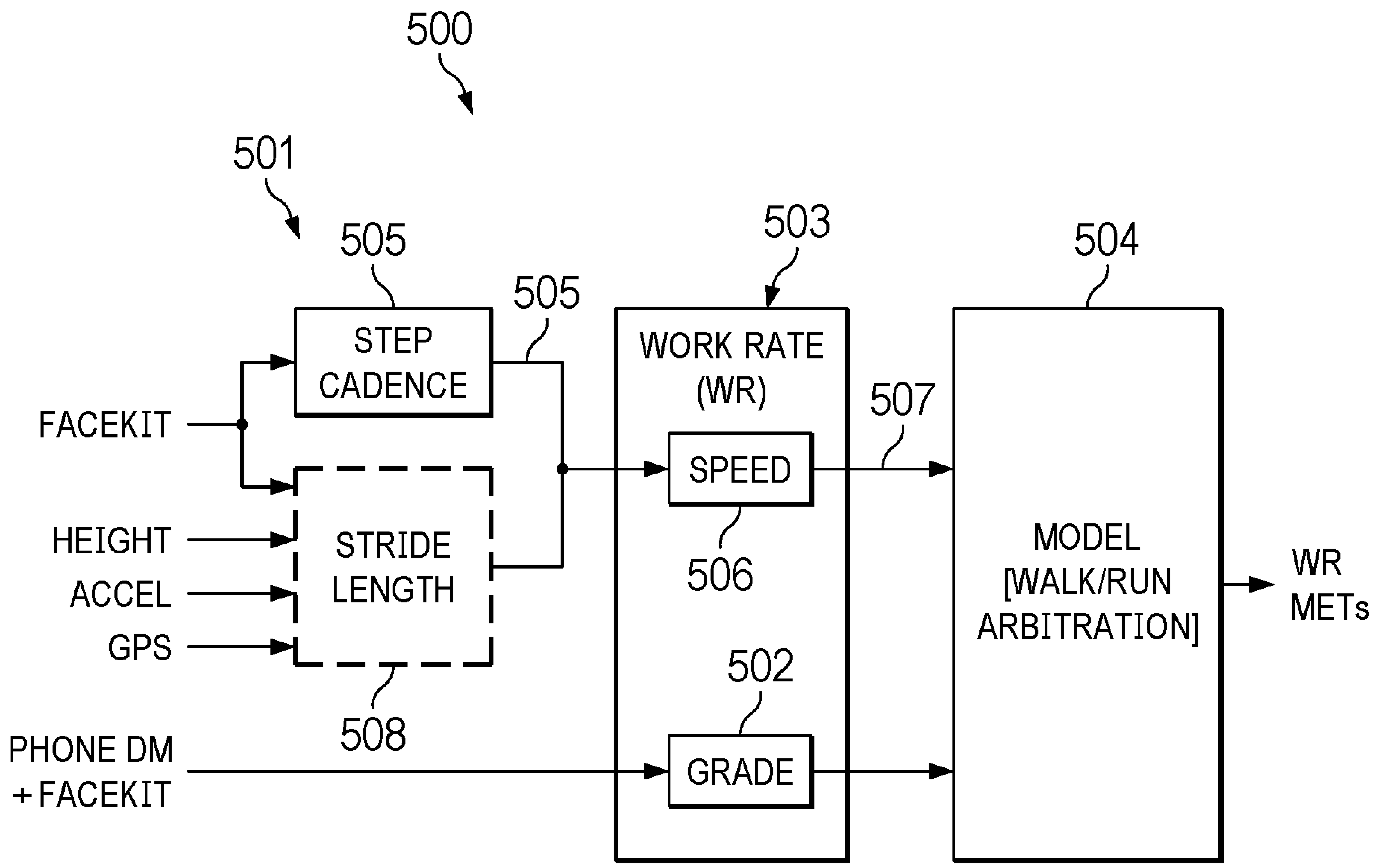

500
501
505
STEP CADENCE
505
503
WORK RATE (WR)
504
FACEKIT
HEIGHT
ACCEL
GPS
STRIDE LENGTH
SPEED
507
506
MODEL [WALK/RUN ARBITRATION]
WR METs
502
508
PHONE DM + FACEKIT
GRADE

FIG. 5

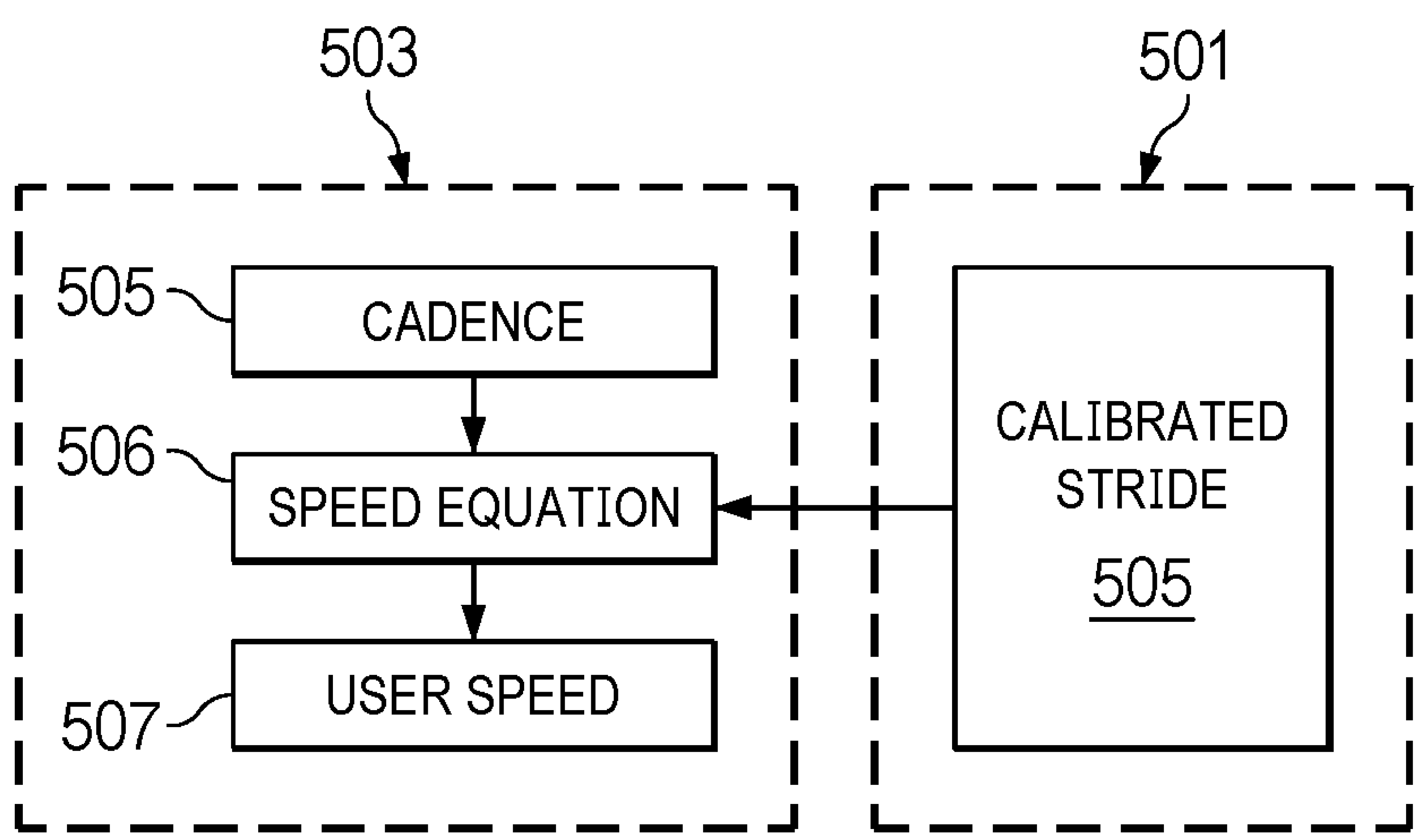

503
501
505
CADENCE
506
SPEED EQUATION
507
USER SPEED
CALIBRATED STRIDE
505

FIG. 6

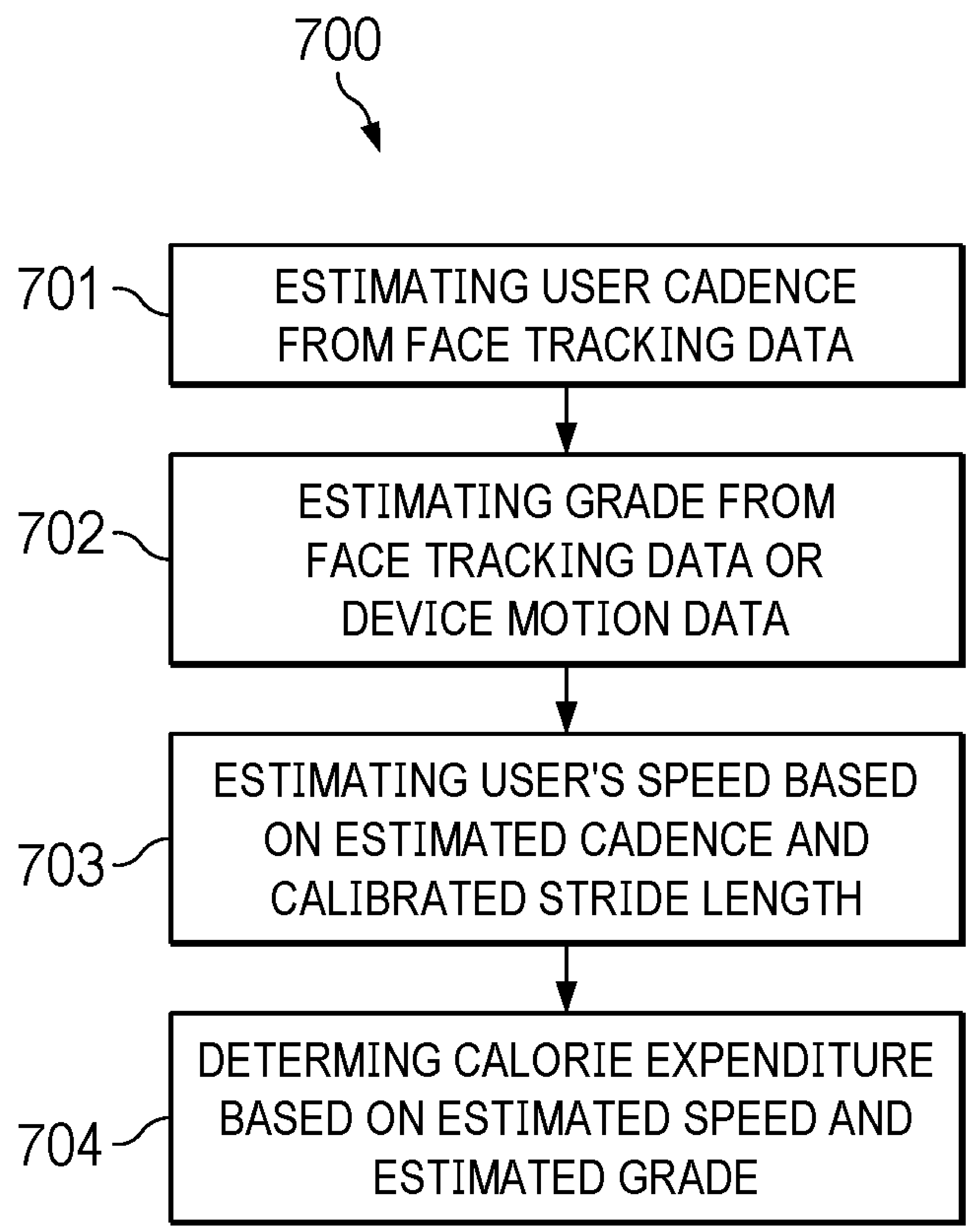
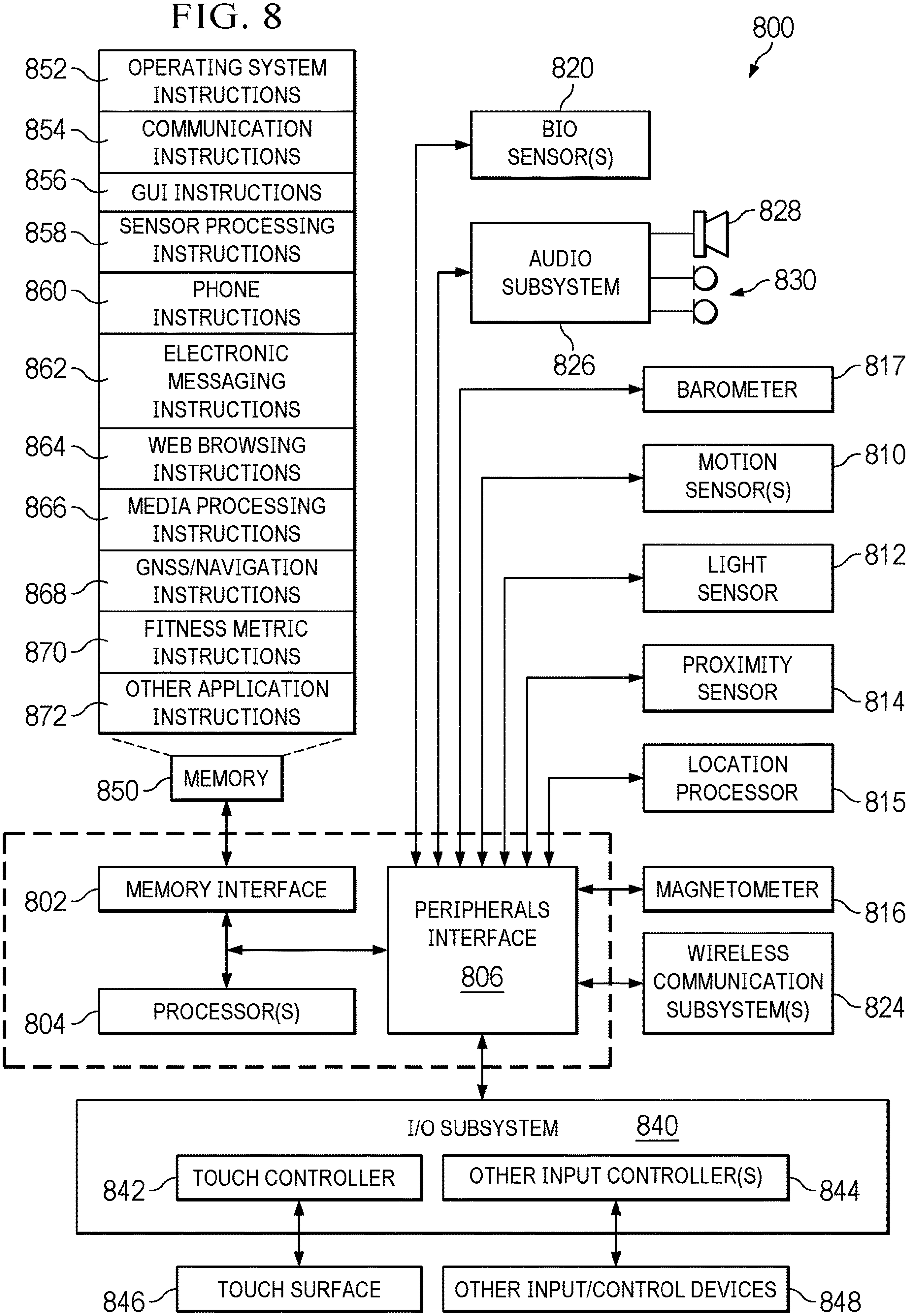

700
701
ESTIMATING USER CADENCE FROM FACE TRACKING DATA
702
ESTIMATING GRADE FROM FACE TRACKING DATA OR DEVICE MOTION DATA
703
ESTIMATING USER'S SPEED BASED ON ESTIMATED CADENCE AND CALIBRATED STRIDE LENGTH
704
DETERMING CALORIE EXPENDITURE BASED ON ESTIMATED SPEED AND ESTIMATED GRADE

FIG. 7

FIG. 8


800
852 OPERATING SYSTEM INSTRUCTIONS
854 COMMUNICATION INSTRUCTIONS
856 GUI INSTRUCTIONS
858 SENSOR PROCESSING INSTRUCTIONS
860 PHONE INSTRUCTIONS
862 ELECTRONIC MESSAGING INSTRUCTIONS
864 WEB BROWSING INSTRUCTIONS
866 MEDIA PROCESSING INSTRUCTIONS
868 GNSS/NAVIGATION INSTRUCTIONS
870 FITNESS METRIC INSTRUCTIONS
872 OTHER APPLICATION INSTRUCTIONS
850 MEMORY
820 BIO SENSOR(S)
826 AUDIO SUBSYSTEM
828
830
817 BAROMETER
810 MOTION SENSOR(S)
812 LIGHT SENSOR
814 PROXIMITY SENSOR
815 LOCATION PROCESSOR
802 MEMORY INTERFACE
804 PROCESSOR(S)
PERIPHERALS INTERFACE 806
816 MAGNETOMETER
824 WIRELESS COMMUNICATION SUBSYSTEM(S)
I/O SUBSYSTEM 840
842 TOUCH CONTROLLER
844 OTHER INPUT CONTROLLER(S)
846 TOUCH SURFACE
848 OTHER INPUT/CONTROL DEVICES

TRACKING CALORIC EXPENDITURE USING A CAMERA

CROSS-REFERENCE TO RELATED APPLICATION

[0001] This application claims priority to U.S. Provisional Patent Application No. 63/394,905, filed Aug. 3, 2022, the entire contents of which is incorporated herein by reference.

TECHNICAL FIELD

[0002] This disclosure relates generally to fitness applications.

BACKGROUND

[0003] Tracking devices (e.g., smartphones and smartwatches), include motion sensors that are used by fitness applications to estimate the caloric expenditure of a user during physical activity. In some fitness applications, motion data from the motion sensors (e.g., acceleration, rotation rate) are used with an energy expenditure model to estimate the amount of calories burned by the user during a workout. Some applications also use a heart rate sensor in combination with the energy expenditure model to estimate calories burned. These fitness applications require that the tracking device be worn on the body of the user, which is typically the wrist, chest, torso or foot.

SUMMARY

[0004] Embodiments are disclosed for tracking caloric expenditure using a camera.

[0005] In some embodiments, a method comprises: obtaining, with at least one processor of a device, face tracking data associated with a user; determining, with the at least one processor, a step cadence of the user based on the face tracking data; determining, with the at least one processor, a speed of the user based on the step cadence and a stride length of the user; obtaining, with the at least one processor, device motion data from at least one motion sensor of the device; determining, with the at least one processor, a grade of a surface on which the user is walking or running based on at least one of the device motion data or the face tracking data; and determining, with the at least one processor, an energy expenditure of the user based on the estimated speed, the estimated grade and a caloric expenditure model.

[0006] In some embodiments, the method further comprises: capturing, with a camera of the device, video data of the user's face; and generating, with the at least one processor, the face tracking data from the video data.

[0007] In some embodiments, the device is a mobile phone and the camera is a front-facing camera of the mobile phone.

[0008] In some embodiments, the method further comprises: correcting, with the at least one processor, the face tracking data to remove vertical face motion due to the user nodding their head.

[0009] In some embodiments, determining, with the at least one processor, the step cadence of the user based on the face tracking data further comprises: extracting features indicative of a step from a window of the face tracking data; and computing the step cadence based on the extracted features.

[0010] In some embodiments, the features include at least one of the following features: 1) one period in vertical displacement and a half a period of horizontal displacement; 2) one horizontal velocity cusp and vertical velocity cusp within each step; 3) the horizontal and vertical velocity intersect near a time of a foot strike where the user's foot is touching the ground; or 4) the horizontal velocity, vertical velocity and vertical displacement amplitudes exceed specified thresholds.

[0011] In some embodiments, determining the grade of the surface on which the user is walking or running based on at least one of the device motion data or the face tracking data, further comprises: tracking a displacement envelope of a vertical axis of a face centered reference frame; responsive to the envelope changing, estimating the grade of the surface based on the face tracking data; and responsive to the envelope not changing, determining the grade of the surface based on device motion data output by a motion sensor of the device.

[0012] In some embodiments, the method further comprises: computing, with the at least one processor, an uncalibrated stride length of the user based at least in part on a height of the user; computing, with the at least one processor, an uncalibrated distance by multiplying the step cadence and the uncalibrated stride length; computing, with the at least one processor, a calibration factor by dividing a truth distance by the uncalibrated distance, and then multiplying the uncalibrated stride length by the calibration factor to get a calibrated stride length; and computing, with the at least one processor, the speed of the user by multiplying the step cadence by the calibrated stride length.

[0013] In some embodiments, the truth distance is obtained or derived from a global navigation satellite system (GNSS) receiver.

[0014] In some embodiments, a system comprises: at least one processor; memory storing instructions that when executed by the at least one processor, cause the at least one processor to perform any of the preceding methods.

[0015] In some embodiments, a non-transitory, computer-readable storage medium having stored thereon instructions, that when executed by at least one processor, causes the at least one processor to perform any of the preceding methods.

[0016] Advantages of the disclosed embodiments include: 1) providing a real-time treadmill fitness experience using the front-facing camera of a tracking device (e.g., a smartphone) when the device is not worn by the user; 2) track caloric expenditure during the user's workout using speed and grade estimated using a single camera; and 3) no need for body-worn sensors (e.g., a smartwatch) or fitness machine connectivity.

[0017] The details of one or more implementations of the subject matter are set forth in the accompanying drawings and the description below. Other features, aspects and advantages of the subject matter will become apparent from the description, the drawings and the claims.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] FIGS. **1**A-**1**C illustrate coordinate reference frames tracking a user's face using a front-facing camera, according to an embodiment.

[0019] FIG. **2** illustrates key features of a step that can be extracted from face tracking data to estimate the user's step cadence, according to an embodiment.

[0020] FIGS. **3**A and **3**B illustrate face vertical axis position over time during a grade change for a treadmill design where the control/display console is detached from the running deck, according to an embodiment.

[0021] FIGS. **3**C and **3**D illustrate device motion pitch data over time during a grade change for a treadmill design where the control/display console is connected to the running deck, according to an embodiment.

[0022] FIG. **4** is block diagram of a system for estimating user step cadence and grade using face tracking data capture from video and device motion data, according to an embodiment.

[0023] FIG. **5** is a block diagram of a system for estimating caloric expenditure based on the estimated user step cadence and estimated grade, according to an embodiment.

[0024] FIG. **6** is a block diagram illustrating estimating user speed based on the estimated step user step cadence and calibrated user stride length, according to an embodiment.

[0025] FIG. **7** is a flow diagram of a process of tracking caloric expenditure using a camera, according to some embodiments.

[0026] FIG. **8** is example system architecture implementing the features and operations described in reference to FIGS. **1**-**7**.

DETAILED DESCRIPTION

Example Speed Estimation

[0027] FIGS. **1**A-**1**C illustrate coordinate reference frames tracking a user's face using a front-facing camera, according to an embodiment.

[0028] In some embodiments, a face tracker of a tracking device (e.g., face tracking software of a smartphone) receives video frames captured by a front-facing camera of the tracking device, such as a smartphone. The tracking device can be, for example, a smartphone resting on a tread mill console while a user is exercising on a treadmill. The face tracker uses various coordinate transformations to track the motion of one or more features of the user's face. In the embodiments that follow, the face tracker is part of Apple Inc.'s ARKit®, and the facial features tracked include the user's face center (e.g., the user's nose), left eye and right eye. Each feature is represented by a Cartesian reference frame. The face center reference frame is illustrated in FIG. **1**A and the reference frames for the left eye and right eye balls are illustrated in FIGS. **1**B and **1**C, respectively. The translation aspect of these three matrices indicate the position of the center of the head/eyeballs, relative to a reference position represented by an anchor transform, where the anchor transform represents a real-world position and orientation of the user's face.

[0029] Referring to FIGS. **1**A-**1**C, the positive z-axis points from the center of the face/eyeballs (in the direction of the nose and pupils, respectively). The rotational information of the matrices (first 3 columns of a 4×4 matrix) indicate the orientation of the face/eyeballs. For example, a rotation about the x-axis directs the head/pupil upward or downward. Note that the eyes do not rotate about the z-axis.

[0030] In addition, to the face center, left and right eye transforms, the face tracker also outputs a look-at point. The look-at-point is represented by a vector which is abstracted from the left and right eye transforms matrices to estimate what point, relative to the user's face, the user's eyes are focused upon. For example, if the user is looking to the left, the look-at point vector has a positive x-axis component, if the user is focused on a nearby object, the vector's length is shorter and if the user is focused on a faraway object, the vector's length is longer. As described in further detail below, the look-at point vector is used to correct head motion due to the user nodding their head while they exercise.

[0031] Although the embodiments described herein utilize Apple Inc.'s ARKit®, any suitable face tracking software can be used that provides motion data as described herein, or that can be mathematically manipulated to provide motion data as described herein. Some examples of face trackers include but are not limited to: Vuforia™, Unity™, ARCore™, Unreal Engine™, Blender™, Amazon Sumerian™, Kivy™, Godot™, HP Reveal™, ZapWorks™ and the like. In some embodiments, the output of the face tracker is a 4×4 transform matrix (e.g., a direction cosine matrix) indicating the position and orientation of the facial feature. In other embodiments, there can be more or fewer facial features tracked, different reference frames utilized and/or different output representations of position/orientation provided by the face trackers (e.g., quaternions rather than direction cosine matrices).

[0032] FIG. **2** illustrates key features of a step that can be extracted from face tracking data output by the face tracker to estimate the user's step cadence, according to an embodiment. In this example, a multivariate plot of filtered user head position (m) and velocity (m/s) versus time (secs) is shown for a user walking on a treadmill at 3 mph. An example time window (e.g., 1.70 secs) is also shown that captures certain key features that indicate that the user has taken a step.

[0033] The key features that indicate a step include: 1) one period in y (vertical) displacement and half a period of x (horizontal) displacement; 2) one x (horizontal) velocity cusp and y (vertical) velocity cusp within each step (see dashed ovals); 3) the x (horizontal) and y (vertical) velocity intersect near a time of a foot strike (i.e., the user's foot touching the ground); and 4) the x (horizontal), y (vertical) velocity and y (vertical) displacement amplitudes exceed specified thresholds. If all four of these key features are present in a single time window, then a step is detected. In some embodiments, more or fewer key features can be used to indicate a step. The step detections taken over a unit of time (e.g., per sec) indicate the user's step cadence, which can be multiplied by the user's stride length to estimate the user's speed, as described in further detail below. As used in this example embodiment, the x (horizontal) axis and the y (vertical) axis form a face-centered Cartesian coordinate system as shown in FIG. **1**A, where the x or horizontal axis points in the direction of the user's left ear, the y or vertical axis points out of the top of the user's head and the z axis points along the user's nose based on the right-hand rule.

Example Grade Estimation

[0034] FIGS. **3**A and **3**B illustrate a first treadmill design where the treadmill console is stationary when the incline of the running deck is changed. For this first treadmill design, grade is computed as:

$$g = \frac{\Delta y}{\Delta X}, \quad [1]$$

where Δy is the vertical displacement of the running deck from ground and Δx is horizontal displacement of the running deck, as illustrated in FIG. **3**A. As shown in FIG. **3**B, grade is estimated based on a detected change of the vertical axis (y-axis) center of the face-centered reference frame over time. Note that the displacement envelope of the face vertical axis center changes when the incline/grade of the running deck changes. In this example, at about the 30 second mark a grade change causes the face vertical axis center to transition upwards until about the forty second mark where the grade change ends. In some embodiments, face vertical axis center is provided by the face tracker, and is corrected for head nodding/bobbing by subtracting the look-at point vector (described above) from the face vertical axis center.

[0035] FIGS. **3**C and **3**D illustrate device motion pitch change over time during a grade change for a treadmill design where the control/display console is connected to the running deck, according to an embodiment. For this treadmill design, grade g is computed as:

$$g=\tan(\Delta\theta)*100, \quad [2]$$

where $\Delta\theta$ is the pitch of the treadmill console relative to ground.

[0036] In some embodiments, device motion data is used as an approximation of $\Delta\theta$. For example, a gyro sensor in the tracking device outputs pitch data ($\Delta\theta$), which is used to estimate grade according to Equation [2].

[0037] FIG. **4** is block diagram of a system for estimating user step cadence and grade using face tracking data and device motion data, according to an embodiment. System **400** includes data filtering **401**, cadence estimator **402**, grade estimator **403** and workout tracker **404**.

[0038] Data filtering **401** filters face tracking data and device motion data. Filtering can include but is not limited to windowing and filtering the face tracking data and device motion data to remove noise. The filtering can include, for example, averaging the tracking data and device motion data to remove noise.

[0039] Cadence estimator **402** estimates the user's step cadence by detecting key features in the face tracking data provided by a face tracker within a specified time window, as shown in FIG. **2**. The key feature detecting includes detecting x-y position cusps **407**, detecting y crossing **408** (indicating a foot strike), detecting x-y velocity intersection **409** (near the y crossing **408**), detecting x-y velocity cusps **410**, checking feature time consistency **411** (checking that there is one period in y displacement and a half period of x displacement in a single window), outputting user's step times **412** and computing user's step cadence **413** based on the user's step times.

[0040] Grade estimator **403** estimates grade from device motion. At initialization, initial values are calibrated **414**. Calibration can include but is not limited to generating reference transforms based on a current position and orientation of the tracking device. After initialization, the vertical axis position of the user's face **415** from the face tracking data (i.e., the y component of the x, y, z position vector provided in the face tracking data) and device motion pitch **416** are employed to detect grade change, as described in reference to FIGS. **3**A, **3**B. In step **417**, a particular grade model (e.g., Equation [1] or Equation [2]) is selected to estimate grade. For example, if the face vertical axis center is changing and the device motion pitch is not changing, then Equation [1] is used to compute grade. Similarly, if the face vertical axis center is not changing and the device motion pitch is changing, then Equation [2] is used to compute grade. If both the face vertical axis center and device motion pitch are changing, it is assumed that the tracking device is not stationary on the console (e.g., it is being handled by the user) and no grade estimate is computed.

[0041] In some embodiments, workout tracker **404** receives the current step cadence of the user and the current grade computed by cadence estimator **402** and grade estimator **403**, and computes estimated work rate (WR) metabolic equivalent for task (METs), as described in reference to FIG. **5**.

[0042] FIG. **5** is a block diagram of a system **500** for estimating caloric expenditure based on the estimated user step cadence and estimated grade, according to an embodiment. System **500** includes stride length estimator **501** and WR generator **503** (which comprises speed calculator **506** and grade calculator **502**) and WR model **504**. The output of the face tracker is the user's step cadence an as described in reference to FIG. **4**. Stride length estimator **510** takes as input the user's step cadence, height, acceleration and speed. Height can be provided by the user through a user interface of the tracking device or otherwise accessed from a storage device. Acceleration can be provided by an accelerometer of the tracking device and speed can be provided by a global navigation satellite system (GNSS) receiver, such as a global positioning system (GPS) receiver embedded in or coupled to the tracking device.

[0043] In some embodiments, an uncalibrated stride length (or average stride length) is computed by multiplying the user's height by a ratio that accounts for the user's gender (e.g., 0.413 for women and 0.415 for men). An uncalibrated distance is then calculated by multiplying the step cadence output by the face tracker and the uncalibrated stride length. While the user is on the treadmill, a calibration factor k is calculated by dividing a "truth" distance taken from GNSS position from a wearable device (e.g., a smart watch) by the uncalibrated distance, and then multiplying the uncalibrated stride length by the calibration factor k to get a calibrated stride length **508** shown in FIG. **6**. Speed calculator **506** includes speed equation **506** which multiplies the user's step cadence **505** output by the face tracker by the calibrated stride length **508** to get the user's speed **507**, also shown in FIG. **6**. Grade calculator **502** uses at least one of face tracking data or device motion (e.g., pitch from a gyro) to determine a surface grade depending on the type of treadmill that the user is exercising on, as described in reference to FIGS. **3**A and **3**B.

[0044] The estimated speed and grade is input into a WR energy expenditure model **504** which estimates the caloric expenditure of the user in METs or any other desirable unit that describes caloric expenditure. WR energy expenditure model **504** can include a model for aerobic capacity (VO2) for walking and for running. For example, an American College of Sports Medicine (ACSM) energy expenditure model for walking is given by:

$$VO2=(0.1*S)+(1.8*S*G)+C, \quad [3]$$

where S is the estimated user speed, G is the estimated grade and C is a resting component (e.g., 3.5). Similarly, the ACSM energy expenditure model for running is given by:

$$VO2=(0.2*S)+(0.9*S*G)+C, \quad [4]$$

where S is the estimated user speed and G is the estimated grade and C is a resting component (e.g., 3.5).

[0045] One MET equates to 3.5 ml·kg−1·min−1. Therefore dividing VO2 Max by the one MET value converts VO2 Max into METs.

[0046] These energy expenditure models are only examples of possible model that can benefit from the disclosed embodiments. Those with ordinary skill in the art will recognize that the disclosed embodiments can be used with any energy expenditure model that utilizes user speed and/or grade, including but not limited to any energy expenditure models based on work rate or that combine work rate based energy expenditure with heart rate based energy expenditure. Also, the disclosed embodiments are not limited to treadmill workouts, but can be used with any exercise or exercise equipment where camera tracking data provides an indication of a fitness metric, including but not limited to tracking other parts of the human body. For example, the disclosed embodiments are applicable to any exercise, health monitoring application or fitness machine where vertical or lateral face motion can be captured by a camera, including but not limited to counting squats, pull-ups or jump rope steps, where there is vertical motion of the face, or lateral motion of the face, such as side step exercises.

Exemplary Process

[0047] FIG. **7** is a flow diagram of process **700** of tracking caloric expenditure using a camera, according to an embodiment. Process **700** can be implemented by, for example, the device architecture **800** described in reference to FIG. **8**.

[0048] Process **700** includes obtaining, from a camera of a tracking device, face tracking data associated with a user (**701**), determining a step cadence of the user based on the face tracking data (**702**), estimating a speed of the user based on the step cadence and a stride length of the user (**703**), obtaining device motion data from at least one motion sensor of the device (**704**), estimating a grade of a surface on which the user is walking or running based on at least one of the device motion data or the face tracking data (**705**), and estimating, using a caloric expenditure model, an energy expenditure of the user based on the estimated speed and estimated grade (**706**).

Exemplary System Architecture

[0049] FIG. **8** illustrates example device architecture **800** implementing the features and operations described in reference to FIGS. **1-7**. Architecture **800** can include memory interface **802**, one or more hardware data processors, image processors and/or processors **804** and peripherals interface **806**. Memory interface **802**, one or more processors **804** and/or peripherals interface **806** can be separate components or can be integrated in one or more integrated circuits. System architecture **800** can be included in any suitable electronic device, including but not limited to: a smartphone, smartwatch, tablet computer, fitness band, laptop computer and the like.

[0050] Sensors, devices and subsystems can be coupled to peripherals interface **806** to provide multiple functionalities. For example, one or more motion sensors **810**, light sensor **812** and proximity sensor **814** can be coupled to peripherals interface **806** to facilitate motion sensing (e.g., acceleration, rotation rates), lighting and proximity functions of the tracking device. Location processor **818** can be connected to peripherals interface **806** to provide geo-positioning. In some implementations, location processor **815** can be a GNSS receiver, such as the Global Positioning System (GPS) receiver. Electronic magnetometer **816** (e.g., an integrated circuit chip) can also be connected to peripherals interface **806** to provide data that can be used to determine the direction of magnetic North. Electronic magnetometer **816** can provide data to an electronic compass application. Motion sensor(s) **810** can include one or more accelerometers and/or gyros configured to determine change of speed and direction of movement. Barometer **817** can be configured to measure atmospheric pressure, which can be used to determine elevation changes.

[0051] Communication functions can be facilitated through wireless communication subsystems **824**, which can include radio frequency (RF) receivers and transmitters (or transceivers) and/or optical (e.g., infrared) receivers and transmitters. The specific design and implementation of the communication subsystem **824** can depend on the communication network(s) over which a tracking device is intended to operate. For example, architecture **800** can include communication subsystems **824** designed to operate over a GSM network, a GPRS network, an EDGE network, a Wi-Fi™ network and a Bluetooth™ network. In particular, the wireless communication subsystems **824** can include hosting protocols, such that the tracking device can be configured as a base station for other wireless devices.

[0052] Audio subsystem **826** can be coupled to a speaker **828** and a microphone **830** to facilitate voice-enabled functions, such as voice recognition, voice replication, digital recording and telephony functions. Audio subsystem **826** can be configured to receive voice commands from the user.

[0053] I/O subsystem **840** can include touch surface controller **842** and/or other input controller(s) **844**. Touch surface controller **842** can be coupled to a touch surface **846**. Touch surface **846** and touch surface controller **842** can, for example, detect contact and movement or break thereof using any of a plurality of touch sensitivity technologies, including but not limited to capacitive, resistive, infrared and surface acoustic wave technologies, as well as other proximity sensor arrays or other elements for determining one or more points of contact with touch surface **846**. Touch surface **846** can include, for example, a touch screen or the digital crown of a smart watch. I/O subsystem **840** can include a haptic engine or device for providing haptic feedback (e.g., vibration) in response to commands from one or more processors **804**. In an embodiment, touch surface **846** can be a pressure-sensitive surface.

[0054] Other input controller(s) **844** can be coupled to other input/control devices **848**, such as one or more buttons, rocker switches, thumb-wheel, infrared port and USB port. The one or more buttons (not shown) can include an up/down button for volume control of speaker **828** and/or microphone **840**. Touch surface **846** or other controllers **844** (e.g., a button) can include, or be coupled to, fingerprint identification circuitry for use with a fingerprint authentication application to authenticate a user based on their fingerprint(s).

[0055] In one implementation, a pressing of the button for a first duration may disengage a lock of the touch surface **846**; and a pressing of the button for a second duration that is longer than the first duration may turn power to the tracking device on or off. The user may be able to customize a functionality of one or more of the buttons. The touch surface **846** can, for example, also be used to implement virtual or soft buttons.

[0056] In some implementations, the tracking device can present recorded audio and/or video files, such as MP3, AAC and MPEG files. In some implementations, the tracking device can include the functionality of an MP3 player. Other input/output and control devices can also be used.

[0057] Memory interface **802** can be coupled to memory **850**. Memory **850** can include high-speed random access memory and/or non-volatile memory, such as one or more magnetic disk storage devices, one or more optical storage devices and/or flash memory (e.g., NAND, NOR). Memory **850** can store operating system **852**, such as the iOS operating system developed by Apple Inc. of Cupertino, California. Operating system **852** may include instructions for handling basic system services and for performing hardware dependent tasks. In some implementations, operating system **852** can include a kernel (e.g., UNIX kernel).

[0058] Memory **850** may also store communication instructions **854** to facilitate communicating with one or more additional devices, one or more computers and/or one or more servers, such as, for example, instructions for implementing a software stack for wired or wireless communications with other devices, such as a sleep/wake tracking device. Memory **850** may include graphical user interface instructions **856** to facilitate graphic user interface processing; sensor processing instructions **858** to facilitate sensor-related processing and functions; phone instructions **860** to facilitate phone-related processes and functions; electronic messaging instructions **862** to facilitate electronic-messaging related processes and functions; web browsing instructions **864** to facilitate web browsing-related processes and functions; media processing instructions **866** to facilitate media processing-related processes and functions; GNSS/Location instructions **868** to facilitate generic GNSS and location-related processes and instructions; and caloric expenditure instructions **870** that implement the features and processes described in reference to FIGS. **1-7**. Memory **850** further includes other application instructions **872** for performing various functions using, for example, health monitoring or fitness applications.

[0059] Each of the above identified instructions and applications can correspond to a set of instructions for performing one or more functions described above. These instructions need not be implemented as separate software programs, procedures, or modules. Memory **850** can include additional instructions or fewer instructions. Furthermore, various functions of the tracking device may be implemented in hardware and/or in software, including in one or more signal processing and/or application specific integrated circuits.

[0060] While this specification contains many specific implementation details, these should not be construed as limitations on the scope of any inventions or of what may be claimed, but rather as descriptions of features specific to particular embodiments of particular inventions. Certain features that are described in this specification in the context of separate embodiments can also be implemented in combination in a single embodiment. Conversely, various features that are described in the context of a single embodiment can also be implemented in multiple embodiments separately or in any suitable sub combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub combination or variation of a sub combination.

[0061] Similarly, while operations are depicted in the drawings in a particular order, this should not be understood as requiring that such operations be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the embodiments described above should not be understood as requiring such separation in all embodiments, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products.

[0062] As described above, some aspects of the subject matter of this specification include gathering and use of data available from various sources to improve services a tracking device can provide to a user. The present disclosure contemplates that in some instances, this gathered data may identify a particular location or an address based on device usage. Such personal information data can include location-based data, addresses, subscriber account identifiers, or other identifying information.

[0063] The present disclosure further contemplates that the entities responsible for the collection, analysis, disclosure, transfer, storage, or other use of such personal information data will comply with well-established privacy policies and/or privacy practices. In particular, such entities should implement and consistently use privacy policies and practices that are generally recognized as meeting or exceeding industry or governmental requirements for maintaining personal information data private and secure. For example, personal information from users should be collected for legitimate and reasonable uses of the entity and not shared or sold outside of those legitimate uses. Further, such collection should occur only after receiving the informed consent of the users. Additionally, such entities would take any needed steps for safeguarding and securing access to such personal information data and ensuring that others with access to the personal information data adhere to their privacy policies and procedures. Further, such entities can subject themselves to evaluation by third parties to certify their adherence to widely accepted privacy policies and practices.

[0064] In the case of advertisement delivery services, the present disclosure also contemplates embodiments in which users selectively block the use of, or access to, personal information data. That is, the present disclosure contemplates that hardware and/or software elements can be provided to prevent or block access to such personal information data. For example, in the case of advertisement delivery services, the present technology can be configured to allow users to select to "opt in" or "opt out" of participation in the collection of personal information data during registration for services.

[0065] Therefore, although the present disclosure broadly covers use of personal information data to implement one or more various disclosed embodiments, the present disclosure also contemplates that the various embodiments can also be implemented without the need for accessing such personal information data. That is, the various embodiments of the present technology are not rendered inoperable due to the lack of all or a portion of such personal information data. For example, content can be selected and delivered to users by inferring preferences based on non-personal information data or a bare minimum amount of personal information, such as the content being requested by the device associated with a user, other non-personal information available to the content delivery services, or publicly available information.

What is claimed is:

1. A method comprising:

obtaining, with at least one processor of a device, face tracking data associated with a user;

determining, with the at least one processor, a step cadence of the user based on the face tracking data;

determining, with the at least one processor, a speed of the user based on the step cadence and a stride length of the user;

obtaining, with the at least one processor, device motion data from at least one motion sensor of the device;

determining, with the at least one processor, a grade of a surface on which the user is walking or running based on at least one of the device motion data or the face tracking data; and

determining, with the at least one processor, an energy expenditure of the user based on the estimated speed, the estimated grade and a caloric expenditure model.

2. The method of claim **1**, further comprising:

capturing, with a camera of the device, video data of the user's face; and

generating, with the at least one processor, the face tracking data from the video data.

3. The method of claim **2**, wherein the device is a mobile phone and the camera is a front-facing camera of the mobile phone.

4. The method of claim **1**, further comprising:

correcting, with the at least one processor, the face tracking data to remove vertical face motion due to the user nodding their head.

5. The method of claim **1**, wherein determining, with the at least one processor, the step cadence of the user based on the face tracking data further comprises:

extracting features indicative of a step from a window of the face tracking data; and

computing the step cadence based on the extracted features.

6. The method of claim **5**, wherein the features include at least one of the following features: 1) one period in vertical displacement and a half a period of horizontal displacement; 2) one horizontal velocity cusp and vertical velocity cusp within each step; 3) the horizontal and vertical velocity intersect near a time of a foot strike where the user's foot is touching the ground; or 4) the horizontal velocity, vertical velocity and vertical displacement amplitudes exceed specified thresholds.

7. The method of claim **1**, wherein determining the grade of the surface on which the user is walking or running based on at least one of the device motion data or the face tracking data, further comprises:

tracking a displacement envelope of a vertical axis of a face centered reference frame;

responsive to the envelope changing, estimating the grade of the surface based on the face tracking data; and

responsive to the envelope not changing, determining the grade of the surface based on device motion data output by a motion sensor of the device.

8. The method of claim **1**, further comprising:

computing, with the at least one processor, an uncalibrated stride length of the user based at least in part on a height of the user;

computing, with the at least one processor, an uncalibrated distance by multiplying the step cadence and the uncalibrated stride length;

computing, with the at least one processor, a calibration factor by dividing a truth distance by the uncalibrated distance, and then multiplying the uncalibrated stride length by the calibration factor to get a calibrated stride length; and

computing, with the at least one processor, the speed of the user by multiplying the step cadence by the calibrated stride length.

9. The method of claim **8**, wherein the truth distance is obtained or derived from a global navigation satellite system (GNSS) receiver.

10. A system comprising:

at least one processor;

memory storing instructions that when executed by the at least one processor, cause the at least one processor to perform operations comprising:

obtaining face tracking data associated with a user;

determining a step cadence of the user based on the face tracking data;

determining a speed of the user based on the step cadence and a stride length of the user;

obtaining device motion data from at least one motion sensor of the device;

determining a grade of a surface on which the user is walking or running based on at least one of the device motion data or the face tracking data; and

determining an energy expenditure of the user based on the estimated speed, the estimated grade and a caloric expenditure model.

11. The system of claim **10**, wherein the operations further comprise:

capturing, with a camera of the device, video data of the user's face; and

generating, with the at least one processor, the face tracking data from the video data.

12. The system of claim **11**, wherein the device is a mobile phone and the camera is a front-facing camera of the mobile phone.

13. The system of claim **10**, wherein the operations further comprise:

correcting, with the at least one processor, the face tracking data to remove face motion caused by the user nodding their head.

14. The system of claim **10**, wherein determining the step cadence of the user based on the face tracking data further comprises:

extracting features indicative of a step from a window of the face tracking data; and

computing the step cadence based on the extracted features.

15. The system of claim **14**, wherein the features include at least one of the following features: 1) one period in vertical displacement and a half a period of horizontal displacement; 2) one horizontal velocity cusp and vertical velocity cusp within each step; 3) the horizontal and vertical velocity intersect near a time of a foot strike where the user's foot is touching the ground; or 4) the horizontal velocity, vertical velocity and vertical displacement amplitudes exceed specified thresholds.

16. The system of claim **10**, wherein determining the grade of the surface on which the user is walking or running based on at least one of the device motion data or the face tracking data, further comprises:

tracking a displacement envelope of a vertical axis of a face centered reference frame;

responsive to the envelope changing, estimating the grade of the surface based on the face tracking data; and

responsive to the envelope not changing, determining the grade of the surface based on device motion data output by a motion sensor of the device.

17. The system of claim **10**, wherein the operations further comprise:

computing an uncalibrated stride length of the user based at least in part on a height of the user;

computing an uncalibrated distance by multiplying the step cadence and the uncalibrated stride length;

computing a calibration factor by dividing a truth distance by the uncalibrated distance, and then multiplying the uncalibrated stride length by the calibration factor to get a calibrated stride length; and

computing the speed of the user by multiplying the step cadence by the calibrated stride length.

18. The system of claim **17**, wherein the truth distance is obtained or derived from a global navigation satellite system (GNSS) receiver.

19. A non-transitory, computer-readable storage medium having stored thereon instructions, that when executed by at least one processor, causes the at least one processor to perform operations comprising:

obtaining face tracking data associated with a user;

determining a step cadence of the user based on the face tracking data;

determining a speed of the user based on the step cadence and a stride length of the user;

obtaining device motion data from at least one motion sensor of the device;

determining a grade of a surface on which the user is walking or running based on at least one of the device motion data or the face tracking data; and

determining an energy expenditure of the user based on the estimated speed, the estimated grade and a caloric expenditure model.

20. The non-transitory, computer-readable storage medium of claim **19**, wherein determining the step cadence of the user based on the face tracking data further comprises:

extracting features indicative of a step from a window of the face tracking data; and

computing the step cadence based on the extracted features.

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