

(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(19) World Intellectual Property
Organization
International Bureau



(10) International Publication Number
WO 2025/226824 A1

(43) International Publication Date
30 October 2025 (30.10.2025)

(51) International Patent Classification:

A61B 5/103 (2006.01) *G01L 1/18* (2006.01)
G01L 1/14 (2006.01) *A61B 5/11* (2006.01)
G01L 1/16 (2006.01)

(21) International Application Number:

PCT/US2025/025982

(22) International Filing Date:

23 April 2025 (23.04.2025)

(25) Filing Language:

English

(26) Publication Language:

English

(30) Priority Data:

63/637,539 23 April 2024 (23.04.2024) US

(71) Applicant: **YALE UNIVERSITY** [US/US]; Two Whitney Avenue, New Haven, CT 06510 (US).

(72) Inventors: **GAO, Joshua**; c/o Yale Ventures, 101 College Street, Suite 200, New Haven, CT 06519 (US). **WILEN, Lawrence**; c/o Yale Ventures, 101 College Street, Suite 200, New Haven, CT 06519 (US).

(74) Agent: **ABDULHAY, Ali, G.** et al.; Riverside Law, LLP, 175 Strafford Ave Ste 100, Wayne, PA 19087 (US).

(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, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UY, 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,

(54) Title: FORCE SENSORS FOR MOTION ASSESSMENT

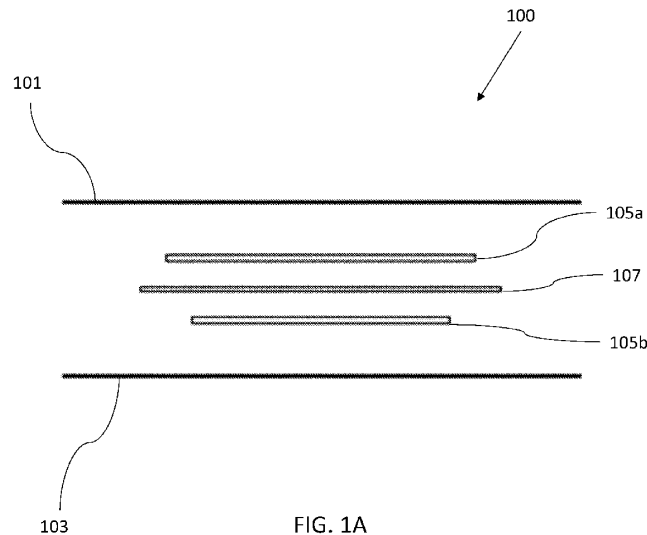


FIG. 1A

(57) Abstract: A force measuring mat may include a bottom layer; at least first and second force measuring sensors positioned over the bottom layer, where each may include: a bottom conducting layer; a force sensitive material positioned over the bottom conducting layer; a top conducting layer positioned over the force sensitive material; and a top layer positioned over the at least first and second force measuring sensors, fixedly attached to the bottom layer.

[Continued on next page]

WO 2025/226824 A1

WO 2025/226824 A1 

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))*

FORCE SENSORS FOR MOTION ASSESSMENT

CROSS-REFERENCE TO REPLATED APPLICATIONS

[0001] This application claims priority to U.S. Provisional Application No. 63/637,539 filed on April 23, 2024, incorporated herein by reference in its entirety.

BACKGROUND OF THE INVENTION

[0002] In the case of high-performance athletics teams, data is heavily relied upon to record an athlete's progress, identify their weaknesses, compare them against other athletes, and overall, optimize training and performance. Used properly, data can be a core part of a team's success and data's role in the industry has been ever evolving. Traditionally, easily observable metrics like an athlete's maximum jump height or maximum bench press weight were commonly measured; however recently, technologies like Global Positioning System (GPS) and Inertial Measurement Units (IMUs), originally developed for adjacent industries, have made their way into the gym to generate new, more comprehensive sets of athletic data.

[0003] Force plates, which have traditionally been used in science labs to gather precise weight data, have been commercialized by sports equipment companies to quantify data surrounding an athlete's jumping abilities. Force plate technology is commonly used by National Basketball Association (NBA) teams and is becoming more popular within the National Collegiate Athletic Association (NCAA) and other divisions. Some players use force plates on a daily basis at the beginning of a training session, and data measured from them often dictate what types of drills and activities athletes perform for the remainder of their training session.

[0004] However, use of force plates is not feasible for drills that test an athlete's ability to execute a Change of Direction ("CoD") or lateral agility because of their 1) inadequacy for withstanding shear forces, 2) substantial weight, and 3) tall and wide form factor. Generally speaking, force plates are designed for measurements at one location in space, and based on 3), would not be used for lateral motion assessment due to an inherent risk for injury. Even if this

issue could be mitigated by use of sensor plates embedded in a raised platform, the result would be unsuitably heavy, unwieldy, and very expensive.

[0005] Moreover, in a real game setting, athletes often perform movements that have lateral movement associated with them. This means that force plates' unsuitability to record CoD movements prevent them from being used to directly measure many movements that an athlete would make in a game. Currently, force plates are used in the training room to measure controlled, vertical hops.

[0006] Accordingly, the art is lacking a solution for athletes to directly measure force, speed, and accuracy data for game-realistic CoD movements and/or lateral movement.

SUMMARY OF THE INVENTION

[0007] Some embodiments of the invention disclosed herein are set forth below, and any combination of these embodiments (or portions thereof) may be made to define another embodiment.

[0008] In some aspects, a device for measuring force is described. A force measuring mat may include a bottom layer; at least first and second force measuring sensors positioned over the bottom layer, where each may include: a bottom conducting layer; a force sensitive material positioned over the bottom conducting layer; a top conducting layer positioned over the force sensitive material; and a top layer positioned over the at least first and second force measuring sensors, fixedly attached to the bottom layer.

[0009] In some embodiments, the force measuring mat may further include at least two pockets encasing the at least two force resistant sensors between the top layer and the bottom layer, wherein the at least two pockets may be formed by adhering a part of the top layer to a part of the bottom layer.

[0010] In some embodiments, the force measuring mat may further include at least two pockets encasing the at least two force resistant sensors between the top layer and the bottom layer, wherein the at least two pockets may be formed by sewing a part of the top layer to a part of the bottom layer.

[0011] In some embodiments, the force measuring mat may have each of the first and second force measuring sensors laminated. In some embodiments, the force measuring mat may have each of the laminated first and second force measuring sensors affixed to a portion of the top and bottom layer with adhesive.

[0012] In some embodiments, the force measuring mat may have the top layer and the bottom layer fixedly attached to one another via sewing or corrosive bonding.

[0013] In some embodiments, the force measuring mat may have the first force measuring sensor laterally displaced from the second force measuring sensor.

[0014] In some embodiments, the force measuring mat may include a set of contact wires which may include at least first and second top contact wires, electrically connected to the top conducting layer of the first and second force measuring sensors; and at least first and second bottom contact wires, electrically connected to the bottom conducting layers of the first and second force measuring sensors; wherein each contact wire of the set of contact wires extends to an outer edge of the force measuring mat.

[0015] In some embodiments, the force measuring mat may have each contact wire of the set of contact wires flat.

[0016] In some embodiments, the force measuring mat may have each contact wire of the set of contact wires comprising textile material.

[0017] In some embodiments, the force measuring mat may have the top conducting layer of the first force measuring sensor wider than the bottom conducting layer of the first force measuring sensor.

[0018] In some embodiments, the force measuring mat may have force sensitive material of the first force measuring sensor wider than the top conducting layer of the first force measuring sensor.

[0019] In some aspects, also described is a system for measuring force. A system may include: a user interface; a processor communicatively connected to the user interface; and a force measuring mat communicatively connected to the processor, comprising: at least two force

measuring sensors each comprising: top and bottom conducting layers; and a force sensitive material positioned between the two conducting layers; and a set of contact wires comprising top and bottom contact wires electrically connected at a first end to each of the top and bottom conducting layers of each of the at least two force measuring sensors, and communicatively connected at a second end to the processor; and a non-transitory computer-readable medium with instructions stored thereon, which when executed by the processor, perform steps comprising: collecting and recording data from the at least two force measurement sensors; calculating a change in pressure from low to high based on the recorded data from a first force measurement sensor of the at least two force measurement sensors; calculating a change in pressure from high to low based on the recorded data from the first force measurement sensor; and based on calculated magnitudes and timestamps of the changes in pressure, calculating at least one movement parameter of a user, selected from Synchronization Index, lateral movement, lateral velocity, rhythm, cadence, contact time, flight time, reactive strength index (RSI), moving RSI, rate of force development, propulsive phase duration, absorptive phase duration, stiffness, takeoff variability, jump height, accuracy distribution, bounce, stability, and fatigue index.

[0020] In some aspects, also described is another system for measuring force. A system may include: a user interface; one or more processors; a memory storing instructions that when executed by the one or more processors causes the one or more processors to perform operations; and a mat that may include: at least two force resistant sensors each comprising: two conducting layers; and force sensitive material placed between the two conducting layers; wherein each of the two conducting layers for each of the at least two force resistant sensors have respective wires; wherein each of the respective two wires are operatively coupled to the one or more processors, wherein the user interface is operatively coupled to the one or more processors; wherein the operations comprise: receiving biometric data from the user interface to configure one or more programs; receiving a selected program from the one or more programs from the user interface; and collecting data based on the selected program, wherein the collected data is processed by a particular subroutine to determine a location of a hit on the mat.

[0021] In some embodiments, the system may include least two force sensors that may comprise at least three force sensors, wherein the subroutine may include triangulation to

determine a location of a hit on the mat based on reverberations surrounding the at least three force sensors.

[0022] In some embodiments, the system may include the subroutine comprising a sensor matrix routine configured to detect hits and nonhits.

[0023] In some embodiments, the system may include the subroutine comprising an array of elements, wherein one of the elements in the array corresponds to one of the at least two force resistant sensors.

[0024] In some embodiments, the system may include the collecting data comprising: comparing the array of elements against a part of the collected data, wherein the collected data is based on a signal from the one of the at least two force resistant sensors.

[0025] In some embodiments, the system may include the operations comprising: calculating at least one movement parameter of a user selected from synchronization index, lateral movement, lateral velocity, rhythm, cadence, contact time, flight time, reactive strength index, rate of force development, propulsive phase duration, absorptive phase duration, stiffness, takeoff variability, jump height, accuracy distribution, bounce, stability, and fatigue index based on calculated magnitudes and timestamps of the changes in pressure;

[0026] In some embodiments, the system may include: an analog to digital converter electrically connected to a first force measurement sensor of the at least two force measurement sensors via the set of wires, configured to provide digital representations of analog voltage values measured at the first force measurement sensor to the processor.

[0027] In some embodiments, the collected data is further processed by one or more machine learning algorithms operating at least in part with one or more neural networks, and the data is analyzed for trends and correlations to provide feedback to a user with the user interface. In some embodiments, the feedback comprises one or more recommendations for improving user performance. In some embodiments, the one or more recommendations comprise location of hit on mat, jump height, flight time, contact time, acceleration, rhythm and cadence.

[0028] In some embodiments, the system further comprises one or more cameras operatively coupled to the one or more processors, wherein the user interface displays a

representation of a user based on one or more images captured by the one or more cameras. In some embodiments, the user interface further displays a representation of the mat, wherein the representation comprises one or more locations of hits on the mat.

BRIEF DESCRIPTION OF THE DRAWINGS

[0029] The foregoing purposes and features, as well as other purposes and features, will become apparent with reference to the description and accompanying figures below, which are included to provide an understanding of the invention and constitute a part of the specification, in which like numerals represent like elements, and in which:

[0030] FIG. 1A is a side view of an exemplary force sensor showing an exemplary arrangement of electrodes.

[0031] FIG. 1B is a top view of the exemplary force sensor of FIG. 1A showing the size differences between the internal elements of the sensor.

[0032] FIG. 1C is a perspective view of the exemplary force sensor of FIG. 1A also showing the size differences between the internal elements of the sensor.

[0033] FIG. 2A shows an isometric view of an exemplary mat or enclosure with an exemplary arrangement of force sensors (i.e., Dot Drill format) where a top mat layer and a bottom mat layer enclose one or more force sensors and their respective wiring.

[0034] FIG. 2B shows a top view of an exemplary arrangement of force sensors highlighting the offset of the wiring between the top mat layer and bottom mat layer to prevent short circuits.

[0035] FIG. 3A is a diagram depicting an exemplary force sensing method wherein a user can interact, gather data, and view results with a front end (e.g., a user interface).

[0036] FIG. 3B is a diagram showing exemplary subroutines that may be executed with any disclosed methods for force sensing.

[0037] FIG. 4 is a diagram of an exemplary algorithm for processing data from force sensors for analysis.

[0038] FIG. 5 is a diagram of an exemplary computing device.

[0039] FIG. 6 is a diagram of an exemplary user interface (UI).

DETAILED DESCRIPTION OF THE INVENTION

[0040] It is to be understood that the figures and descriptions of the present invention have been simplified to illustrate elements that are relevant for a clearer comprehension of the present invention, while eliminating, for the purpose of clarity, many other elements found in systems and methods. Those of ordinary skill in the art may recognize that other elements and/or steps are desirable and/or required in implementing the present invention. However, because such elements and steps are well known in the art, and because they do not facilitate a better understanding of the present invention, a discussion of such elements and steps is not provided herein. The disclosure herein is directed to all such variations and modifications to such elements and methods known to those skilled in the art.

[0041] Unless otherwise specifically defined herein, all terms are to be given their broadest reasonable interpretation. This includes meanings implied from the specification as well as meanings understood by those skilled in the art and/or as defined in dictionaries, treatises, etc.

[0042] It is noted that, as used in the specification and the appended claims, the singular forms “a,” “an” and “the” include plural referents unless otherwise specified. The terms “includes” and/or “including,” when used in this specification, specify the presence of stated features, elements, and/or components, but do not preclude the presence or addition of one or more other features, steps, operations, elements, components, and/or groups thereof.

[0043] Relative terms such as “horizontal,” “vertical,” “up,” “down,” “top,” and “bottom” as well as derivatives thereof (e.g., “horizontally,” “downwardly,” “upwardly,” etc.) should be construed to refer to the orientation as then-described or as shown in the drawing figure under discussion. These relative terms are for convenience of description and normally are not intended to require a particular orientation in actuality. Terms including “inwardly” versus “outwardly,” “longitudinal” versus “lateral” and the like are to be interpreted relative to one another or relative to an axis of elongation, or an axis or center of rotation, as appropriate. Terms concerning

attachments, coupling and the like, such as “connected” and “interconnected,” refer to a relationship wherein structures are secured or attached to one another either directly or indirectly through intervening structures, as well as both movable or rigid attachments or relationships, unless expressly described otherwise. The phrases “operatively” or “operably connected” indicates such an attachment, coupling or connection that allows the pertinent structures to operate as intended by virtue of that relationship.

[0044] Reference throughout the specification to “exemplary”, “one embodiment”, “an embodiment” or “some embodiments” means that a particular feature, structure, or characteristic described in connection with at least one embodiment of the subject matter disclosed. Thus, the appearance of the phrases “in one embodiment”, “in an embodiment” or “in some embodiments” in various places throughout the specification is not necessarily referring to the same embodiment. Further, the particular features, structures or characteristics of “one embodiment”, “an embodiment” or “some embodiments” may be combined in any suitable manner with each other to form additional embodiments of such combinations. It is intended that embodiments of the disclosed subject matter cover modifications and variations thereof. Terms such as “first,” “second,” “third,” etc., merely identify one of a number of portions, components, steps, operations, functions, and/or points of reference as disclosed herein, and likewise do not necessarily limit embodiments of the present disclosure to any particular configuration or orientation.

[0045] Moreover, throughout this disclosure, various aspects can be presented in a range format. It should be understood that the description in range format is merely for convenience and brevity and should not be construed as an inflexible limitation on the scope of the disclosure. Accordingly, the description of a range should be considered to have specifically disclosed all the possible subranges as well as individual numerical values within that range. For example, description of a range such as from 1 to 6 should be considered to have specifically disclosed subranges such as from 1 to 3, from 1 to 4, from 1 to 5, from 2 to 4, from 2 to 6, from 3 to 6, etc., as well as individual numbers within that range, for example, 1, 2, 2.7, 3, 4, 5, 5.3, 6, and any whole and partial increments there between. This applies regardless of the breadth of the range. As used herein, the term “about” in reference to a measurable value, such as an amount, a temporal duration, and the like, is meant to encompass the specified value, and variations of plus

or minus 20%, plus or minus 10%, plus or minus 5%, plus or minus 1%, and plus or minus 0.1% of the specified value, as such variations are appropriate.

[0046] The terms “proximal,” “distal,” “anterior,” “posterior,” “medial,” “lateral,” “superior,” and “inferior” are defined by their standard usage indicating a directional term of reference. For example, “proximal” refers to a position that is situated nearer to the center of a body or point of attachment or interest, while “distal” refers to a position that is situated away from the center of the body or point of attachment or interest. In another example, “anterior” refers to the front of a body or structure, while “posterior” refers to the rear of a body or structure, in relation to a relative viewpoint. In another example, “medial” refers to the direction towards the midline of a body or structure, and “lateral” refers to the direction away from the midline of a body or structure. In some examples, “lateral” or “laterally” may refer to any sideways direction. In another example, “superior” refers to the top of a body or structure, while “inferior” refers to the bottom of a body or structure. It should be understood, however, that the directional term of reference may be interpreted within the context of a specific body or structure, such that a directional term referring to a location in the context of the reference body or structure may remain consistent as the orientation of the body or structure changes.

[0047] The terms “patient,” “subject,” “individual,” and the like are used interchangeably herein, and refer to any animal amenable to the systems, devices, and methods described herein. The patient, subject or individual may be a mammal, and in some instances, a human. In some embodiments, the subject is a sports athlete or player.

[0048] The term “force sensitive material” is defined as any material which changes its electrical properties when a mechanical force is applied.

[0049] Disclosed herein are various force sensors and related devices, systems and methods for measuring force and motion assessment, for example, lateral motion assessment. Being able to capture data about each individual step of a subject (e.g., an athlete or player) opens up a new realm of possibilities for the types of data and metrics that can be collected and used during practice/conditioning to enhance subject performance. The disclosed technology facilitates the determination of speed, accuracy, and intensity of lateral motion through the use of inexpensive, fast, robust, and low-profile force sensors with real time data collection. While raw electrical

signals generated by the force sensors may be 1) collected by a computing device (e.g., microcontroller or computer 500 disclosed herein), the data is simultaneously 2) analyzed and 3) presented to a user. The user can be the subject themselves, or another individual monitoring one or more subjects, such as a trainer. These three functions occur simultaneously with one another while the disclosed technology is being used. The presentation of data to the user can occur in various manners including visualization of the data on a screen interface, such as a user interface (UI), on a handheld, wearable, or computer monitor. The UI is designed to provide intuitive response and feedback to users. In some embodiments, a subset of sensors in a mat or enclosure may be used for simple training and assessment of lateral shifting of weight (a common defensive drill for basketball) or shifting from the back to front foot (as might be used to assess reaction and proper starting motion for a sprint).

[0050] Referring now to FIG. 1A, shown is a side view of an exemplary force sensor 100 comprising electrodes with at least one force sensitive material 107 positioned in between the electrodes. In some embodiments, the electrodes comprise a top electrode 105a and a bottom electrode 105b. In some embodiments, the top electrode 105a is an anode, and the bottom electrode 105b is the cathode. However, the top electrode 105a may alternatively be the cathode, and the bottom electrode 105b may be the anode. In some embodiments, the top electrode 105a may be larger than bottom electrode 105b in order to increase measurement precision when top electrode 105a is stacked on top of bottom electrode 105b, as seen from a top view of the force sensor 100 in FIG. 1B, or from the isometric view of the force sensor 100 in FIG. 1C. In some embodiments, the force sensor 100 comprises two conductive layers sandwiching a dielectric material. In some embodiments, force sensor 100 is configured as a force sensitive resistor (FSR). In some embodiments, force sensor 100 is configured as a capacitance sensor, or capacitance matrix. It should be appreciated that force sensor 100 may operatively connect to one or more computing devices, such as computer 500 disclosed herein.

[0051] In some embodiments, the electrodes may be formed in any size and shape and/or be configured to cover large areas. For example, in some embodiments, the electrodes may range in size from 1 cm to 5 m in width or diameter and length. In some embodiments, the sensors can be any shape to cover irregularly shaped surfaces (e.g., stairs or footsteps) and may be sized accordingly. In some embodiments, the electrodes are formed in one or more shapes selected

from round, circular, oblong, irregular, square, rectangular, polygonal, and any combinations thereof.

[0052] Alternatively, smaller electrodes can also be used. For example, in some embodiments, the electrodes may range in size from 1 mm to 3 cm in width or diameter and length. In some embodiments, each electrode has a thickness ranging between 0.01 mm and 1 cm. In some embodiments, each electrode has the same thickness, or different thicknesses. For small electrode sizes, manufacturing methods like screen printing can be used to produce the sensors accurately and efficiently. Other manufacturing methods may be used, including, but not limited to: electrodeposition, chemical vapor deposition, printing, roll pressing, and the like.

[0053] In some embodiments, force sensitive material 107 is sized larger than the size of the largest electrode (e.g., either 105a or 105b) to separate the cathode and anode in order to prevent a short-circuit between the electrodes. In some embodiments, the force sensitive material 107 is sized to be smaller than first electrode 105a but larger than second electrode 105b. In some embodiments, force sensitive material 107 is shaped similarly to the electrodes and can share similar dimensions. For example, in some embodiments, force sensitive material 107 comprises a width or diameter, and length, ranging between 1 mm and 5 m, and a thickness ranging between 0.01 mm and 3 cm. In some embodiments, the force sensitive material 107 is formed in one or more shapes selected from round, circular, oblong, irregular, square, rectangular, polygonal, and any combinations thereof.

[0054] In some embodiments, force sensitive material 107 comprises one or more materials selected from: pressure sensitive material, variable resistance sensor fabric, force sensitive resistor, dielectric material, compressible dielectric material, Velostat, carbon Velostat sensor, Linqstat, and Eeonyx, piezoelectrical materials, capacitive materials, rubber, silicone, compressible material, or other materials that exhibit force sensitive properties as would be appreciated by a person of ordinary skill in the art. For example, in some embodiments, force sensitive material 107 comprises Velostat which is a low cost material, thereby reducing the manufacturing complexity.

[0055] The force sensitive material 107 itself may not exhibit different electrical properties under mechanical load, but at least portions of force sensor 100 will have changing electrical

properties due to an experienced force. Namely, as the dielectric material (e.g., force sensitive material 107) is compressed and the dielectric material thickness is reduced, a total capacitance of force sensor 100 will decrease roughly according to a relationship:

[0056]
$$c = eA/d$$

Equation 1

[0057] where e is a dielectric permittivity coefficient, A is an overlapping area of the two electrodes 105a and 105b, and d is a distance between the electrodes 105a and 105b, or equivalently, a thickness of the force sensitive material 107. It should be appreciated that force sensitive material 107 changes resistivity when pressure is applied on or across the material. Selection of a force sensitive material 107 that exhibits linearity (constant spring coefficient) for loading forces typical to measuring human performance may be chosen and tailored for optimized results.

[0058] In some embodiments, top electrode 105a and bottom electrode 105b may comprise any electrode or electrode material known in the art, including textile-based circuitry as in the embodiments described below. In some embodiments, the electrodes comprise any suitably conductive materials, including but not limited to: copper, silver, silver chloride, gold, platinum, aluminum, carbon, graphite, graphene, conductive ink, alloys, and combinations thereof.

[0059] Carbon Velostat Sensors comprise a carbon matrix suspended within a plastic polymer. As the force applied on the material increases, quantum tunneling occurs across the carbon, allowing for electricity to flow through the material. The electric resistivity (Ω) of the material is a function of the force applied upon it, effectively making it a force sensitive resistor. In some embodiments, force sensor 100 comprises a force sensitive material 107 comprising one or more force sensitive resistors (e.g., carbon Velostat sensors) sandwiched between two conductive sheets (e.g., alternatively top electrode 105a and bottom electrode 105b) which are wired to circuitry and/or a computing device. In some embodiments, the force exerted on the force sensor 100 is measured with a voltage divider circuit that applies a 5V signal across a swatch of one or more force sensitive material 107 (e.g., Velostat) wired in series with a fixed resistor, and calculates the change in voltage of the circuit as resistance across the force sensitive material 107 changes depending on subject force output. In some embodiments, when a

dielectric material is used as the force sensitive material 107 (capacitive sensor and force detection method), a different electronics system than the voltage divider may be used to accurately measure changes in capacitance of the force sensor 100. For example, a Wheatstone bridge circuit, comparing the capacitances of the force sensor 100 against a pre-determined comparator capacitor may be used to measure changes in capacitance. Other techniques known in the art for measuring small capacitive changes may also be used with the disclosed sensors.

[0060] In some embodiments, force sensor 100 comprises one or more layers at least partially enclosing the electrodes (105a, 105b) and force sensitive material 107. In some embodiments, the one or more layers comprise a top layer 101 and a bottom layer 103. In some embodiment, the top layer 101 and/or bottom layer 103 may comprise one or more materials selected from flexible material, polymer, rubber, turf, fabric, canvas, rigid material, semi-rigid material, resilient material, hard material, porous material, non-porous material, a simulated material (e.g., starting line or gym floor) and any combinations thereof. In some embodiments, the one or more layers comprise hard surfaces serrated at locations to allow for localized force detection. For example, the bottom layer 103 may comprise rubber while the top layer 101 may comprise another material like turf. In the case of turf, or any of the aforementioned materials, the top surface of top layer 101 may be colored any color (e.g., green) and striped to simulate the look and feel of grass or any other surface like a football field. In some embodiments, any surfaces of the one or more layers may be patterned and/or colored with markers, graduations, rulers, stripes, numbers, letters, and logos, and/or embossed or debossed with any of the aforementioned.

[0061] In some embodiments, the force sensor 100 comprises a cluster of smaller force sensors positioned or arranged together in an area to allow for greater resolution of data. In some embodiments, the force sensor 100 comprises a cluster of anode/cathode arrangements provided that each of the adjacent anode/cathodes are adequately spaced to prevent short-circuiting. Additionally, the cluster of anode/cathode arrangements may each sandwich the force sensitive material 107 which may be a sheet across the anode/cathode arrangements. In some embodiments, force sensor 100 and/or the components thereof are configured as a capacitive matrix (e.g., a capacitive sensor) comprising a matrix grid operatively connected to a capacitance measurement circuit. In some embodiments, the matrix grid replaces the electrodes of force

sensor 100, and is layered on one or more surfaces of force sensitive material 107. However, it should be appreciated that any described portions or components of force sensor 100 may be used in conjunction with any disclosed capacitive sensor. In an exemplary capacitive measurement technique, the matrix grid may be used to measure capacitance at every intersection of the grid. Parallel traces (power or drive lines) can be driven with an AC signal, and another set of traces (measuring or sensing lines) orthogonal to these parallel traces may complete the capacitor. By scanning through the matrix, one drive line and one sensing line pair at a time, the capacitance at each intersection point can be independently measured.

[0062] Top layer 101 and/or bottom layer 103 may have any suitable thickness including a thickness ranging between 0.1 mm and 50 mm, or a thickness of less than 10 mm, less than 9 mm, less than 8 mm, less than 7 mm, less than 6 mm, less than 5 mm, less than 4 mm, less than 3 mm, less than 2 mm, or less than 1 mm. In some embodiments, top layer 101 and/or bottom layer 103 have a thickness of greater than 10 mm, greater than 15 mm, greater than 20 mm, or greater than 25 mm. The top layer 101 and bottom layer 101 may be adhered to each other, thereby creating a one or more protective pockets enveloping one or more force sensor 100, and function to hold the various components in place when the force sensor is being used. In some embodiments, an adhesive may be applied to all areas except specified “pockets” where one or more force sensor 100 are placed to ensure that the distance between the edge of either or both of the electrodes 105a and 105b and the adhesive is minimal, such that shear force (e.g. from the sensor assembly sliding around within the pocket) does not affect the sensor measurements. Thus, in some embodiments, the sizes of the one or more pockets are similar to the sizes of the one or more force sensor 100 to significantly arrest movement of the sensor in the pocket.

[0063] In some embodiments, the force sensor 100 may comprise two conducting or conductive layers (i.e., alternatively a top electrode 105a and/or bottom electrode 105b). The force sensitive material 107 (e.g., Velostat layer) between the two conducting layers may be encased in a separate flexible enclosure or mat, for example via lamination, such that adhesive can be applied to the enclosure of the force sensor 100 directly, and the encased force sensor may be directly adhered to one or both of the top layer 101 or bottom layer 103. In some embodiments, the enclosure can be sewn together, for example using a soft material such as rubber or another polymer. In some embodiments, the enclosure may be sewn with conductive

thread that acts as wiring for the circuitry of the mat. Other manufacturing methods may be used, including, but not limited to: gluing, sewing, weaving, lamination, chemical welding, chemical bonding, solvent welding, solvent bonding, and the like, and combinations thereof.

[0064] In some embodiments, top layer 101 and bottom layer 103 comprise rubber sheets that can be fused together or corrosively bonded on high traffic/sensitive areas like the edges of the enclosure or mat. In an alternative embodiment, injection molded plastic or some form of silicone may be positioned around the force sensors to create the enclosure and/or adhere the sensor to the enclosure. In some embodiments, force sensor 100 comprises three layers of rubber (or silicone, or any other compressible material) sheets. A middle layer may act as the force sensitive material 107 (e.g., dielectric material). In between a top layer and the middle layer and in between a bottom layer and the middle layer, the sensing and power lines may be wired to measure a deformation of the middle layer at a given X, Y coordinate. Knowing the deformation of the middle layer provides insight to the force applied.

[0065] Referring now to FIG. 1C, shown is an embodiment of a force sensor 100, which may be about 60 mm in diameter. The force sensor 100 seeks to collect data on live-game, realistic movements by measuring the 1) timing and 2) location, in addition to the 3) relative force output of movements made by a subject. From these three pieces of information, a multitude of values and indices quantifying metrics ranging from a player's speed to explosivity can be extrapolated. Specifically, moving reactive strength index (RSI) is an index that measures an athlete's ability to alter their force output direction. Traditionally RSI is calculated in the setting of a vertical jump where RSI is the height a player jumps divided by the time they remain in contact with the ground as they bounce. The disclosed sensors and devices allow for the measurement of the RSI in lateral movement settings (i.e., moving RSI). For example, backward cutting reactive strength of a basketball player can be measured by calculating the time it takes them to revert forward momentum to backward momentum as they try to stop quickly after a forward run. This could provide insight into a player's agility and RSI can now be measured for left/right/forward/backward cutting or continuously moving settings.

[0066] Referring now to FIG. 2A, shown is an isometric view of an exemplary mat or enclosure 200. Specifically, shown is an embodiment of the mat or enclosure 200 comprising one or more force sensors 100 in an exemplary arrangement (i.e., Dot Drill format) where a top layer

201 and a bottom layer 203 enclose one or more force sensors 100 with their respective wiring 205. The configuration or arrangement of force sensors 100 within the mat may be positioned for various other applications, including but not limited to: a classic training aid for CoD, plyometric, and footwork drills, to collect underlying data of the workout. In some embodiments, the one or more force sensors 100 are about 0.5 mm thick, and the enclosure 200 comprises 2 mm thick sheets of rubber for each of the top layer 201 and bottom layer 203 thereby making the enclosure thickness of enclosure 200 less than 5 mm. In some embodiments, a plurality of enclosure 200 may be operatively connected or linked, for example using a communication protocol like Bluetooth Low Energy (BLE), to a central processing unit (e.g. a handheld, a computer). By receiving data from each enclosure 200 simultaneously, a larger force sensitive area may be constructed. In some embodiments, the plurality of enclosure 200 may be linked together with custom central data receiving, processing, and sending hubs to amalgamize high amounts of data and create large surfaces.

[0067] In some embodiments, the mat or enclosure 200 may comprise one or more force sensors 100 arranged in a sensor matrix or grid such that, even if steps or misses were detected on unintended locations, the force may still be measured. For example, a sensor mat or enclosure 200 may have a matrix of the rows and columns of force sensors 100 arranged based on the size of each force sensor. In some embodiments, the structure of the grid may vary based on the size of the force sensors 100 with electrodes ranging in the dimensions as discussed above. However, the structure of the grid may also vary depending on the size of the mat or enclosure 200 with the size of the electrodes. In some embodiments, the structure of the grid may comprise, for example, between a 1x1 array and a 1000x1000 array; a 36x48 array; or 3x3 array, 3x4 array, 4x3 array, 4x4 array, 4x5 array, 5x4 array; or any array based on the size of the force sensors and the mat. For example, for smaller force sensors 100 with electrodes ranging between about 1 mm to 3 cm in diameter, it can be appreciated that the matrix or grid may comprise a 1000x1000 array of sensors. Alternatively, for larger force sensors with electrodes, it can be appreciated that the matrix or grid may comprise a smaller array of sensors such as 36x48.

[0068] In the case where the mat comprises a 1000x1000 array of sensors or a larger array of sensors, processing data speed may not be sufficient to process the large amount of input being sensed. With a higher-density array, it can be assumed that for any given step or impact on the

mat, multiple sensors may be triggered. Therefore, in some embodiments, rather than monitoring the entire array of sensors (e.g., 1000x1000) at each time index, a lower density of sensors or subset of sensors may be monitored at each time index. For example, one force sensor 100 may be continuously monitored for every two-hundred force sensor 100 while the others in between are on stand-by or dormant. In some embodiments, the subset of sensors being monitored is constant across all time indices, but in other embodiments, different subsets of sensors are monitored at different times. Such a configuration would decrease the processing requirements based on the hardware/software. In some embodiments, when an impact is detected at a given sensor, then the surrounding sensors become active and gather additional data (i.e., the surrounding sensors are no longer on stand-by). Other data transmission load-easing techniques may be used. For example, rather than encoding raw sensor values, a set of sensor delta values may be encoded to minimize data bytes required to store the information. Moving averages may be applied to the data, and other signal processing techniques (e.g. Fast Fourier Transform (FFT)) may be employed to minimize noise and decrease the likelihood of noise-related delta values from being transmitted.

[0069] In some embodiments, one or more force sensors 100 are each wired to a common computing device that measures voltage across each sensor independently. The timing and magnitude of force output across the network of sensors can be precisely recorded as the athlete moves from sensor to sensor as discussed below in FIG. 4. Previous knowledge of the location of the sensors is considered by the calculations made to elucidate data on CoD movements.

[0070] In some embodiment, the top layer 201 and/or bottom layer 203 of the enclosure or mat 200 may be made of rubber, or share any other materials or properties as detailed herein for top layer 101 and bottom layer 103 of force sensor 100. In the case of the dot drill format, the top layer 201 may be painted, for example including dots (not shown) approximately over and corresponding to each of the one or more force sensors 100. In some embodiments, dots may be painted or placed on the mat or enclosure 200 in a dot drill configuration, however the one or more force sensors 100 may be arranged in any pattern, such as in a sensor matrix as described above. In this way, force may still be measured using extrapolation even if the subject missed one or more particular dots. Top layer 201 and/or bottom layer 203 may have any suitable thickness including a thickness ranging between 0.1 mm and 50 mm, or a thickness of less than

10 mm, less than 9 mm, less than 8 mm, less than 7 mm, less than 6 mm, less than 5 mm, less than 4 mm, less than 3 mm, less than 2 mm, or less than 1 mm. In some embodiments, top layer 201 and/or bottom layer 203 have a thickness of greater than 10 mm, greater than 15 mm, greater than 20 mm, or greater than 25 mm.

[0071] Any surfaces of enclosure 200 may comprise one or more materials or coatings such as non-slip materials, high friction materials, grippy materials, and the like. Further, any portions of enclosure 200 may comprise one or more adhesives or adhesive layers for joining the layers of the enclosure 200. For example, in some embodiments, the bottom surface of bottom layer 203 may be coated with or comprise one or materials that minimizes the movement of enclosure 200 and makes the bottom layer 203 high friction and/or slip resistant. Additionally, the top side of the bottom layer 203 can be coated an adhesive that binds it with the top layer 201. In some embodiments, any portions or components of force sensor 100 and/or enclosure 200 may comprise one or more fixing means for releasably attaching the sensor or enclosure to a surface (e.g., a gym floor) for preventing movement of the sensor or enclosure while being used. The one or more fixing means may comprise any of latches, straps, pins, stakes, adhesive, velcro, suction cups, and the like, and any combinations thereof. For example, in some embodiments, one or more fixing means are attached to bottom layers 103 or 203 for preventing movement of the respective sensor or enclosure.

[0072] In some embodiments, wiring 205 may be made from a textile or fabric with embedded conductive particles to maintain flexibility/pliability and a thin profile or flat profile for the mat or enclosure 200. For example, in some embodiments, stranded wire, 24 AWG, may be used. In some embodiment, the wires may be about 3 mm wide, or ranging between 0.1 mm and 30 mm wide. In some embodiments, flexible and impact resistance wiring is used. In some embodiments, flat fabric strips comprising embedded copper and/or silver may be used for wiring instead of traditional round wiring. These fabric strips are shear-force resistant, flexible, and fatigue resistant, which is particularly useful in a flexible or soft mat or enclosure 200 format (e.g., rubber) when force is applied to the mat. In some embodiments, printed circuits, like those of flex printed circuit boards (PCBs) or other soft sensor designs, may be used with any disclosed sensor or device. Any disclosed wires, circuits, sensors may be at least partially

enclosed in one or more insulating materials, for example a non-conductive material or a shielding material.

[0073] Referring now to FIG. 2B, shown is a top view of mat or enclosure 200. FIG. 2B shows a top view of force sensor 100 and wiring 205a and 205b, which in some embodiments, do not overlap as shown. That is, wiring 205a may not overlap with wiring 205b to prevent an electrical shortage, especially in embodiments where the mat or enclosure 200 is highly flexible. In some embodiment, the wiring 205 may be flat as discussed above. In the case of the wiring 205 being flat, the end of the wiring 206 may be converted to traditional rounded wiring and may be wired out of the mat and into a computing device. For example, end of the wiring 206 may include a connection point where wiring 205 is pulled out from the rubber mat enclosure and then traditional wires are soldered to the textile-based wiring and wrapped in a nautilus spiral shape to protect the soldered connection to create slack resistive to damage on the connection point during pulling of the cable or flexion of the mat or enclosure (e.g., in the case of the mat being made of rubber). In some embodiments, the wiring 205a and 205b may be configured to overlap on the x-y plane (defined by the top surface of the mat) but may be offset from one another on the z axis (defined as the thickness/height of the mat). With sufficient shielding, such a configuration could avoid shorting or crosstalk, and also reduce the surface area of the mat that was vulnerable to creating strain on the wiring.

[0074] In some embodiments, the computing device may be embedded within the mat or enclosure 200, and the wiring 205, which may be flat, may be wired into the computing device. In such a case, the computing device may be a microcontroller. In another embodiment, the wiring may be connected to a wireless device that may connect to the computing device (e.g., microcontroller) such that forming an electrical connection between the one or more force sensors 100 and the outside of the mat is a nonissue. In some embodiments, enclosure 200 comprises a power source that is internal to the enclosure (a battery, a flat battery, a lithium ion battery) or may be connected to an external power source with a plug. In some embodiments, enclosure 200 comprises an external power source and computing device enclosed in a housing (such as in the size and shape of a power bank) that may be removably connected to the enclosure 200, wherein the computing device connects wirelessly to a handheld or second computing device. In some embodiments, each enclosure 200 and/or force sensor 100 may

comprise one or more sensors. The one or more sensors may comprise an inertial measurement unit (IMU) or accelerometer, or any sensor described for computer 500. In some embodiments, the data measured from the one or more sensors may be used to accommodate for movement of the enclosure 200 or sensor 100 during operation and during calculations of force sensor data to produce more accurate results.

[0075] Aspects of the present invention relate to a force sensing or sensor system. In some embodiments, a force sensing system may comprise any of the disclosed force sensors and/or devices (e.g., force sensor 100, enclosure 200) and one or more computing devices (e.g., computer 500). For example, in some embodiments, a force sensing system comprises one or more force sensors 100 operatively connected to one or more computing devices. In another embodiment, a force sensor system comprises one or more enclosures 200 operatively connected to one or more computing devices. In some embodiments, the force sensor system further comprises a user interface (UI) and/or graphical user interface (GUI), as discussed further herein. In some embodiments, the force sensor system may comprise an external housing that contains a computer and a power source, wherein a UI is configured on a portion of the housing comprising one or more LCD screens displaying data and/or results measured from the force sensors and controlled with one or more input devices (e.g., buttons, switches).

[0076] Referring now to FIG. 3A, shown is a flow chart showing a method 300 of how a user may interact with a front end (e.g., UI) through an input device (e.g., a touchscreen) and then gather data from the mat or enclosure 200, which may get pushed to the backend to be processed as discussed below in FIG. 4. Examples of front end and/or input devices include a mobile device, a handheld device, a television, a touch screen, a tablet, or any other suitable computing device. In step 301, the user may input biometric data such as height, weight and age. In step 302, the user may select one or more programs such as preprogrammed drills, or custom drills. The programs may be measured for 303a endurance, 303b change in direction, 303c plyometric, and/or 303d reaction and agility. In step 304, the program (such as a drill) is performed by the subject and data is collected. For example, the one or more force sensors 100 gather force data for every step taken by the subject, or lateral movement of the subject. For step 304, data collected may be processed by executing subroutines that may extrapolate location. For example, if a user does not directly hit or misses the force sensor on their step, the occurrence of their step

elsewhere on the mat or enclosure 200 may be determined by executing one or more subroutines. Exemplary subroutines are discussed herein and shown in FIG. 3B.

[0077] Referring now to FIG. 3B, shown are exemplary subroutines 304a which are defined as follows:

[0078] Expected Hits—the computing device can track the total number of expected hits that should be made in a pre-specified drill and compare it with the number of hits actually detected by the mat to determine how many force sensors were missed. The expected number of hits and actual number of hits measured by the device could be recorded for each sensor to determine which sensors were missed during the drill.

[0079] Sequence of Hits—the computing device may track the sequence of hits that it measures and compare this with a pre-input string of expected sensor hits. This analysis could be performed as the drill is performed and provide near-immediate feedback on misses rather than waiting for the entire drill to be finished to assess misses.

[0080] Sensor Matrix—the computing device may track hits and nonhits using large force sensors or a sensor matrix that covers the entire area of the mat. In this case, all steps, even missteps on unintended locations, may be tracked and measured, and in some embodiments the severity of deviations from the expected steps in the drill may be calculated.

[0081] Triangulation—the computing device may measure shock vibrations that reverberate through the material when the mat or enclosure is stepped on. Moreover, these reverberations may be detected by surrounding force sensors since one or more of the sensors may be bonded within the enclosure. As such, the origin of each shock may be triangulated by comparing the shock waves detected by sensors in different locations.

[0082] Artificial Intelligence (AI) Model – raw data received from the force sensors can be used to train an AI model that extrapolates what a user is doing on the mat. Raw data, or data more downstream in processing such as force sensor hits, can be used in conjunction with videos of users performing the drill, or user-provided data, to help the device intelligently understand how users are moving above the mat and provide predictions for subject progress and/or

recommendations for improving subject performance. Further description of AI as used with the disclosed sensors, devices and systems is discussed below.

[0083] Referring back now to FIG. 3A, in step 305, the user is able to view the results. The results may comprise 306a athletic profile, 306b previous trial, and/or 306c team profile. This may include some metrics measured related to power output or speed that can be measured with existing force plate technology. However, while data can be gathered for these metrics, the ability to measure force in CoD drills allows for variations of the existing metrics and the creation of new metrics and categories based on different data being measured. The following are examples of indices/metrics that are unique to what may be measured and displayed in Athletic Profile 306a:

[0084] Synchronization index – can measure how synchronized a player's movements are and whether their left/right feet are replicating a movement consistently; Lateral velocity – granularly assess lateral movement of a player during agility drills; Rhythm and Cadence – measure how consistently athletes are executing repeated movements and quantify their cadence, similar to how beats per minute (bpm) may be used to describe music; Contact time and flight time – measure how long an athlete is in contact with the ground vs. in the air (e.g., while jumping); Reactive Strength Index – traditionally used in the drop jump test to assess an athlete's ability to rapidly change the direction of force output and serves as a key indicator of an athlete's Change of Direction (CoD) ability; Stiffness – tendons and muscles used in a jump can be approximated as a spring. The spring constant is traditionally used to see how quickly one can rebound, where greater stiffness is desired; Takeoff Variability – comparing the time at which a person takes off for a jump on their left and right feet can elucidate any muscular or reactionary asymmetries.

[0085] Comparing takeoff times between subsequent jumps can elucidate information about an athlete's rhythm or tempo development; Jump Height - center of mass displacement can be measured using flight time information gathered by the mat; Accuracy Distribution – measures how precise an athlete is with their foot placement in high-speed scenarios as accuracy in greater pace drills is desired; Bounce/Stability – oftentimes, poor balance can yield a hopping/bouncing pattern during the drop jump where a "stutter step" is performed to regain stability. Ideally, these are eliminated; and Fatigue Index – each above metric can be compared over a number of

repetitions to quantify fatigue and data points to consider are speed and accuracy over a period of time. Exemplary drills or practice motions are disclosed herein, but any drill or practice motion known by one of ordinary level of skill in the art may be measured or assessed with the disclosed technology. In some embodiments, the disclosed technology can be used to measure and assess sports drills, basketball defensive drills, lateral shifting of weight, sprint starting reaction, sprint starting motion, shifting from back to front of foot, and the like.

[0086] Referring now to FIG. 4, an exemplary algorithm 400 for raw data processing is shown. A raw voltage signal generated from the one or more force sensors 100 enters the computing device when the drill is performed in step 304 of method 300, and the data is digitized by the onboard digital to analog convertor (DAC) into a stream of numbers that describe the measured pressure on the sensors (inversely related to the voltage), which may include some noise. After the data is collected in step 401, this data may be recorded in step 402 for subsequent study in detail of many aspects of the timing and intensity of the forces on the sensors. In step 403 a change in pressure across a threshold is queried and may register a hit 405, wherein a 406 change in threshold may occur. Step 407 comprises prompting or querying for change in pressure across a threshold, with a 408 registered release and a 409 change in threshold. When timing and location are most critical, the data is processed by the computing device so that it can be effectively used for further analysis through the following stages: Pressure (stream of raw data) → Touch (stream of 1s or 0s) → Hit (flag) → Release (flag)

[0087] A touch may be determined by a Threshold Value of the pressure in step 403, potentially in conjunction with a series of derivative calculations and other timing calculations to filter for false triggers, for example a debouncing algorithm. If the stream of raw pressure data is below the Threshold Value, then the device registers that there is no touch on top of the sensor (denoted “0”), and when the raw data is above the threshold value, the device registers that there is a touch on top of the mat (denoted “1”).

[0088] Hits and Releases are moments when the touch transitions from a 0 to 1 or 1 to 0, respectively. Hits and Releases can be filtered to eliminate false triggers that may be due to signal bounce across the Threshold Value by setting a Lockout Time where the device will not detect a Hit on the same force sensor if a subsequent Hit on the same sensor is detected at a subsequent time that is faster than what is humanly possible to obtain. In some embodiments, the

lockout time may be encoded as a hard value from 0.1 to 4 seconds, which in past tests with athletes, have been found effective. Alternatively, since the speed and accuracy of movement may vary from athlete to athlete and may depend on the drill being performed, the lockout time may be calculated based on the average movement speed and accuracy while the athlete is performing the drill. Alternatively, the lockout time may be determined by measuring how long an athlete takes to move from one force sensor to another for a particular movement. Additionally, the average number of force sensors an athlete might miss in a given drill may also be measured. With this information, the shortest lockout time can be calculated (e.g., which is the time long enough to not prematurely end data collection during the drill).

[0089] In some embodiments, the force sensors 100 are sampled at a frequency which may in some embodiments be at least 10 Hz, at least 50 Hz, at least 100 Hz, at least 150 Hz, at least 200 Hz, at least 250 Hz, at least 300 Hz, or about 100 Hz, or about 150 Hz, or about 200 Hz. Each sensor may be scanned individually at this rate, or sensors may be scanned simultaneously. For any disclosed sensor grids, at least a portion of the grid may be scanned at a frame rate of at least 10 Hz, at least 50 Hz, at least 100 Hz, at least 150 Hz, at least 200 Hz, at least 250 Hz, at least 300 Hz, or about 100 Hz, or about 150 Hz, or about 200 Hz. Each grid may have at least 4 sensors, at least 25 sensors, at least 80 sensors, or about 5000 sensors. The system (e.g., the UI) then generates a force profile plot (e.g., a graph of force vs time), which can be analyzed to get the timing, location, and intensity of the user's motion which is important feedback for the users and, for example, coaches or trainers, and may be displayed later, as described in step 305 of method 300 above.

[0090] Rather than calculating the force output of a player by only measuring the load that they exert on top of a force sensor, a number of force sensors placed in different locations may be used in conjunction with the disclosed device to record the 1) timing, 2) location, and 3) relative force output of each step that an athlete makes. When a player's body posture is similar at both the moment they jump off the mat and then subsequently land, the positioning of the center of mass of their body relative to the positioning of their feet is also similar, meaning the vertical displacement of their center of mass (Jump Height) can be calculated by kinematics physics principles. Furthermore, by applying some additional mathematical and physics analysis

on the timing and location data derived by the device and the previous knowledge of a user's weight, the average force output of an athlete can be extrapolated through the following steps:

[0091] Timing → Ground-Contact/Flight Time → Jump Height (h) → Impulse (P) → Avg. Force (F). By knowing whether a user is on the mat or not at any given time, the time that they spend in the air during a jump (flight time) can be determined. For example, using kinematic equations, the user's jump height can be calculated and the user's velocities for takeoff and landing can be determined. Based on the user's velocities for takeoff and landing at one dot during a continuous series of hops, their impulse at that dot can be determined by calculating their change in momentum. Since impulse is also equal to force multiplied with time, their average force exerted at that dot can also be calculated.

[0092] By overlaying location data on top of this, another dimension of analysis and information is gathered, and the force data can now be seen in the context of various CoD movements. Combining the previously mentioned set of data (i.e., Timing, Ground-Contact/Flight Time, Jump Height, takeoff/landing velocity, Impulse (P), Avg. Force (F)) with the location that these pieces of data are gathered, additional metrics can be calculated. For example, by knowing 1) the flight time for an athlete travelling from one dot to another and 2) the location of the two dots, the lateral velocity of the athlete can be calculated. Stringing multiple instances of the athlete jumping from that particular dot to the other can yield multiple samples of the athlete's lateral velocity in that direction and thus generate generalized, representative values of what the athlete is capable of in terms of lateral motion.

[0093] When a high density of sensors are used such that a pressure distribution of an impact may be measured, the pressure distribution may be further analyzed to obtain more information. For example, a foot colliding with the ground heel first may elucidate improper running form, or, in a jump, if a person lands with the balls of their feet first, slowly absorbing impact until their heel strikes, information gathered may be corroborated with flight time data to better estimate center of mass vertical (i.e. jump height). Detecting patterns within the data may be difficult with deterministic algorithms. Statistical methods and machine learning methods, like convolutional neural networks, may be used to calculate desired parameters from the data.

[0094] Aspects of the present invention relate to force sensing methods using any of the disclosed sensors, systems and devices. In some embodiments, any of the disclosed methods may comprise at least some of the steps described in method 300 and/or algorithm 400 described above. Some or all of the steps of the disclosed methods may be at least operated in part with one or more computing devices, as discussed further herein. In some embodiments, a force sensing method comprises the steps of collecting and recording data from the at least two force measurement sensors, calculating a change in pressure from low to high based on the recorded data from a first force measurement sensor of the at least two force measurement sensors, calculating a change in pressure from high to low based on the recorded data from the first force measurement sensor, and based on calculated magnitudes and timestamps of the changes in pressure, calculating at least one movement parameter of a user, selected from Synchronization Index, Lateral Velocity, Lateral Movement, Rhythm, Cadence, Contact time, Flight time, RSI, Moving RSI, Rate of Force Development, Propulsive Phase Duration, Absorptive Phase Duration, Stiffness, Takeoff Variability, Jump Height, Accuracy Distribution, Bounce/stability, and Fatigue Index.

[0095] In some embodiments, the method further comprises the steps of receiving biometric data from the user interface to configure one or more programs, receiving a selected program from the one or more programs from the user interface, and collecting data based on the selected program, wherein the collected data is processed by a particular subroutine to determine a location of a hit on the mat. In some embodiments, the step of collecting data comprises comparing the array of elements against a part of the collected data, wherein the collected data is based on a signal from the one of the at least two force resistant sensors. In some embodiments, the step of calculating at least one movement parameter of a user is based on Synchronization Index, Lateral Velocity, Lateral Movement, Rhythm, Cadence, Contact time, Flight time, RSI, moving RSI Rate of Force Development, Propulsive Phase Duration, Absorptive Phase Duration, Stiffness, Takeoff Variability, Jump Height, Accuracy Distribution, Bounce/stability, and Fatigue Index based on calculated magnitudes and timestamps of the changes in pressure.

[0096] Accordingly, the disclosed systems, devices and sensors may comprise one or more computing systems or environments. A generic computing environment for at least partially operating any disclosed sensors, devices, systems or UIs is described herein. In some aspects of

the present invention, software executing the instructions provided herein may be stored on a non-transitory computer-readable medium, wherein the software performs some or all of the steps of the present invention when executed on a processor.

[0097] Aspects of the invention relate to algorithms executed in computer software. Though certain embodiments may be described as written in particular programming languages, or executed on particular operating systems or computing platforms, it is understood that the system and method of the present invention is not limited to any particular computing language, platform, or combination thereof. Software executing the algorithms described herein may be written in any programming language known in the art, compiled or interpreted, including but not limited to C, C++, C#, Objective-C, Java, JavaScript, MATLAB, Python, PHP, Perl, Ruby, or Visual Basic. It is further understood that elements of the present invention may be executed on any acceptable computing platform, including but not limited to a server, a cloud instance, a workstation, a thin client, a mobile device, an embedded microcontroller, a television, a computing chip capable of computing, or any other suitable computing device known in the art.

[0098] Parts of this invention are described as software running on a computing device. Though software described herein may be disclosed as operating on one particular computing device (e.g. a dedicated server or a workstation), it is understood in the art that software is intrinsically portable and that most software running on a dedicated server may also be run, for the purposes of the present invention, on any of a wide range of devices including desktop or mobile devices, laptops, tablets, smartphones, watches, wearable electronics or other wireless digital/cellular phones, televisions, cloud instances, embedded microcontrollers, thin client devices, or any other suitable computing device known in the art.

[0099] Similarly, parts of this invention are described as communicating over a variety of wireless or wired computer networks. For the purposes of this invention, the words “network”, “networked”, and “networking” are understood to encompass wired Ethernet, fiber optic connections, wireless connections including any of the various 802.11 standards, cellular WAN infrastructures such as 3G, 4G/LTE, or 5G networks, Bluetooth®, Bluetooth® Low Energy (BLE) or Zigbee® communication links, or any other method by which one electronic device is capable of communicating with another. In some embodiments, elements of the networked portion of the invention may be implemented over a Virtual Private Network (VPN).

[00100] FIG. 5 and the following discussion are intended to provide a brief, general description of a suitable computing environment in which the invention may be implemented. While the invention is described above in the general context of program modules that execute in conjunction with an application program that runs on an operating system on a computer, those skilled in the art will recognize that the invention may also be implemented in combination with other program modules.

[00101] Generally, program modules include routines, programs, components, data structures, and other types of structures that perform particular tasks or implement particular abstract data types. Moreover, those skilled in the art will appreciate that the invention may be practiced with other computer system configurations, including hand-held devices, multiprocessor systems, microprocessor-based or programmable consumer electronics, minicomputers, mainframe computers, and the like. The invention may also be practiced in distributed computing environments where tasks are performed by remote processing devices that are linked through a communications network. In a distributed computing environment, program modules may be located in both local and remote memory storage devices.

[00102] FIG. 5 depicts an illustrative computer architecture for a computer 500 for practicing the various embodiments of the invention. The computer architecture shown in FIG. 5 illustrates a conventional personal computer, including a central processing unit 550 ("CPU"), a system memory 505, including a random-access memory 510 ("RAM") and a read-only memory ("ROM") 515, and a system bus 535 that couples the system memory 505 to the CPU 550. A basic input/output system containing the basic routines that help to transfer information between elements within the computer, such as during startup, is stored in the ROM 515. The computer 500 further includes a storage device 520 for storing an operating system 525, application/program 530, and data.

[00103] The storage device 520 is connected to the CPU 550 through a storage controller (not shown) connected to the bus 535. The storage device 520 and its associated computer-readable media, provide non-volatile storage for the computer 500. Although the description of computer-readable media contained herein refers to a storage device, such as a hard disk or CD-ROM drive, it should be appreciated by those skilled in the art that computer-readable media can be any available media that can be accessed by the computer 500.

[00104] By way of example, and not to be limiting, computer-readable media may comprise computer storage media. Computer storage media includes volatile and non-volatile, removable and non-removable media implemented in any method or technology for storage of information such as computer-readable instructions, data structures, program modules or other data. Computer storage media includes, but is not limited to, RAM, ROM, EPROM, EEPROM, flash memory or other solid state memory technology, CD-ROM, DVD, or other optical storage, magnetic cassettes, magnetic tape, magnetic disk storage or other magnetic storage devices, or any other medium which can be used to store the desired information, and which can be accessed by the computer.

[00105] According to various embodiments of the invention, the computer 500 may operate in a networked environment using logical connections to remote computers through a network 540, such as TCP/IP network such as the Internet or an intranet. The computer 500 may connect to the network 540 through a network interface unit 545 connected to the bus 535. It should be appreciated that the network interface unit 545 may also be utilized to connect to other types of networks and remote computer systems.

[00106] The computer 500 may also include an input/output controller 555 for receiving and processing input from a number of input/output devices 560, including a keyboard, a mouse, a touchscreen, a camera, a microphone, a controller, a joystick, or other type of input device. Similarly, the input/output controller 555 may provide output to a display screen, a printer, a speaker, or other type of output device. The computer 500 can connect to the input/output device 560 via a wired connection including, but not limited to, fiber optic, ethernet, or copper wire or wireless means including, but not limited to, Bluetooth, Near-Field Communication (NFC), infrared, or other suitable wired or wireless connections.

[00107] As mentioned briefly above, a number of program modules and data files may be stored in the storage device 520 and RAM 510 of the computer 500, including an operating system 525 suitable for controlling the operation of a networked computer. The storage device 520 and RAM 510 may also store one or more applications/programs 530. In particular, the storage device 520 and RAM 510 may store an application/program 530 for providing a variety of functionalities to a user. For instance, the application/program 530 may comprise many types of programs such as a word processing application, a spreadsheet application, a desktop

publishing application, a database application, a gaming application, internet browsing application, electronic mail application, messaging application, and the like. According to an embodiment of the present invention, the application/program 530 comprises a multiple functionality software application for providing word processing functionality, slide presentation functionality, spreadsheet functionality, database functionality and the like. In some embodiments, computer 500 operates a software that produces a user interface (UI) or graphical user interface (GUI), as discussed herein and shown in FIG. 5.

[00108] The computer 500 in some embodiments can include a variety of sensors 565 for monitoring the environment surrounding and the environment internal to the computer 500. These sensors 565 can include a Global Positioning System (GPS) sensor, a photosensitive sensor, a camera, a gyroscope, a magnetometer, thermometer, a proximity sensor, an accelerometer, a force sensor (e.g., force sensor 100), a microphone, biometric sensor, barometer, humidity sensor, radiation sensor, or any other suitable sensor.

[00109] Discussed herein is an exemplary UI comprising a graphical user interface (GUI) for arranging and presenting any aspects of the disclosed systems and methods such as live imaging, augmented reality, subject data, force sensor data, and other information, results and analysis. In some embodiments, the GUI is produced to a wearable device, such as a set of smart-glasses or a smart watch worn by the subject. In some embodiments, the GUI displays real-time data overlaying imaging of the subject. In some embodiments, historical, real-time and/or predictive data is displayed with the GUI. In some embodiments, based on measured force sensor data, one or more results or outcomes for the subject may be calculated and presented in the GUI. In some embodiments, the GUI provides one or more recommendations for a subject to improve performance.

[00110] In some embodiments, any system, device, or sensor as disclosed herein may comprise a software producing the GUI for operating the system, device or sensor and viewing results or other information. Referring now to FIG. 6, shown is a diagram of an exemplary GUI that may comprise one or more screens or dashboards. FIG. 6 depicts an exemplary screen or dashboard 300 for the GUI comprising a navigation bar 310 and content area 320. In some embodiments, dashboard 300 provides means for configuring and viewing one or more profiles related to a subject or team. In some embodiments, dashboard 300 further comprises a search

tool 330 and drop down menu or selector 340 (e.g., for profiles, content and/or analytics). In some embodiments, dashboard 300 provides one or more tabs and/or lists with organized widgets, modules, alerts, graphs, and/or reports displayed in the content area 320 that provides force sensor data, plots, subject-related data and other metrics. In some embodiments, content area 320 displays data and analytics for a profile related to each subject or team.

[00111] The GUI is configured to display imaging, data and results of the disclosed sensors, devices, systems for real-time data analysis and prediction. This includes any imaging, live-imaging, subject data, imaging data and associated results as produced by the disclosed sensors, devices and systems. In some embodiments, the GUI can produce and save one or more profiles, each profile representative of a subject. In some embodiments, the GUI can produce and save one or more team profiles, each team profile representative of a grouping of players, a sports team, a university sports team, or a professional team or association. In some embodiments, the GUI shows live imaging of a subject. In some embodiments, the GUI shows an augmented reality, virtual reality, or mixed reality comprising the subject and environment. For example, the GUI may show a series of movements performed by the subject, wherein the movements are superimposed on one another for differentiation. The GUI may perform analytics of individual subjects, or teams, and provide comparisons to other subjects or teams.

[00112] The GUI can display and store any metrics or results for a subject or team. It should be appreciated that this information may be entered by a user or the subject, may be captured by the disclosed systems, devices and methods, and/or may generated with any disclosed systems and methods. Any information shown in the GUI may be uploaded to a portal or synced with a database. This information includes, but is not limited to, change of direction (CoD), lateral agility, lateral motion assessment, explosivity, power, power input, force, speed, and accuracy data (e.g., for game-realistic CoD movements and/or lateral movements), timing, ground-contact, flight time, jump height, takeoff velocity, lateral velocity, landing velocity, contact time, impulse (P), average force(F), assessment of lateral shifting of weight (a common defensive drill for basketball), shifting from the back to front foot, relative force output of movements made by a subject, reactive strength, reactive strength index (RSI), Moving RSI, left, right, forward, and backward cutting RSI, continuously moving RSI, endurance, plyometrics, reaction, agility, synchronization index, rhythm, cadence, stiffness, takeoff variability, accuracy distribution,

bounce, stability, fatigue index, rate of force development, propulsive phase duration, absorptive phase duration, and accuracy distribution. The GUI may further display previous trials of a subject or team, as well as projected trials for a subject or team. The GUI may further display a visualization of a force sensor 100 or enclosure 200 including live-imaging of the subject on the sensor or enclosure, or a visualization of the subject relative to the sensor or enclosure. In some embodiments, the GUI provides a visualization indicating where the subject is standing, movement of the subject, hit points, and recommendations to positions and directional movements for the subject relative to the sensor or enclosure.

[00113] Accordingly, any of the aforementioned data and information may be used with an AI module or machine learning algorithm operating on one or more computing devices. It should be appreciated that any information captured by the sensors or produced by the systems (including imaging of the subject) may be used to train one or more neural networks for providing analytics, feedback and recommendations for a subject or team based on performance. For example, in some embodiments, the computing devices enable deep learning, machine learning and/or artificial intelligence with various networks (e.g., neural networks) and algorithms for learning force sensor data, correlating the force sensor data to player and/or team data, and providing one or more predictions or recommendations for players or teams. Further, the neural network may be further trained on the specific drills or exercises related to the player or team and provide predictions and recommendations specific to the drill or exercise.

[00114] Aspects of the invention relate to machine learning executed on a computing device, for example computer 500 disclosed herein. In some embodiments, one or more neural networks may operate on at least one computing device (e.g., computer 500). The computing environment may employ various types of neural networks known in the art, including but not limited to feedforward neural networks (FNNs), convolutional neural networks (CNNs), recurrent neural networks (RNNs), transformer networks, autoencoders, generative adversarial networks (GANs), Radial Basis Function Networks (RBFNs), extreme learning machines (ELMs), quantum neural networks (QNNs), and deep neural networks (DNNs).

[00115] Machine learning is a branch of artificial intelligence (AI) that enables systems to learn and improve from experience without being explicitly programmed. Machine learning models analyze data sets to identify patterns and correlations, and then use those patterns to

make predictions or decisions. Any of the following details relating to machine learning may be used and or implemented with the systems, devices and methods of the present disclosure.

Machine learning models can generally be categorized into three primary types: supervised learning, unsupervised learning, and semi-supervised learning.

[00116] Supervised learning involves training a model using labeled datasets to classify data or predict outcomes accurately. As input data is fed into the model, the model adjusts its internal parameters (e.g., weights) to minimize prediction errors. Common methods used in supervised learning include neural networks, naïve Bayes classifiers, linear regression, logistic regression, random forests, and support vector machines (SVMs).

[00117] Classification is a common task in supervised learning, where data inputs are categorized into distinct classes. Classification models may include binary classifiers (e.g., spam vs. non-spam) and multi-class classifiers (e.g., identifying different species of animals). A decision tree is a widely used classification method that applies a sequence of "if-then" conditions to narrow down possible outcomes. Regression is another form of supervised learning where the output is a continuous variable rather than a discrete category. Linear regression predicts a continuous value based on a linear relationship between inputs and outputs, while logistic regression predicts categorical outcomes based on defined inputs.

[00118] Unsupervised learning involves analyzing unlabeled datasets to identify hidden patterns or groupings without human intervention. Principal component analysis (PCA) and singular value decomposition (SVD) are common techniques used to reduce data dimensionality and reveal underlying structures.

[00119] Clustering is a key unsupervised learning technique where data points are grouped based on shared features or proximity. K-means clustering is a widely used method where the number of clusters is defined by a variable "k," and the algorithm iteratively adjusts cluster centroids to minimize variance within each cluster. Other clustering methods include hierarchical clustering and probabilistic clustering.

[00120] Semi-supervised learning combines elements of both supervised and unsupervised learning. A model is initially trained using a smaller labeled dataset, which then guides the

classification and feature extraction from a larger unlabeled dataset. Semi-supervised learning is particularly useful when acquiring large amounts of labeled data is costly or impractical.

[00121] Multi-modal sensing machine learning involves combining data from multiple sensors (like cameras, microphones, and radar) to create a more complete and accurate understanding of the environment. This approach leverages the strengths of different sensors, allowing machines to "see" and "hear" the world in a way that's more like human perception, and improves the performance of machine learning models in tasks like object recognition, scene understanding, robot navigation.

[00122] Deep learning is a subfield of machine learning that uses neural networks with multiple hidden layers to process and analyze complex data. Neural networks mimic the structure and function of the human brain, comprising layers of interconnected nodes (neurons). Each neuron receives input data, applies a transformation based on assigned weights, and passes the result to the next layer.

[00123] A typical neural network consists of: input layer – receives raw data inputs; hidden layer(s) – applies mathematical transformations using weighted connections; and output layer – generates the final prediction or classification.

[00124] Convolutional neural networks (CNNs) are a type of neural network particularly well-suited for processing image and spatial data. CNNs use convolutional layers to extract spatial features from input data, pooling layers to reduce dimensionality, and fully connected layers to generate output predictions. Deep neural networks (DNNs) are composed of multiple hidden layers and are capable of learning complex patterns in large datasets. Recurrent neural networks (RNNs) are a type of deep learning network designed for sequential data, such as time series or natural language, where previous inputs influence future outputs. Long short-term memory (LSTM) networks are a specialized form of RNN that mitigates issues with long-term dependencies.

[00125] Generative Adversarial Networks (GANs) are a class of machine learning models in which two neural networks — a generator and a discriminator — are trained together in a competitive framework. The generator creates synthetic data (e.g., images, audio) from random noise, while the discriminator evaluates whether the generated data is real or fake. The generator

improves its output by trying to fool the discriminator, while the discriminator becomes better at distinguishing real data from generated data. This adversarial process drives both networks to improve over time, leading to the generation of highly realistic data.

[00126] Types of GANs include: Vanilla GAN – The original GAN model, where the generator and discriminator are trained using a minimax loss function. Deep Convolutional GAN (DCGAN) – Uses convolutional layers instead of fully connected layers, improving the quality of generated images. Conditional GAN (cGAN) – Conditions the generation process on class labels or other input data, enabling targeted generation (e.g., generating images of specific objects). Wasserstein GAN (WGAN) – Introduces the Wasserstein distance (Earth Mover's distance) as the loss function, which improves training stability and reduces mode collapse (when the generator produces limited variations of data). WGAN-GP (Wasserstein GAN with Gradient Penalty) – Improves WGAN by adding a gradient penalty to enforce the Lipschitz constraint, further enhancing training stability. CycleGAN – Used for unpaired image-to-image translation (e.g., converting paintings to photos) by enforcing consistency between the forward and backward transformations. StyleGAN – Generates high-resolution and highly detailed images using a style-based generator architecture, allowing greater control over features like face shape and texture. GANs are widely used in fields such as computer vision, natural language processing, and creative design, but they can be difficult to train due to instability and mode collapse — challenges that models like WGAN and WGAN-GP address effectively.

[00127] In some embodiments, the disclosed system may include an AI model trained using reinforcement learning, where an agent learns to make decisions through trial and error by interacting with an environment and receiving feedback in the form of rewards or penalties.

[00128] The disclosures of each and every patent, patent application, and publication cited herein are hereby incorporated herein by reference in their entirety. While this invention has been disclosed with reference to specific embodiments, it is apparent that other embodiments and variations of this invention may be devised by others skilled in the art without departing from the true spirit and scope of the invention. The appended claims are intended to be construed to include all such embodiments and equivalent variations.

CLAIMS

What is claimed is:

1. A force measuring mat comprising:
a bottom layer;
at least first and second force measuring sensors positioned over the bottom layer, each comprising:
a bottom conducting layer;
a force sensitive material positioned over the bottom conducting layer;
a top conducting layer positioned over the force sensitive material; and
a top layer positioned over the at least first and second force measuring sensors, fixedly attached to the bottom layer.
2. The force measuring mat of claim 1, further comprising at least two pockets encasing the at least first and second force measuring sensors between the top layer and the bottom layer, wherein the at least two pockets are formed by adhering a portion of the top layer to a portion of the bottom layer.
3. The force measuring mat of claim 1, further comprising at least two pockets encasing the at least first and second force measuring sensors between the top layer and the bottom layer, wherein the at least two pockets are formed by sewing a part of the top layer to a part of the bottom layer.
4. The force measuring mat of claim 1, wherein each of the first and second force measuring sensors is laminated.
5. The force measuring mat of claim 4, wherein the each of the laminated first and second force measuring sensors is affixed to a portion of the top and bottom layer with adhesive.

6. The force measuring mat of claim 1, wherein the top layer and the bottom layer are fixedly attached to one another via sewing or corrosive bonding.
7. The force measuring mat of claim 1, wherein the first force measuring sensor is laterally displaced from the second force measuring sensor.
8. The force measuring mat of claim 1, further comprising:
 - a set of contact wires, comprising:
 - at least first and second top contact wires, electrically connected to the top conducting layer of the first and second force measuring sensors; and
 - at least first and second bottom contact wires, electrically connected to the bottom conducting layers of the first and second force measuring sensors;
 - wherein each contact wire of the set of contact wires extends to an outer edge of the force measuring mat.
9. The force measuring mat of claim 8, wherein each contact wire of the set of contact wires is flat.
10. The force measuring mat of claim 8, wherein each contact wire of the set of contact wires comprises textile material.
11. The force measuring mat of claim 8, wherein the top conducting layer of the first force measuring sensor is wider than the bottom conducting layer of the first force measuring sensor.
12. The force measuring mat of claim 11, wherein the force sensitive material of the first force measuring sensor is wider than the top conducting layer of the first force measuring sensor.
13. A force sensing system comprising:
 - a user interface;
 - a processor communicatively connected to the user interface; and
 - a force measuring mat communicatively connected to the processor, comprising:

at least two force measuring sensors each comprising:
top and bottom conducting layers; and
a force sensitive material positioned between the two conducting layers;
and
a set of contact wires comprising top and bottom contact wires electrically connected at a first end to each of the top and bottom conducting layers of each of the at least two force measuring sensors, and communicatively connected at a second end to the processor; and
a non-transitory computer-readable medium with instructions stored thereon, which when executed by the processor, perform steps comprising:
collecting and recording data from the at least two force measurement sensors;
calculating a change in pressure from low to high based on the recorded data from a first force measurement sensor of the at least two force measurement sensors;
calculating a change in pressure from high to low based on the recorded data from the first force measurement sensor; and
based on calculated magnitudes and timestamps of the changes in pressure, calculating at least one movement parameter of a user, selected from change of direction (CoD), lateral movement, lateral velocity, synchronization index, lateral velocity, rhythm, cadence, contact time, flight time, reactive strength index (RSI), moving RSI, rate of force development, propulsive phase duration, absorptive phase duration, stiffness, takeoff Variability, jump height, accuracy distribution, bounce, stability, and fatigue index.

14. A force sensing system comprising:
a user interface;
one or more processors;
a memory storing instructions that when executed by the one or more processors causes the one or more processors to perform operations; and
a mat comprising:
at least two force sensors each comprising:
two conducting layers; and
force sensitive material placed between the two conducting layers;

wherein each of the two conducting layers for each of the at least two force sensors have respective wires;

wherein each of the respective two wires are operatively coupled to the one or more processors, wherein the user interface is operatively coupled to the one or more processors;

wherein the operations comprise:

receiving biometric data from the user interface to configure one or more programs;

receiving a selected program from the one or more programs from the user interface; and

collecting data based on the selected program, wherein the collected data is processed by a particular subroutine to determine a location of a hit on the mat.

15. The system of claim 14, wherein at least two force sensors comprise at least three force sensors, wherein the subroutine comprises triangulation to determine a location of a hit on the mat based on reverberations surrounding the at least three force sensors.

16. The system of claim 14, wherein the subroutine comprises a sensor matrix routine configured to detect hits and nonhits.

17. The system of claim 14, wherein the subroutine comprises an array of elements, wherein one of the elements in the array corresponds to one of the at least two force sensors.

18. The system of claim 17, wherein the collecting data comprises:
comparing the array of elements against a part of the collected data, wherein the collected data is based on a signal from the one of the at least two force sensors.

19. The system of claim 14, wherein the operations further comprise:
calculating at least one movement parameter of a user selected from CoD, synchronization index, lateral movement, lateral velocity, rhythm, cadence, contact time, flight time, RSI, moving RSI, rate of force development, propulsive phase duration, absorptive phase

duration, stiffness, takeoff variability, jump height, accuracy distribution, bounce, stability, and fatigue index based on calculated magnitudes and timestamps of the changes in pressure.

20. The system of claim 14, further comprising:

an analog to digital converter electrically connected to a first force measurement sensor of the at least two force measurement sensors via the set of wires, configured to provide digital representations of analog voltage values measured at the first force measurement sensor to the processor.

21. The system of claim 14, wherein the collected data is further processed by one or more machine learning algorithms operating at least in part with one or more neural networks, and the data is analyzed for trends and correlations to provide feedback to a user with the user interface.

22. The system of claim 21, wherein the feedback comprises one or more recommendations for improving user performance.

23. The system of claim 21, wherein the one or more recommendations comprise location of hit on mat, jump height, flight time, contact time, acceleration, rhythm and cadence.

24. The system of claim 14, wherein the system further comprises one or more a cameras operatively coupled to the one or more processors, wherein the user interface displays a representation of a user based on one or more images captured by the one or more cameras.

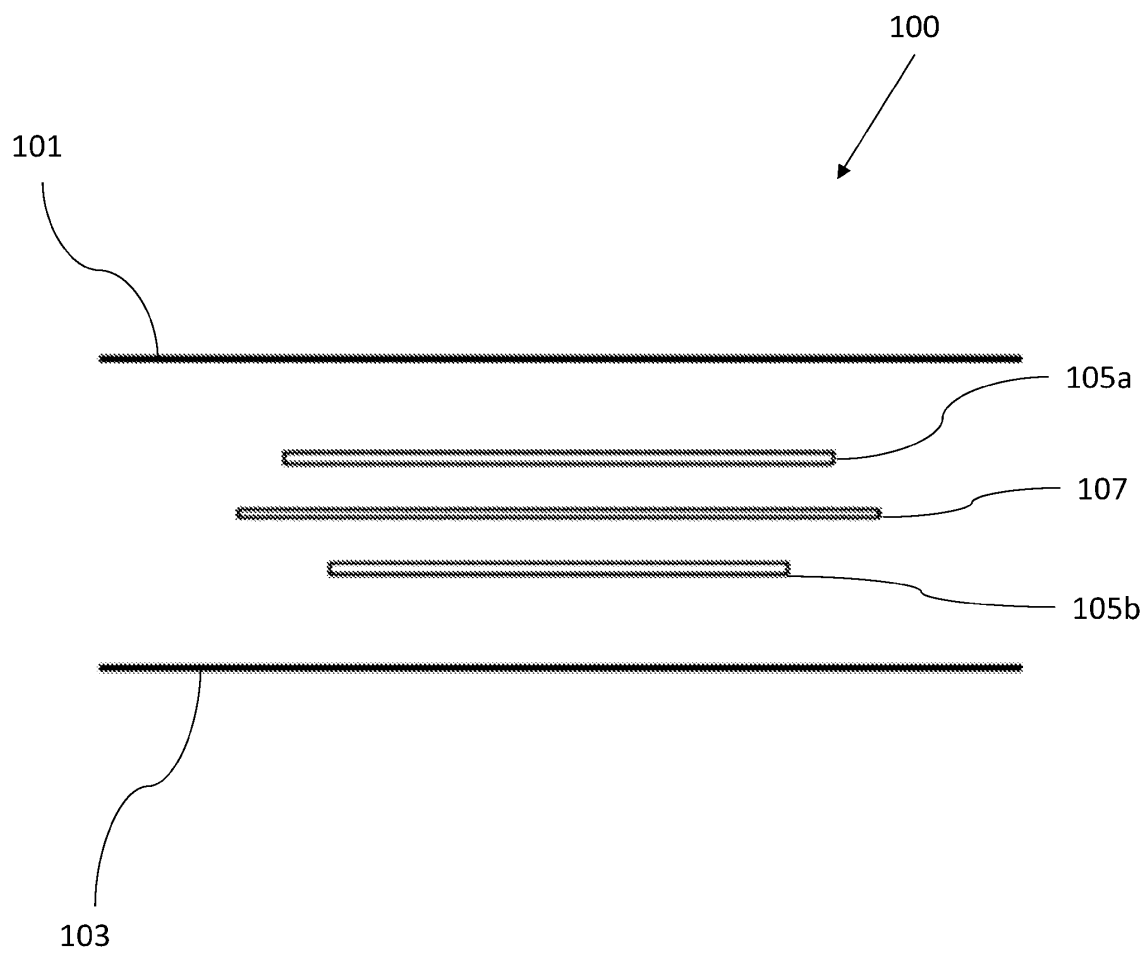


FIG. 1A

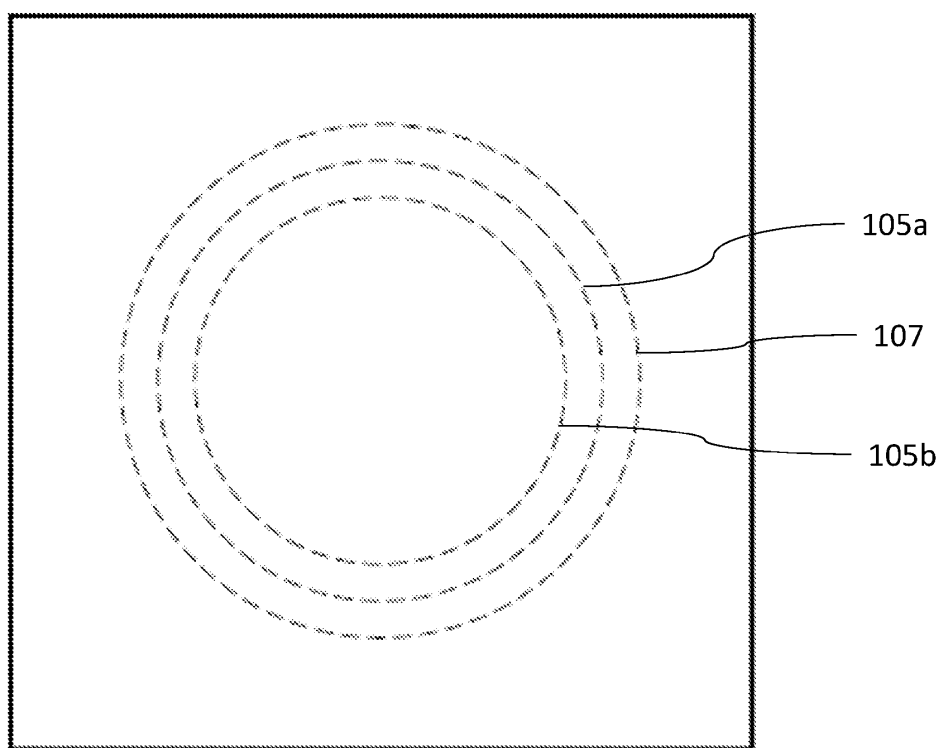


FIG. 1B

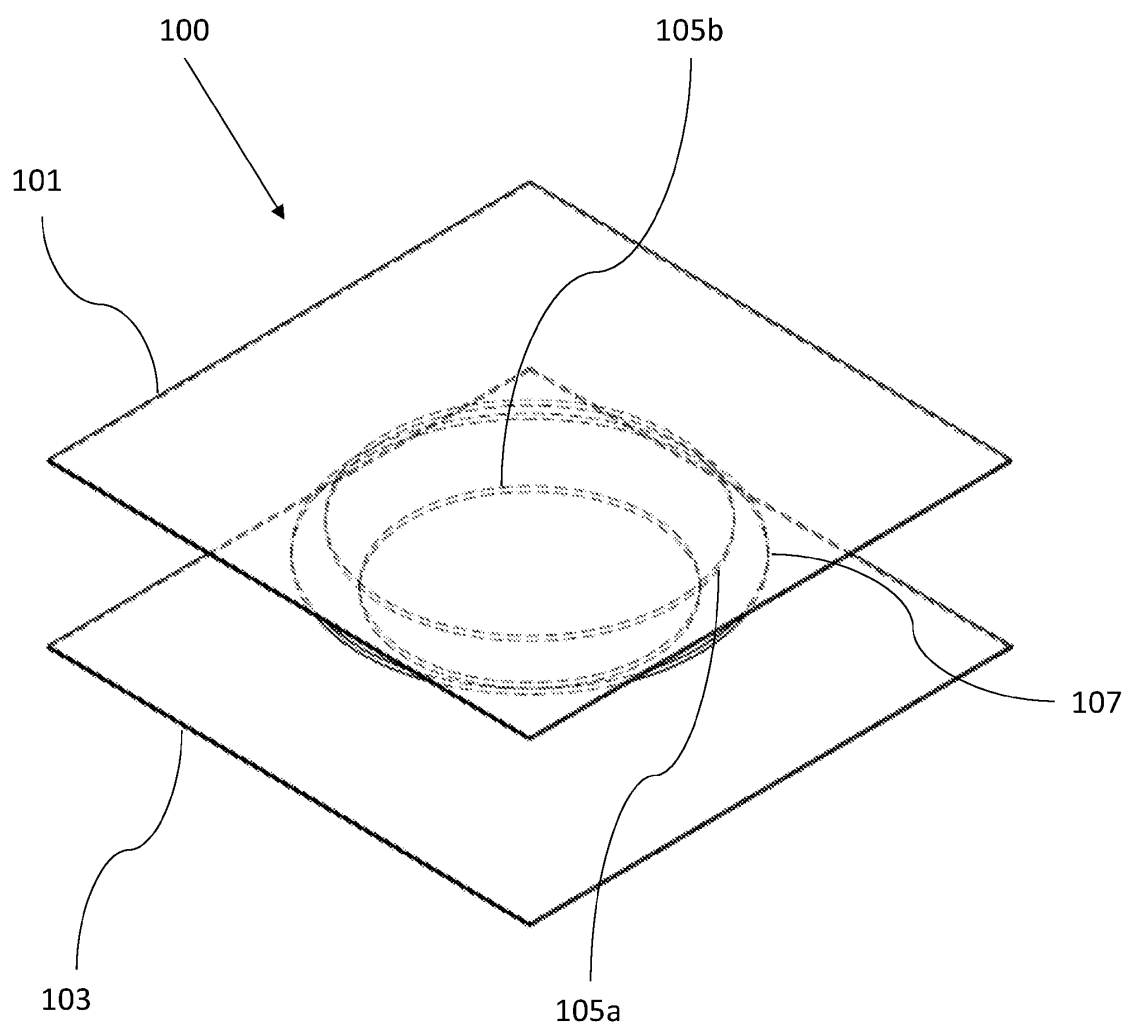


FIG. 1C

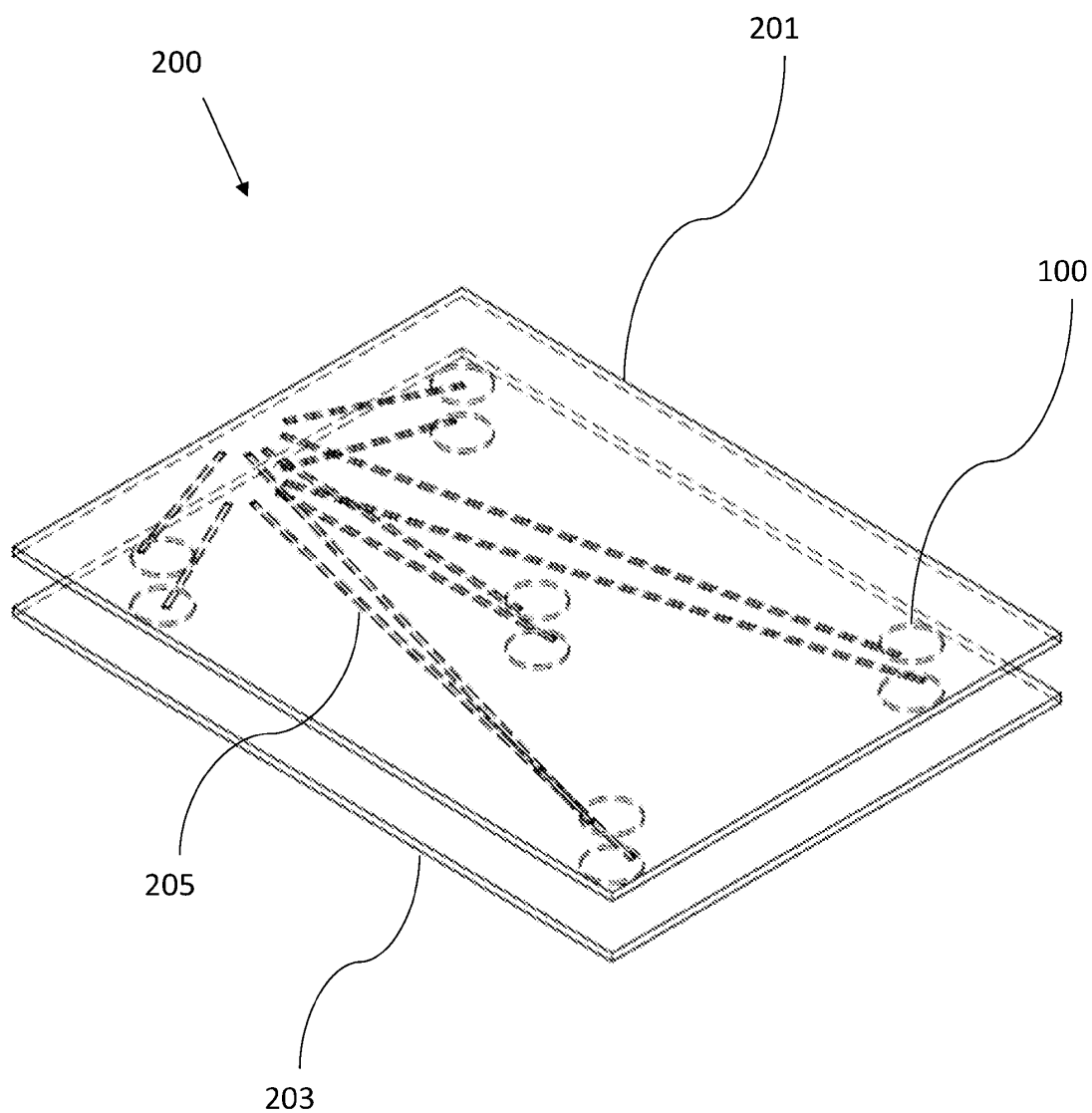


FIG. 2A

5/10

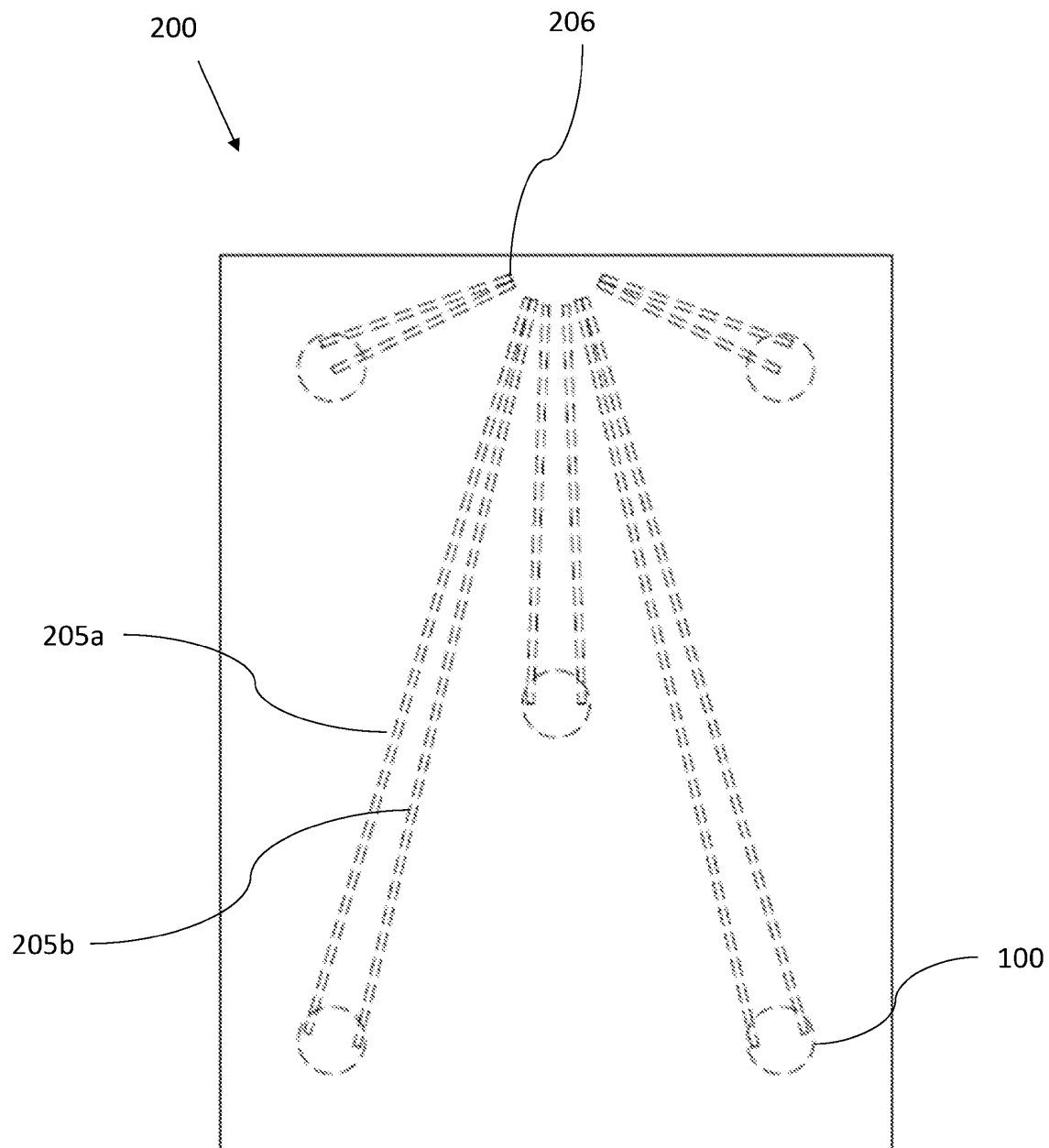


FIG. 2B

6/10

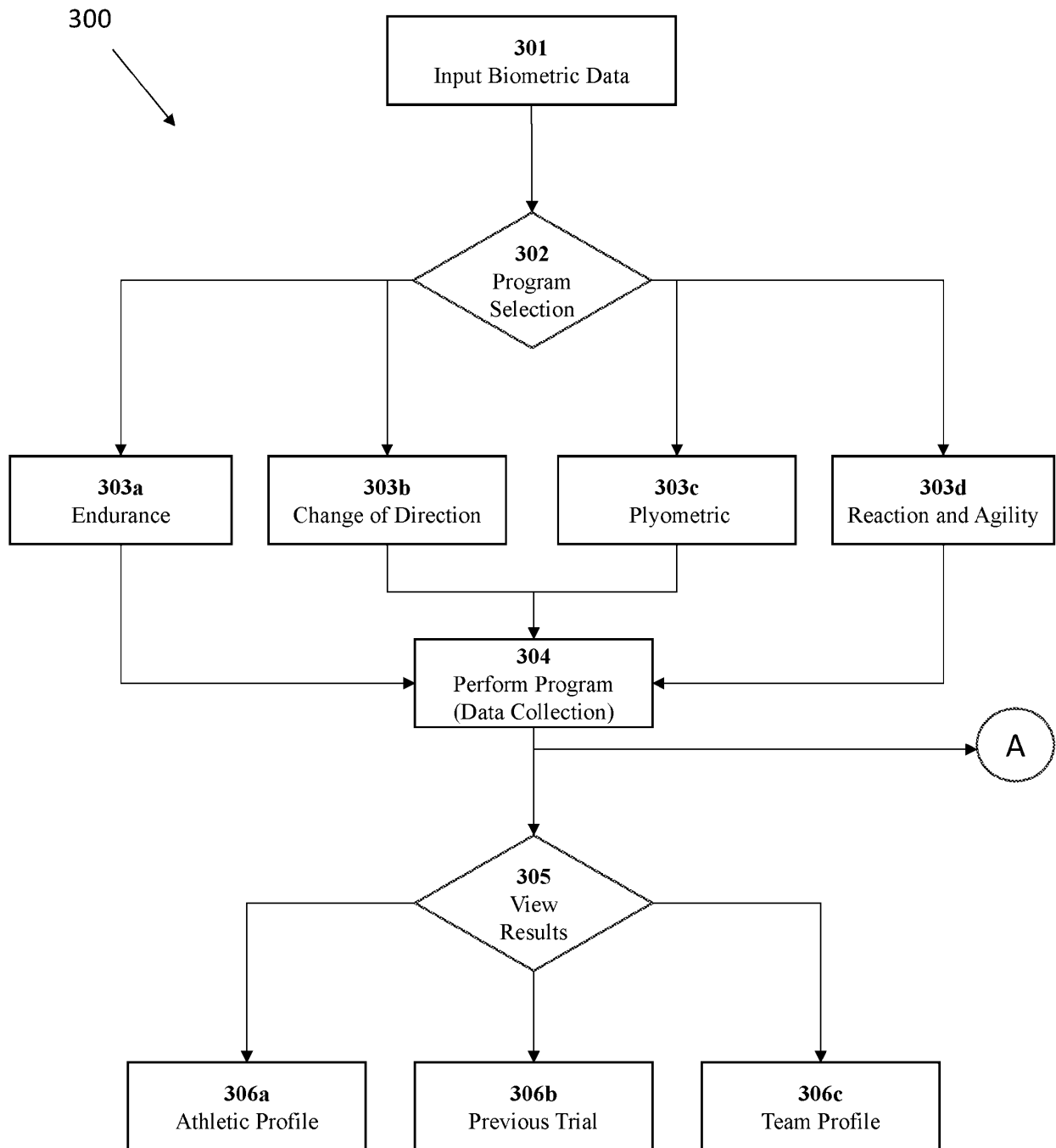


FIG. 3A

7/10

304a

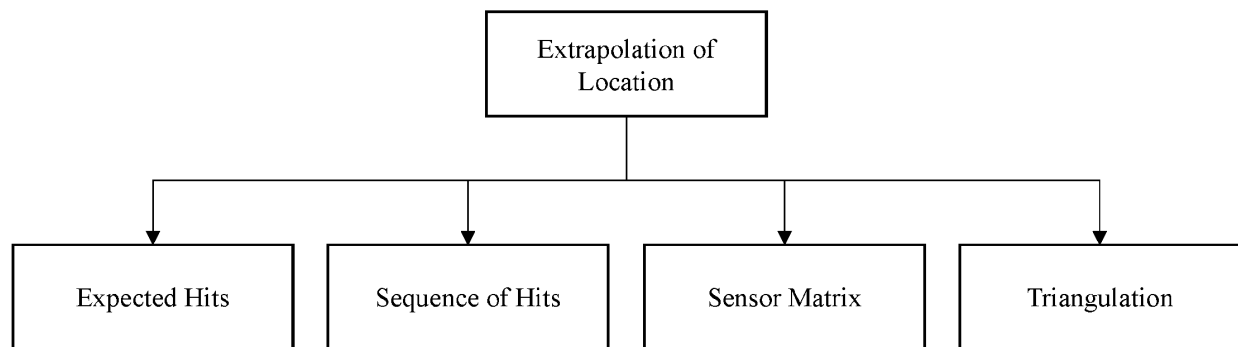


FIG. 3B

8/10

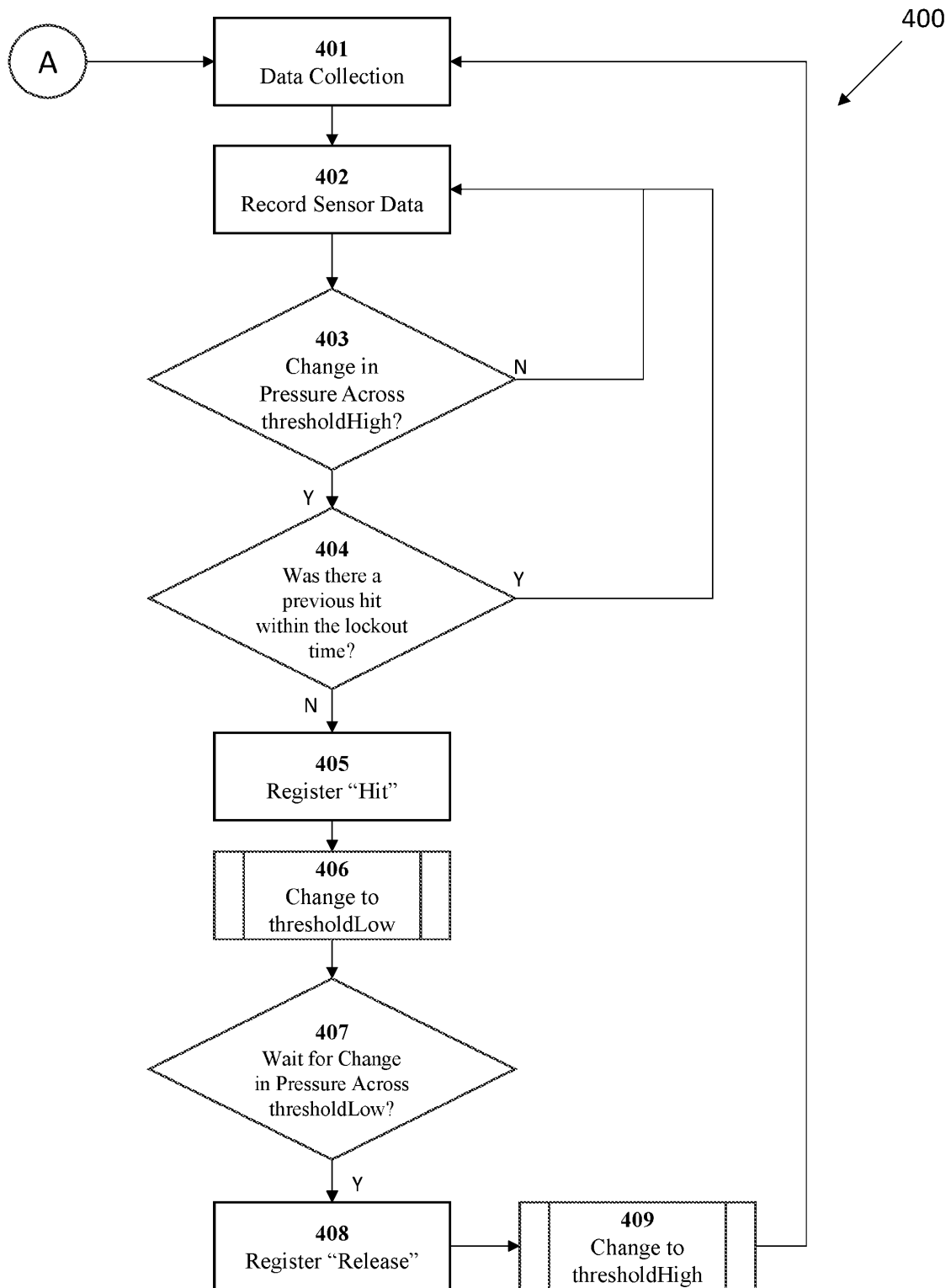


FIG. 4

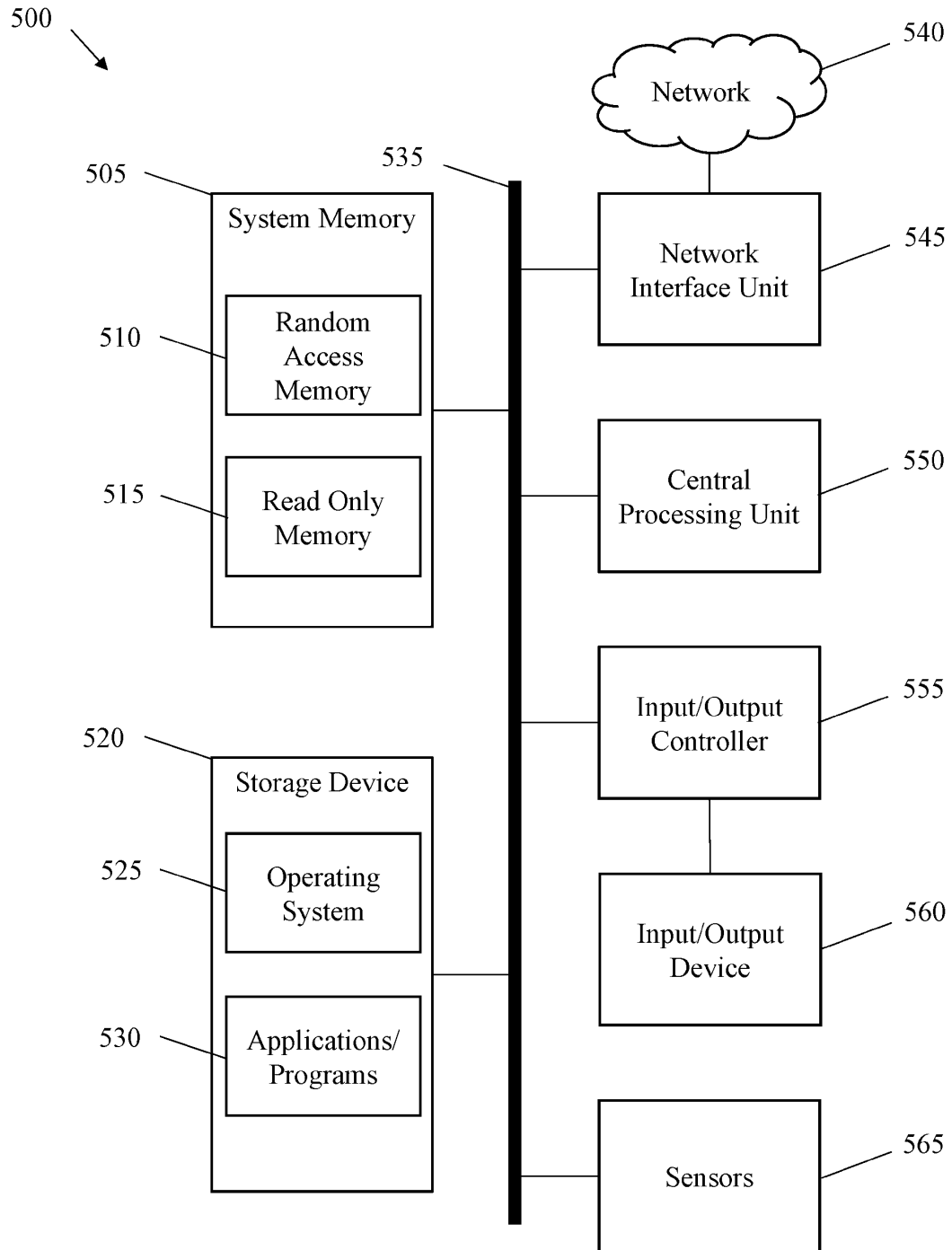


FIG. 5

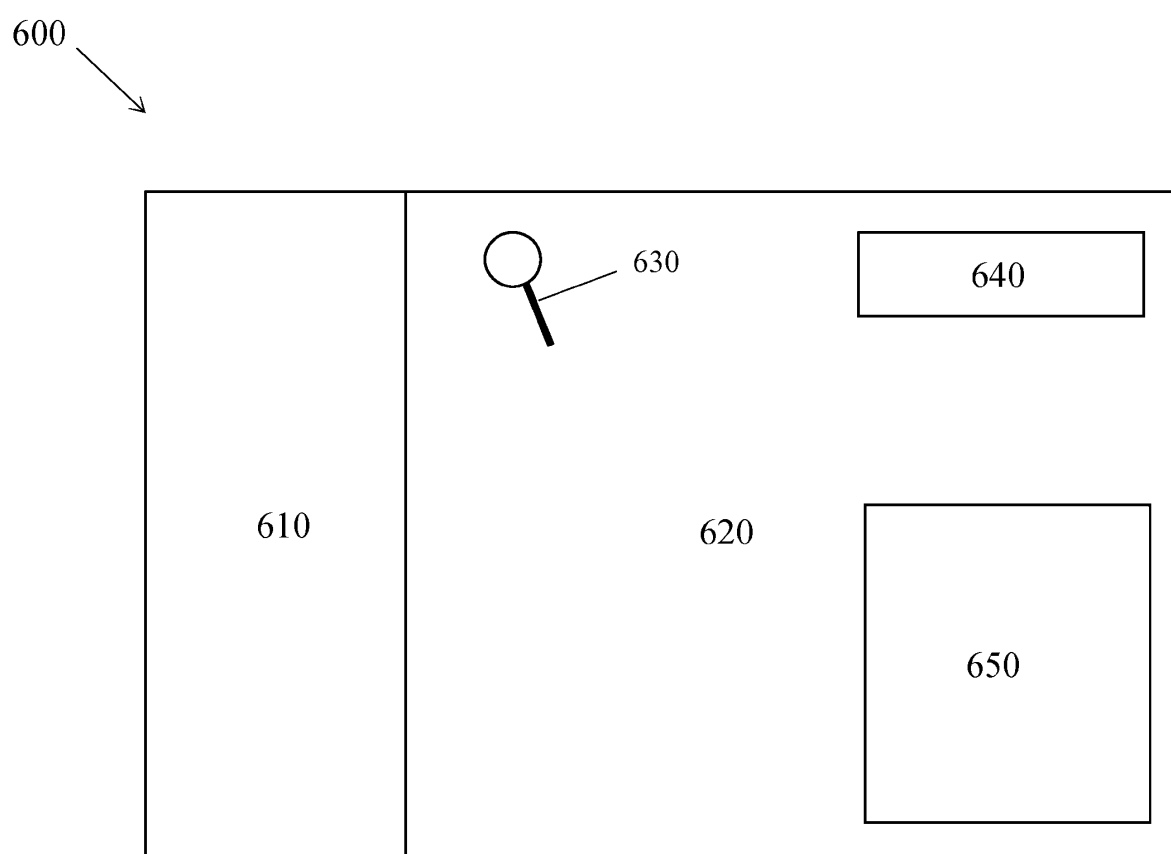


FIG. 6

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2025/025982

A. CLASSIFICATION OF SUBJECT MATTER IPC: A61B 5/103 (2025.01); G01L 1/14 (2025.01); G01L 1/16 (2025.01); G01L 1/18 (2025.01); A61B 5/11 (2025.01) CPC: A61B 5/6892 ; A61B 5/1036 ; G01L 1/146 ; G01L 1/16 ; G01L 1/18 ; A61B 2562/046 ; A61B 2562/164 According to International Patent Classification (IPC) or to both national classification and IPC		
B. FIELDS SEARCHED Minimum documentation searched (classification system followed by classification symbols) See Search History Document Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched See Search History Document Electronic data base consulted during the international search (name of data base and, where practicable, search terms used) See Search History Document		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2022/0268647 A1 (HP1 Technologies Limited) 25 August 2022 (25.08.2022) Fig 5-7, para [0083]-[0087], para [0114], para [0125]-[0126], para [0130]-[0142], para [0214]	1-2, 4-5, 8-9, 11-12
X	US 2021/0244333 A1 (Takano Co, Ltd) 12 August 2021 (12.08.2021) Fig 11, Fig 13A-B, para [0107]-[0114]	1, 3
X	US 2022/0061699 A1 (Apple Inc) 03 March 2022 (03.03.2022) Fig 1A-B, Fig 3, Fig 8A, para [0005], para [0043]-[0062], para [0067], para [0087]-[0088]	1, 4, 6-7
X	US 2018/0125413 A1 (J Brasch Co, LLC) 10 May 2018 (10.05.2018) Fig 1, Fig 3, para [0042]-[0051], para [0058], para [0068]	1, 8
Y	Fig 1, Fig 3, para [0042]-[0051], para [0058], para [0068]	10
Y	US 2020/0354863 A1 (Dartex Coatings Limited) 12 November 2020 (12.11.2020) para [0004]-[0015]	10
A	US 2016/0015311 A1 (University of Southampton) 21 January 2016 (21.01.2016) entire document	1-12
☒ 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 28 May 2025 (28.05.2025)		Date of mailing of the international search report 30 July 2025 (30.07.2025)
Name and mailing address of the ISA/US COMMISSIONER FOR PATENTS MAIL STOP PCT, ATTN: ISA/US P.O. Box 1450 Alexandria, VA 22313-1450 UNITED STATES OF AMERICA Facsimile No. 571-273-8300		Authorized officer HARRY KIM Telephone No. PCT Help Desk: 571-272-4300

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2025/025982

Box No. III Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

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

This application contains the following inventions or groups of inventions which are not so linked as to form a single general inventive concept under PCT Rule 13.1.

Group I: Claims 1-12 directed to a force measuring mat with at least two force measuring sensors between a top layer fixedly attached to a bottom layer.

Group II: Claim 13 directed to a force sensing system comprising a user interface, a force measuring mat comprising at least two force sensors with respective wires, and a processor for collecting and reading data to calculate at least one movement parameter of a user.

Group III: Claims 14-24 directed to a force sensing system comprising a user interface for receiving biometric data, a force measuring mat comprising at least two force sensors with respective wires, and a processor for collecting data based on a selected program from the user interface and biometric data.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.: **1-12**

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
- ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
- ☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US2025/025982**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 2022/0125335 A1 (Wellsense, Inc) 28 April 2022 (28.04.2022) entire document	1-12
