



(51) International Patent Classification:
G01S 5/00 (2006.01)

(21) International Application Number:
PCT/US2017/016259

(22) International Filing Date:
02 February 2017 (02.02.2017)

(25) Filing Language: English

(26) Publication Language: English

(71) Applicant: **HEWLETT-PACKARD DEVELOPMENT COMPANY, L.P.** [US/US]; 11445 Compaq Center Drive W., Houston, Texas 77070 (US).

(72) Inventors: **ALLEN, Will**; 1070 NE Circle Blvd., Corvallis, Oregon 97330-4239 (US). **O'SHEA, Terry**; 1301 SE Tech Center Dr., Vancouver, Washington 98683 (US). **MURPHY, David**; 1501 Page Mill Road, Palo Alto, California

94304 (US). **GE, Ning**; 1501 Page Mill Road, Palo Alto, California 94304 (US).

(74) Agent: **BURROWS, Sarah** et al.; HP Inc., 3390 E. Harmony Road, Mail Stop 35, Fort Collins, Colorado 80528 (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, CZ, DE, DJ, DK, DM, DO, DZ, EC, EE, EG, ES, FI, GB, GD, GE, GH, GM, GT, HN, HR, HU, ID, IL, IN, IR, IS, JP, KE, KG, KH, KN, KP, KR, KW, KZ, LA, LC, LK, LR, LS, LU, LY, MA, MD, ME, MG, MK, MN, 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, SM, ST, SV, SY, TH, TJ, TM, TN, TR, TT, TZ, UA, UG, US, UZ, VC, VN, ZA, ZM, ZW.

(84) Designated States (*unless otherwise indicated, for every kind of regional protection available*): ARIPO (BW, GH, GM, KE, LR, LS, MW, MZ, NA, RW, SD, SL, ST, SZ, TZ,

(54) Title: FUNCTIONAL ELEMENT POSE DETERMINATION

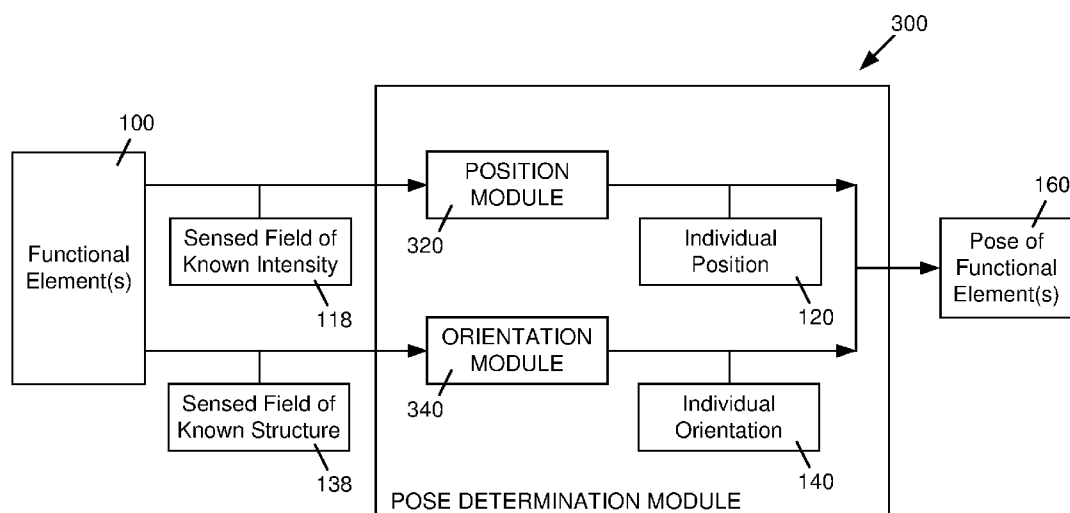


FIG. 3

(57) **Abstract:** A system to determine a pose of functional elements includes a set of functional elements, with each of the functional elements including a housing and a processor, memory, power supply, sensor, and wireless communication module each within the housing, and a position module to determine a position of a respective one of the functional elements based on a field of known intensity sensed by the respective one of the functional elements in each a first orientation of the system, a second orientation of the system rotated relative to the first orientation of the system, and a third orientation of the system rotated relative to the second orientation of the system.



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, MK, MT, NL, NO, PL, PT, RO, RS, SE, SI, SK, SM, TR), OAPI (BF, BJ, CF, CG, CI, CM, GA, GN, GQ, GW, KM, ML, MR, NE, SN, TD, TG).

Declarations under Rule 4.17:

- *as to the identity of the inventor (Rule 4.17(i))*
- *as to applicant's entitlement to apply for and be granted a patent (Rule 4.17(ii))*

Published:

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

5

FUNCTIONAL ELEMENT POSE DETERMINATION

Background

10

The Internet of Things (IoT) may include smart objects with embedded technology to sense, communicate and/or interact with their internal states, each other, and/or their external environment.

15

Brief Description of the Drawings

Figure 1 is a block diagram illustrating an example of a functional element.

20

Figure 2 is a schematic illustration of an example of a plurality of functional elements.

Figure 3 is a block diagram illustrating an example of determining a pose of a functional element.

Figures 4A, 4B, 4C schematically illustrate an example of determining a position of a functional element.

25

Figures 5A, 5B, 5C schematically illustrate another example of determining a position of a functional element.

Figures 6A, 6B schematically illustrate an example of determining an orientation of a functional element.

30

Figures 7A, 7B schematically illustrate another example of determining an orientation of a functional element.

Figures 8A and 8B are flow diagrams illustrating an example of a method of determining a pose of a functional element.

Detailed Description

Figure 1 is a block diagram illustrating an example of a functional
5 element 100. In one implementation, functional element 100 includes a shell or
housing 102 with components, such as a processor 104, memory 106, power
supply 108, sensor 110, and wireless communication module 112, provided
within housing 102.

Processor 104 transfers, communicates, and/or processes signals,
10 commands, conditions, states, and/or parameters for and/or between
components of functional element 100, and may include analog and/or digital
elements and/or circuits. In examples, processor 104 implements and/or
executes computer-readable, computer-executable instructions for data
processing functions and/or functionality of functional element 100. In
15 examples, such instructions are stored in memory, such as memory 106.
Memory 106 may include volatile and non-volatile memory, and includes a non-
transitory computer-readable storage medium suitable for tangibly embodying
program instructions and data. Power supply 108 provides energy for operating
components of functional element 100. In one implementation, power supply
20 108 is a rechargeable battery.

Sensor 110 provides information about one or more than one operating
and/or environmental condition and/or state of functional element 100. In
examples, sensor 110 includes one or more than one instrument or device for
reading, detecting, measuring, indicating, and/or responding to a condition
25 and/or state of functional element 100, including, for example, position,
orientation, gravitational force, magnetic force, and/or ambient or environmental
conditions such as temperature, humidity, and/or pressure.

Wireless communication module 112 facilitates the exchange and/or
transmission of information and/or data between functional element 100 and
30 another device or system, including an external device such as, for example,
computing device 10. Such information and/or data may include, for example,
control and/or logic instructions or commands, condition or state information, as

well as other information and/or data to be exchanged with and/or transmitted to and/or from functional element 100.

In some examples, functional element 100 includes an actuator 114. Actuator 114 includes, operates, and/or controls one or more than one
5 mechanism or mechanical element, component, or system of functional element 100.

Figure 2 is a schematic illustration of an example of a plurality of functional elements 100. In one implementation, functional elements 100 are individually addressable such that information and/or data of and/or for each
10 functional element 100 of the plurality of functional elements 100 may be serialized or individualized. As such, information and/or data exchanged with and/or transmitted to and/or from an individual functional element 100, for example, via wireless communication module 112, may be recognized and/or identified as being from a specific functional element 100. For example, as
15 described below, a pose (position/location and/or orientation) of a functional element 100 (of a plurality of functional elements 100) may be individually determined and serialized such that transmission of the determined pose may be recognized and/or identified as being of a specific functional element 100.

As illustrated in the example of Figure 2, a collection, set, accumulation,
20 or grouping of functional elements 100 is provided or established. In one implementation, functional elements 100 are spherical in shape. Functional elements 100, however, may be of other shapes, including, for example, polyhedral shapes, such as dodecahedral. In addition, functional elements 100 may be irregularly shaped, and may be of different shapes and/or different sizes
25 relative to each other.

In the illustrated example, functional elements 100 are held or contained by or within an enclosure or container 200. Although illustrated as being a rectangular prism, container 200 may be of other shapes and/or sizes. In other examples, functional elements 100 are accumulated, grouped, and/or
30 maintained in a pile or mound without an enclosure or container.

It is to be understood that Figure 2 is a schematic representation of a collection, set, accumulation, or grouping of functional elements 100 within

container 200. Although illustrated with a void between a top of the functional elements 100 and a top of container 200, the void may be filled with additional functional elements and/or a fill material. In addition, the number of functional elements 100 within container 200 may vary such that the number of functional elements 100 within container 200 may be more or less than that illustrated.

In one example, the collection, set, accumulation, or grouping of functional elements 100 is random such that an initial pose of each functional element 100, for example, within container 200, is unknown. In one implementation, each functional element 100 includes six degrees of freedom, namely translation in three perpendicular axes and rotation about the three perpendicular axes. As such, a pose of each functional element 100 includes three degrees of position (location) and three degrees of orientation. For example, the three degrees of position include x, y, and z coordinates, and the three degrees of orientation include degrees of rotation about x, y, and z axes.

More specifically, the three degrees of position include, for example, surge (movement forward and backward along an x-axis), sway (movement left and right along a y-axis), and heave (movement up and down along a z-axis), and the three degrees of orientation include, for example, roll (tilting side to side about the x-axis), pitch (tilting forward and backward about the y-axis), and yaw (left and right turning about the z-axis). With a collection, set, accumulation, or grouping of functional elements 100, the pose of each functional element 100 may be established relative to each other and/or relative to an environment or surrounding, such as container 200.

Figure 3 is a block diagram illustrating an example of determining a pose of a functional element. In examples, as described below, a pose determination unit or module 300 determines a pose of a functional element 100, including an individual position and an individual orientation of a respective functional element 100, based on a condition or conditions sensed by a respective functional element 100.

In one implementation, as schematically illustrated in Figure 3, pose determination module 300 includes a position unit or module 320, and an orientation unit or module 340. As described below, position module 320

determines an individual position 120 of a respective functional element 100, and orientation module 340 determines an individual orientation 140 of a respective functional element 100, such that an individual pose 160 of the respective functional element 100 may be established from individual position
5 120 and individual orientation 140.

Pose determination module 300 includes hardware, software, firmware, or a combination of these. In one implementation, pose determination module 300 is included in a computer, computer server, or other microprocessor-based system capable of performing a sequence of logic operations. Components of
10 pose determination module 300, including position module 320, and/or orientation module 340, can be implemented in hardware via a microprocessor, programmable logic device, or state machine, in firmware, or in software within a given device. Position module 320, and/or orientation module 340 may be implemented, for example, as a subroutine of a computer program. Pose
15 determination module 300, including position module 320, and/or orientation module 340, can be implemented, wholly or in part, on a respective functional element 100 or on an external device, such as computing device 10 (Figure 1).

In one implementation, position module 320 determines individual position 120 based on a field with a known intensity sensed by a respective
20 functional element 100, as described below. As such, position module 320 receives, as input, a measure of a sensed field of known intensity 118 from a respective functional element 100. The field of known intensity may be sensed, for example, by an implementation of sensor 110 (Figure 1) of a respective functional element 100. In one implementation, the measure of the sensed field
25 of known intensity 118 is transmitted or communicated to pose determination module 300, including, more specifically, position module 320, via wireless communication module 112 (Figure 1) of the respective functional element 100.

In one implementation, orientation module 340 determines individual orientation 140 based on a field with a known structure sensed by a respective
30 functional element 100, as described below. As such, orientation module 340 receives, as input, a measure of a sensed field of known structure 138 from a respective functional element 100. The field of known structure may be sensed,

for example, by an implementation of sensor 110 (Figure 1) of a respective functional element 100. In one implementation, the measure of the sensed field of known structure 138 is transmitted or communicated to pose determination module 300, including, more specifically, orientation module 340, via wireless communication module 112 (Figure 1) of the respective functional element 100.

Figures 4A, 4B, 4C schematically illustrate an example of determining a position of a functional element, such as individual position 120 of a respective functional element 100. In one example, as described above, determination of individual position 120 is based on a field with a known intensity, including, more specifically, a field with a known intensity profile, intensity gradient, or three-dimensional intensity. In one implementation, the field of known intensity is ambient pressure, including, more specifically, atmospheric pressure (i.e., air pressure or gas pressure). As such, the field of known intensity may be sensed, for example, by an altimeter, as an example of sensor 110 of a respective functional element 100.

As illustrated in the example of Figure 4A, container 200, with functional elements 100 therein, is positioned in or has a first orientation. With the first orientation, atmospheric pressure at a respective functional element 100 is measured such that a "depth" or position of the respective functional element 100 relative to a first surface, face, or boundary of container 200, such as boundary 201, is resolved, as represented, for example, by arrow 401. As such, a first positional coordinate, such as an x-coordinate, of the respective functional element 100 is determined. In one implementation, container 200 includes a transmitter or sensor 210 at one or more known locations such that a sensed measurement by a respective functional element 100 is compared with a sensed measurement by sensor 210.

As illustrated in the example of Figure 4B, container 200, with functional elements 100 therein, is positioned in or has a second orientation. With the second orientation, atmospheric pressure at the respective functional element 100 is measured such that a "depth" or position of the respective functional element 100 relative to a second surface, face, or boundary of container 200, such as boundary 202, is resolved, as represented, for example, by arrow 402.

As such, a second positional coordinate, such as a y-coordinate, of the respective functional element 100 is determined.

As illustrated in the example of Figure 4C, container 200, with functional elements 100 therein, is positioned in or has a third orientation. With the third
5 orientation, atmospheric pressure at the respective functional element 100 is measured such that a "depth" or position of the respective functional element 100 relative to a third surface, face, or boundary of container 200, such as boundary 203, is resolved, as represented, for example, by arrow 403. As such, a third positional coordinate, such as a z-coordinate, of the respective functional
10 element 100 is determined.

In one example, container 200, with functional elements 100 fixed therein, is re-oriented or rotated, as represented by arrow 221, between the first orientation of Figure 4A and the second orientation of Figure 4B, and re-oriented or rotated, as represented by arrow 222, between the second
15 orientation of Figure 4B and the third orientation of Figure 4C. In one implementation, container 200 is rotated ninety degrees between the first orientation and the second orientation, and rotated ninety degrees between the second orientation and the third orientation such that the second orientation of Figure 4B is orthogonal to the first orientation of Figure 4A, and the third
20 orientation of Figure 4C is orthogonal to both the first orientation of Figure 4A and the second orientation of Figure 4B. Although illustrated as being rotated ninety degrees between the first orientation and the second orientation, and rotated ninety degrees between the second orientation and the third orientation, container 200, with functional elements 100 fixed therein, may be rotated a
25 different amount (or amounts) between the first orientation and the second orientation, and/or between the second orientation and the third orientation such that the rotation (or rotations) include a non-zero orthogonal vector component (e.g., 30 degrees, 120 degrees).

Figures 5A, 5B, 5C schematically illustrate another example of
30 determining a position of a functional element, such as individual position 120 of a respective functional element 100. In one example, as described above, determination of individual position 120 is based on a field with a known

intensity, including, more specifically, a field with a known intensity profile, intensity gradient, or three-dimensional intensity. In one implementation, the field of known intensity is ambient pressure, including, more specifically, liquid pressure (e.g., water pressure). As such, the field of known intensity may be
5 sensed, for example, by a liquid pressure sensor or transducer or hydrostatic depth sensor, as an example of sensor 110 of a respective functional element 100.

As illustrated in the example of Figure 5A, container 200, with functional elements 100 therein, is positioned in or has a first orientation, and is filled with
10 a liquid 230, such as water, oil, alcohol, acetone, mercury or other liquid or liquid mixture, such that functional elements 100 are submerged in liquid 230. With the first orientation, liquid pressure at a respective functional element 100 is measured such that a "depth" or position of the respective functional element 100 relative to a first surface, face, or boundary of container 200, such as
15 boundary 201, is resolved, as represented, for example, by arrow 401. As such, a first positional coordinate, such as an x-coordinate, of the respective functional element number 100 is determined. In one implementation, container 200 includes a transmitter or sensor 210 at one or more known locations such that a sensed measurement by a respective functional element 100 is compared with
20 a sensed measurement by sensor 210.

As illustrated in the example of Figure 5B, container 200, with functional elements 100 submerged in liquid 230 therein, is positioned in or has a second orientation. With the second orientation, liquid pressure at the respective functional element 100 is measured such that a "depth" or position of the
25 respective functional element 100 relative to a second surface, face, or boundary of container 200, such as boundary 202, is resolved, as represented, for example, by arrow 402. As such, a second positional coordinate, such as a y-coordinate, of the respective functional element 100 is determined.

As illustrated in the example of Figure 5C, container 200, with functional
30 elements 100 submerged in liquid 230 therein, is positioned in or has a third orientation. With the third orientation, liquid pressure at the respective functional element 100 is measured such that a "depth" or position of the

respective functional element 100 relative to a third surface, face, or boundary of container 200, such as boundary 203, is resolved, as represented, for example, by arrow 403. As such, a third positional coordinate, such as a z-coordinate, of the respective functional element 100 is determined.

5 Similar to the example of Figures 4A, 4B, 4C, container 200, with functional elements 100 fixed and submerged in liquid 230 therein, is re-oriented or rotated, as represented by arrow 221, between the first orientation of Figure 5A and the second orientation of Figure 5B, and re-oriented or rotated, as represented by arrow 222, between the second orientation of Figure 5B and
10 the third orientation of Figure 5C. Although illustrated as being rotated ninety degrees between the first orientation and the second orientation, and rotated ninety degrees between the second orientation and the third orientation, container 200, with functional elements 100 fixed and submerged in liquid 230 therein, may be rotated a different amount (or amounts) between the first
15 orientation and the second orientation, and/or between the second orientation and the third orientation such that the rotation (or rotations) include a non-zero orthogonal vector component (e.g., 30 degrees, 120 degrees).

 In the examples described above, the field of known intensity is ambient pressure, including, more specifically, atmospheric pressure (i.e., air pressure or
20 gas pressure) and liquid pressure (e.g., water pressure). In other examples, the field of known intensity may include light or radio signals directed from or generated by a respective source. As such, and similar to the examples of Figures 4A, 4B, 4C, and Figures 5A, 5B, 5C, container 200, with functional elements 100 fixed therein, may be re-oriented or rotated between a first
25 orientation, a second orientation, and a third orientation, and the field of known intensity (e.g., light intensity or radio signal strength) may be sensed by a respective functional element 100 such that a position of the respective functional element 100 may be determined.

 Figures 6A, 6B schematically illustrate an example of determining an
30 orientation of a functional element, such as individual orientation 140 of a respective functional element 100. In one example, as described above, determination of individual orientation 140 is based on a field with a known

structure. In one implementation, the field of known structure is a gravitational field. As such, the field of known structure may be sensed, for example, by an accelerometer or tilt sensor, as an example of sensor 110 of a respective functional element 100.

5 As illustrated in the example of Figure 6A, container 200, with functional elements 100 therein, is positioned in or has a first orientation. With the first orientation, a direction of the gravitational field (i.e., a direction of gravitational force), as represented, for example, by arrow 410 (i.e., "down"), is sensed by a respective functional element 100. As such, a first orientation parameter
10 relative to the sensed direction of the gravitational field, such as roll, and a second orientation parameter relative to the sensed direction of the gravitational field, such as pitch, of the respective functional element 100 is determined.

 As illustrated in the example of Figure 6B, container 200, with functional elements 100 therein, is positioned in or has a second orientation. With the
15 second orientation, a direction of the gravitational field (i.e., a direction of gravitational force), as represented, for example, by arrow 411 (i.e., "down"), is sensed by the respective functional element 100. As such, a third orientation parameter relative to the sensed direction of the gravitational field, such as yaw, of the respective functional element 100 is determined.

20 In one example, container 200, with functional elements 100 fixed therein, is re-oriented or rotated, as represented by arrow 223, between the first orientation of Figure 6A and the second orientation of Figure 6B. In one implementation, the second orientation of Figure 6B is orthogonal to the first orientation of Figure 6A such that container 200 is rotated ninety degrees
25 between the first orientation and the second orientation.

 Figures 7A, 7B schematically illustrate another example of determining an orientation of a functional element, such as individual orientation 140 of a respective functional element 100. In one example, as described above, determination of individual orientation 140 is based on a field with a known
30 structure. In one implementation, the field of known structure is a magnetic field. As such, the field of known structure may be sensed, for example, by a

magnetometer, as an example of sensor 110 of a respective functional element 100.

As illustrated in the example of Figure 7A, container 200, with functional elements 100 therein, is positioned in a magnetic field 241 having a first
5 orientation. With the first orientation of magnetic field 241, an orientation of the magnetic field is sensed by a respective functional element 100 such that a first orientation parameter, such as roll, and a second orientation parameter, such as pitch, of the respective functional element 100 is determined.

As illustrated in the example of Figure 7B, container 200, with functional
10 elements 100 therein, is positioned in a magnetic field 242 having a second orientation. With the second orientation of magnetic field 242, an orientation of the magnetic field is sensed by the respective functional element 100 such that a third orientation parameter, such as yaw, of the respective functional element 100 is determined.

15 In one implementation, the orientation of magnetic field 242 of Figure 7B is orthogonal to the orientation of magnetic field 241 of Figure 7A, and is established by re-orienting or rotating a magnetic field ninety degrees relative to functional elements 100, for example, relative to container 200, with functional elements 100 therein. As such, the first orientation includes a first orientation of
20 the field of known structure (i.e., magnetic field), and the second orientation includes a second orientation of the field of known structure (i.e., magnetic field) rotated relative to the first orientation of the field of known structure. In another implementation, container 200, with functional elements 100 fixed therein, is re-oriented or rotated ninety degrees relative to a magnetic field to establish a first
25 orientation of the magnetic field and a second orientation of the magnetic field relative to container 200 and functional elements 100.

Figures 8A and 8B are flow diagrams illustrating an example of a method
500 of determining a pose of a functional element, such as functional element 100, as schematically illustrated, for example, in Figure 1.

30 In one example, as illustrated in Figure 8A, at 502, method 500 includes grouping a plurality of functional elements, such as functional elements 100, with each of the functional elements including a housing, such as housing 102,

and a processor, such as processor 104, memory, such as memory 106, power supply, such as power supply 108, sensor, such as sensor 110, and wireless communication module, such as wireless communication module 112, each within the housing, as schematically illustrated, for example, in Figure 1.

5 As such, in one example, at 504, method 500 includes determining an individual position of a respective one of the functional elements, such as individual position 120 of a respective functional element 100. In one example, determining an individual position of a respective one of the functional elements includes sensing a field of known intensity by the respective one of the
10 functional elements in each a first orientation, a second orientation rotated relative to the first orientation, and a third orientation rotated relative to the second orientation, as schematically illustrated, for example, in Figures 4A, 4B, 4C, and Figures 5A, 5B, 5C.

 In one implementation, sensing the field of known intensity, for example,
15 at 504, includes sensing atmospheric pressure by the respective one of the functional elements in each the first orientation, the second orientation, and the third orientation, as schematically illustrated, for example, in Figures 4A, 4B, 4C.

 In another implementation, method 500 includes submerging the functional elements in liquid, such that sensing the field of known intensity, for
20 example, at 504, includes sensing liquid pressure by the respective one of the functional elements in each the first orientation, the second orientation, and the third orientation, as schematically illustrated, for example, in Figures 5A, 5B, 5C.

 In one example, as illustrated in Figure 8B, at 506, method 500 further includes determining an individual orientation of the respective one of the
25 functional elements, such as individual orientation 140 of a respective functional element 100. In one example, determining an individual orientation of the respective one of the functional elements includes sensing a field of known structure by the respective one of the functional elements in both the first orientation and the second orientation, as schematically illustrated, for example,
30 in Figures 6A, 6B, and Figures 7A, 7B.

 In one implementation, sensing the field of known structure, for example, at 506, includes sensing a direction of a gravitational field by the respective one

of the functional elements in both the first orientation and the second orientation, as schematically illustrated, for example, in Figures 6A, 6B.

In another implementation, sensing the field of known structure, for example, at 506, includes sensing an orientation of a magnetic field by the
5 respective one of the functional elements in both the first orientation and the second orientation, as schematically illustrated, for example, in Figures 7A, 7B.

Although illustrated and described as separate and/or sequential steps, the method may include a different order or sequence of steps, and may combine one or more steps or perform one or more steps concurrently, partially
10 or wholly.

Although specific examples have been illustrated and described herein, a variety of alternate and/or equivalent implementations may be substituted for the specific examples shown and described without departing from the scope of the present disclosure. This application is intended to cover any adaptations or
15 variations of the specific examples discussed herein.

CLAIMS

1. A system to determine a pose of functional elements, comprising:
a set of functional elements, each of the functional elements including a housing and a processor, memory, power supply, sensor, and wireless communication module each within the housing; and
a position module to determine a position of a respective one of the functional elements based on a field of known intensity sensed by the respective one of the functional elements in each a first orientation of the system, a second orientation of the system rotated relative to the first orientation of the system, and a third orientation of the system rotated relative to the second orientation of the system.
2. The system of claim 1, wherein the field of known intensity comprises atmospheric pressure, and each of the functional elements is to sense a magnitude of the atmospheric pressure in each the first orientation, the second orientation, and the third orientation of the system.
3. The system of claim 1, wherein the functional elements are submerged in liquid, wherein the field of known intensity comprises liquid pressure, and each of the functional elements is to sense a magnitude of the liquid pressure in each the first orientation, the second orientation, and the third orientation of the system.
4. The system of claim 1, further comprising:
an orientation module to determine an orientation of the respective one of the functional elements based on a field of known structure sensed by the respective one of the functional elements in both the first orientation of the system and the second orientation of the system.

5. The system of claim 4, wherein the field of known structure comprises a gravitational field, and each of the functional elements is to sense a direction of the gravitational field in both the first orientation and the second orientation of the system.

6. The system of claim 4, wherein the field of known structure comprises a magnetic field, and each of the functional elements is to sense an orientation of the magnetic field in both the first orientation and the second orientation of the system.

7. The system of claim 1, wherein the first orientation of the system comprises a first orientation of a container with the functional elements contained therein, the second orientation of the system comprises a second orientation of the container with the functional elements contained therein, and the third orientation of the system comprises a third orientation of the container with the functional elements contained therein, the third orientation of the container rotated relative to the second orientation of the container, and the second orientation of the container rotated relative to the first orientation of the container.

8. A system to determine a pose of functional elements, comprising:

an accumulation of functional elements, each of the functional elements including a housing and a processor, memory, power supply, sensor, and wireless communication module each within the housing;

each of the functional elements to sense a field of known intensity and a field of known structure; and

a pose of a respective one of the functional elements comprising an individual position based on the field of known intensity sensed in first, second, and third orientations of the system rotated relative to each other, and an individual orientation based on the field of known structure sensed in first and second orientations of the system rotated relative to each other.

9. A method of determining a pose of functional elements, comprising:
grouping a plurality of functional elements, each of the functional elements including a housing and a processor, memory, power supply, sensor, and wireless communication module each within the housing; and
determining an individual position of a respective one of the functional elements, including sensing a field of known intensity by the respective one of the functional elements in each a first orientation, a second orientation rotated relative to the first orientation, and a third orientation rotated relative to the second orientation.
10. The method of claim 9, wherein sensing the field of known intensity comprises sensing atmospheric pressure by the respective one of the functional elements in each the first orientation, the second orientation, and the third orientation.
11. The method of claim 9, further comprising:
submerging the functional elements in liquid,
wherein sensing the field of known intensity comprises sensing liquid pressure by the respective one of the functional elements in each the first orientation, the second orientation, and the third orientation.
12. The method of claim 9, further comprising:
determining an individual orientation of the respective one of the functional elements, including sensing a field of known structure by the respective one of the functional elements in both the first orientation and the second orientation.
13. The method of claim 12, wherein sensing the field of known structure comprises sensing a direction of a gravitational field by the respective one of the functional elements in both the first orientation and the second orientation.

14. The method of claim 12, wherein sensing the field of known structure comprises sensing an orientation of a magnetic field by the respective one of the functional elements in both the first orientation and the second orientation.

15. The method of claim 9, wherein the first orientation comprises a first orientation of a container with the functional elements contained therein, the second orientation comprises a second orientation of the container with the functional elements contained therein, and the third orientation comprises a third orientation of the container with the functional elements contained therein, the third orientation of the container rotated relative to the second orientation of the container, and the second orientation of the container rotated relative to the first orientation of the container.

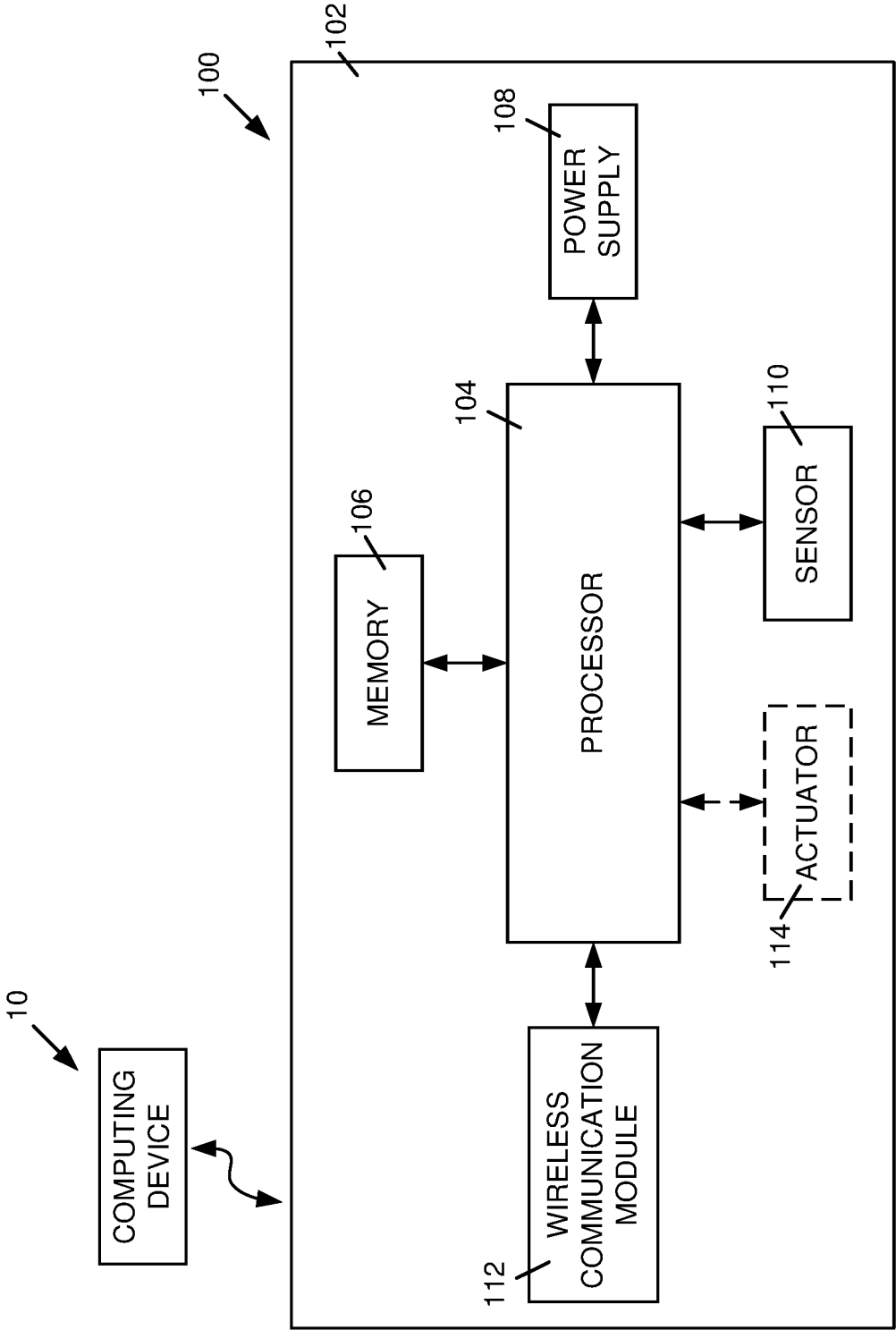


FIG. 1

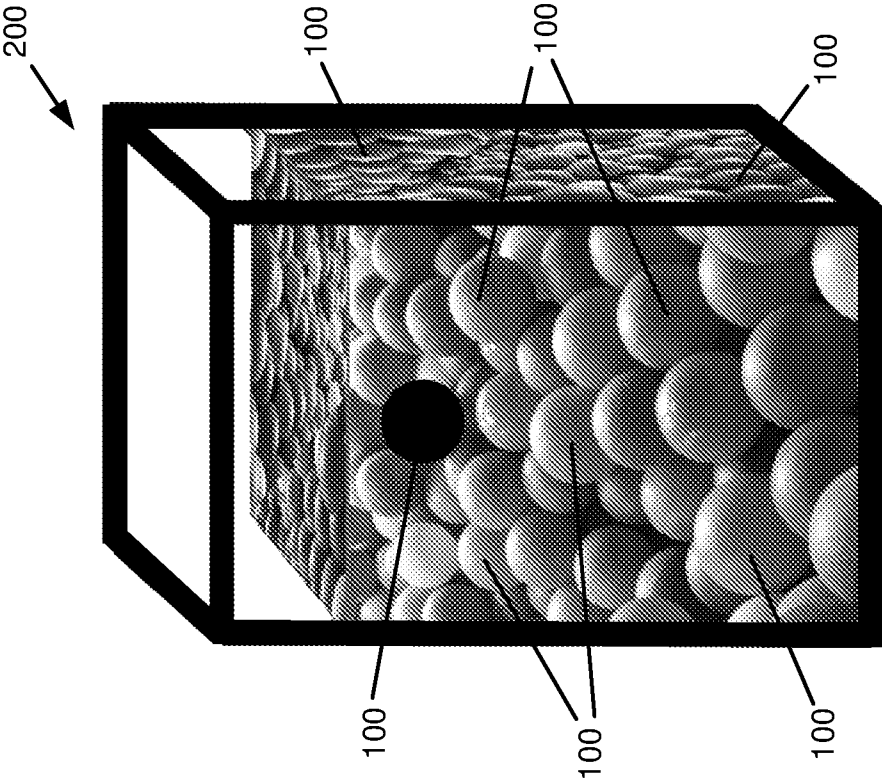


FIG. 2

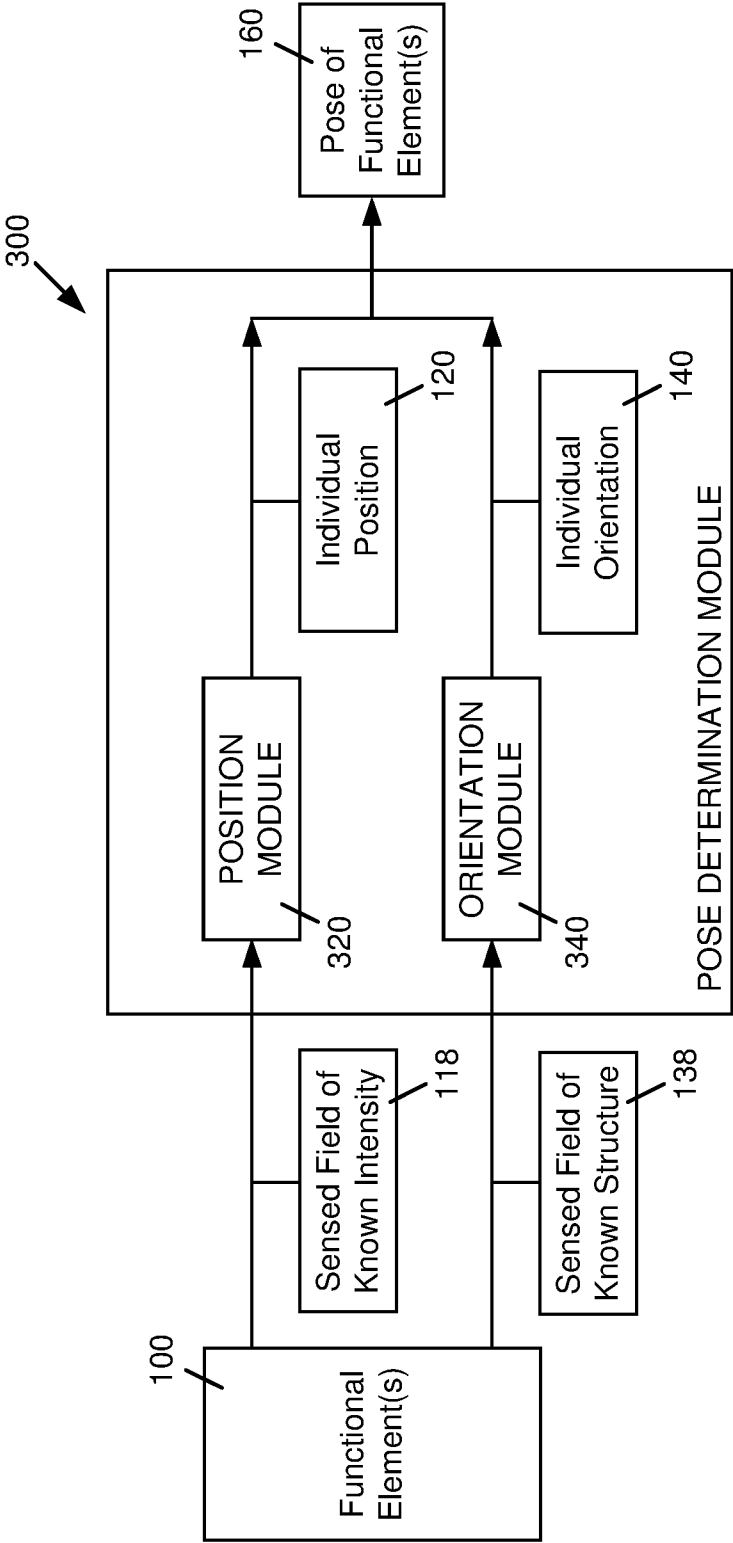


FIG. 3

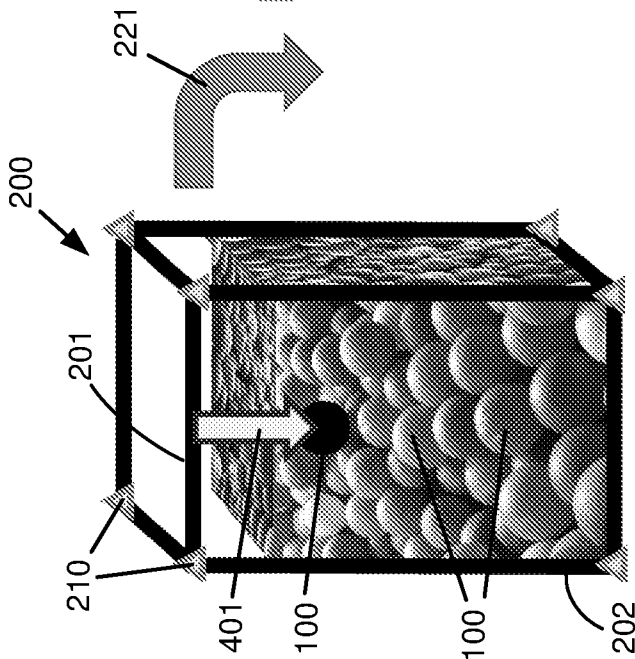


FIG. 4A

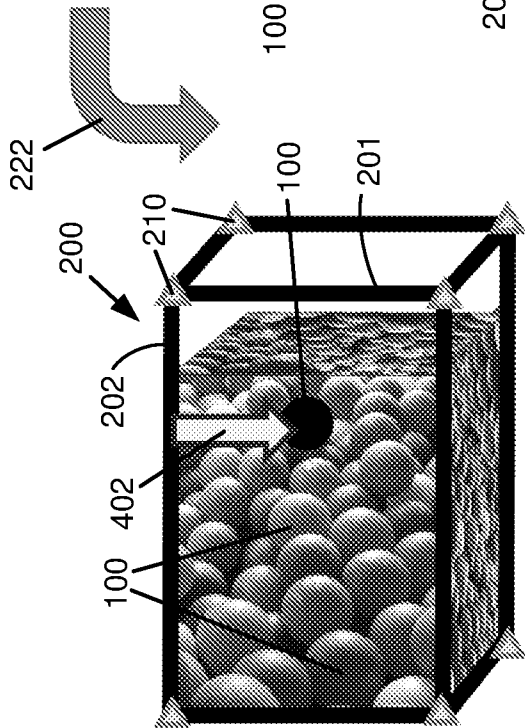


FIG. 4B

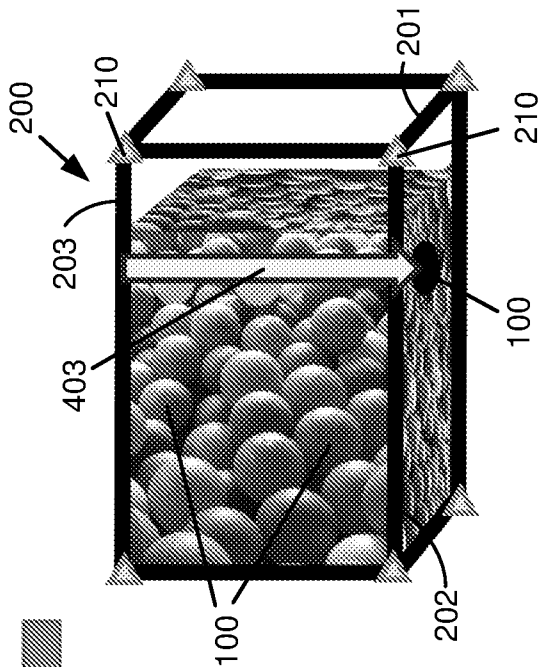


FIG. 4C

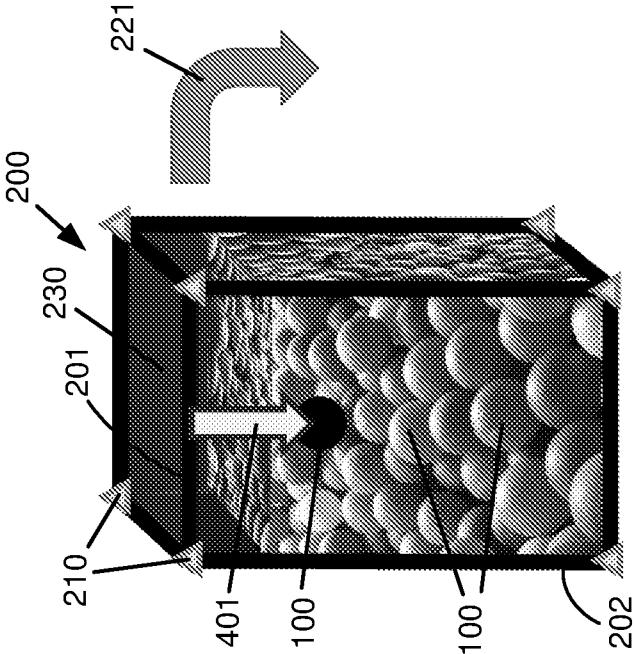


FIG. 5A

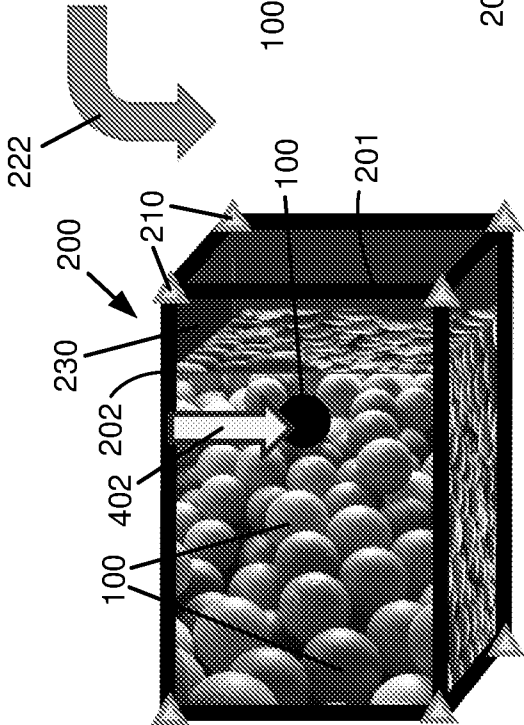


FIG. 5B

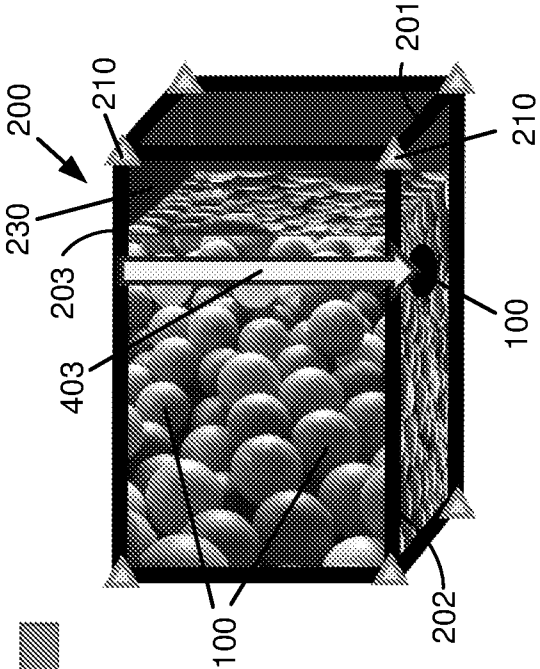


FIG. 5C

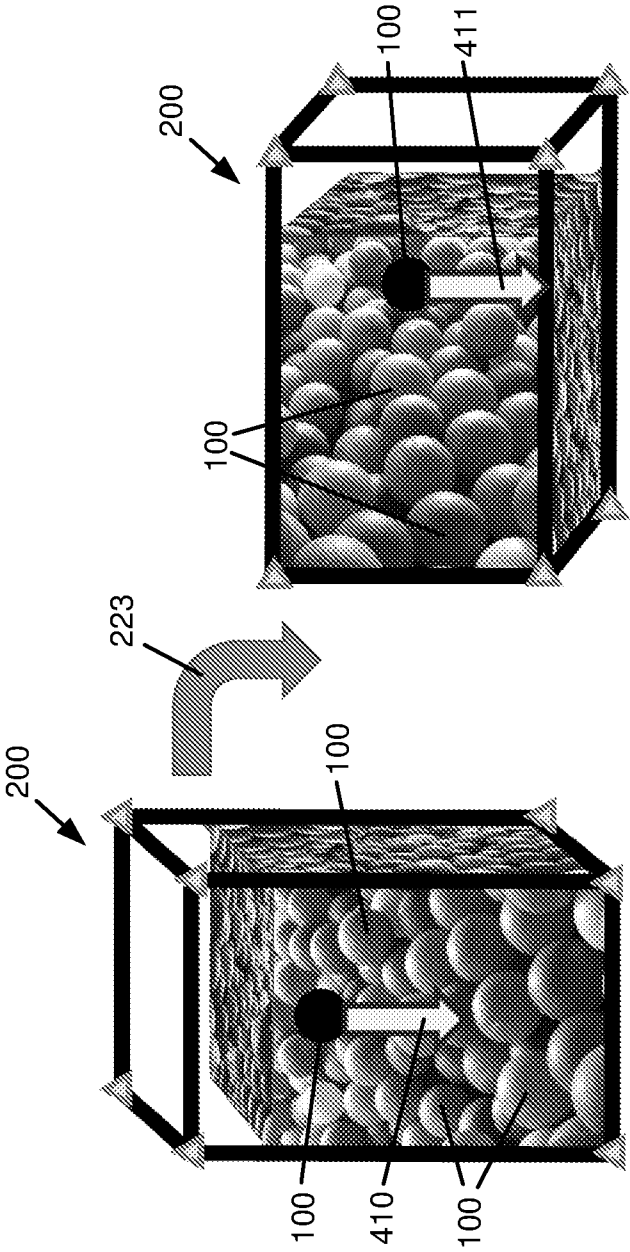


FIG. 6B

FIG. 6A

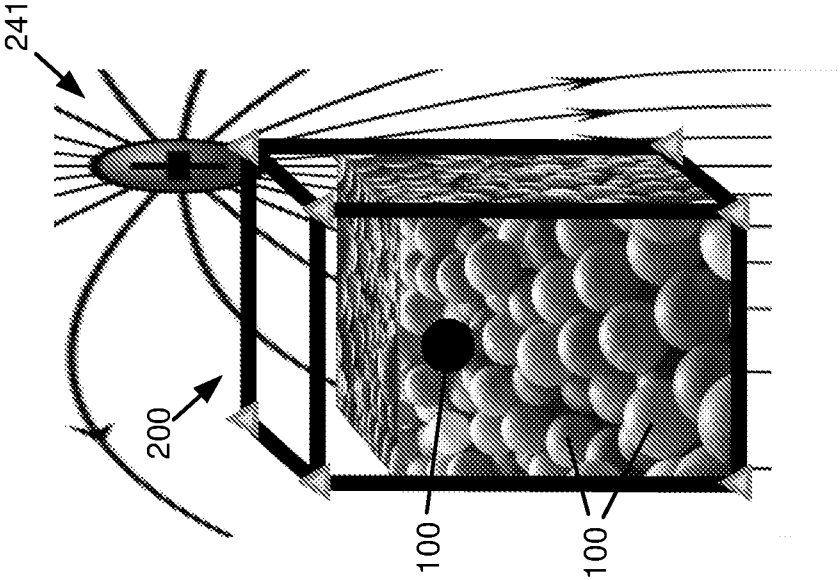


FIG. 7A

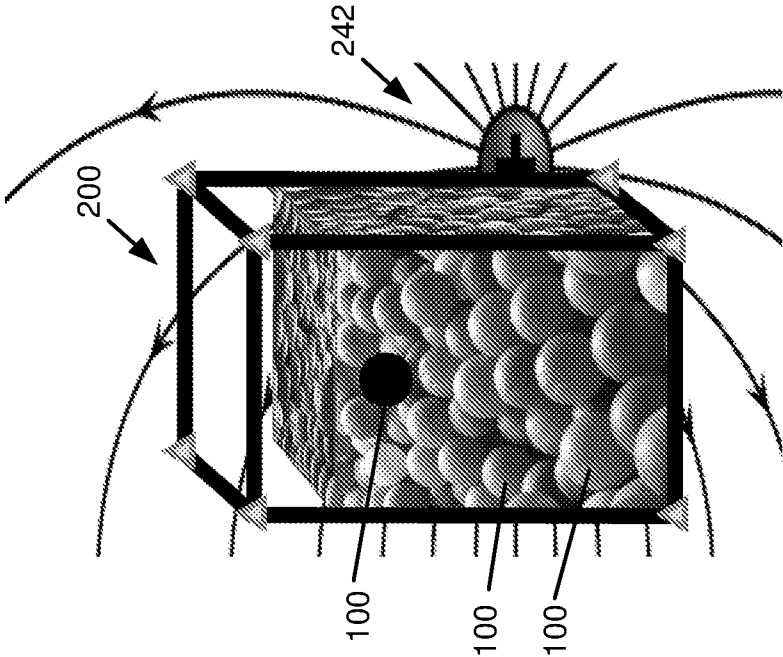
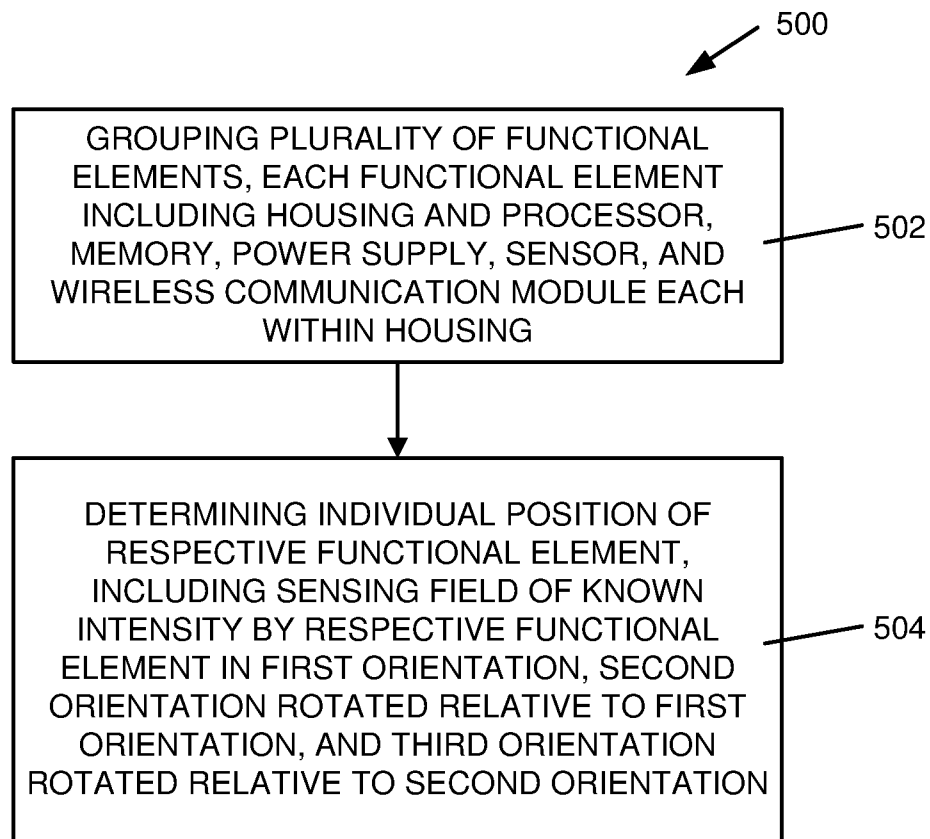
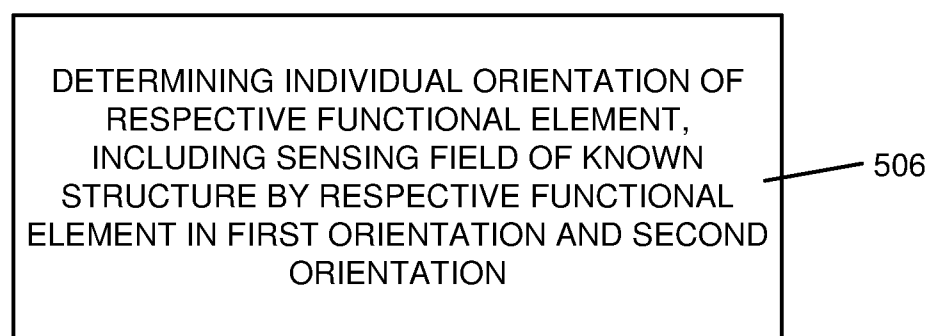


FIG. 7B

**FIG. 8A****FIG. 8B**

INTERNATIONAL SEARCH REPORT

International application No.

PCT/US 2017/016259

A. CLASSIFICATION OF SUBJECT MATTER		
G01S5/00 (2006.01)		
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)		
G01S 5/00-5/30, G01B 13/00-13/03, 7/00-7/02, H04W 4/00-4/02, G06F 1/00-1/16, G09G 5/00		
Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched		
Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)		
PAJ, ESP@cenet, USPTO DB, Google		
C. DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2014155098 A1 (ISIS INNOVATION LIMITED) 05.06.2014, abstract, paragraphs [0256], [0259]-[0261], [0264], [0268], [0299], [0309], [0317], [0457]	1, 4, 6-9, 12, 14-15
Y		2, 3, 5, 10-11, 13
Y	US 2016320810 A1 (SAMSUNG ELECTRONICS CO., LTD) 03.11.2016, paragraph [0109]	2, 10
Y	CN 201382772 Y (SHANDONG UROICA AUTOMATIC EQUIPMENT CO., LTD) 13.01.2010, abstract	3, 11
Y	US 5526022 A (VIRTUAL I/O, INC) 11.06.1996, abstract	5, 13
☐ Further documents are listed in the continuation of Box C. ☐ See patent family annex.		
* Special categories of cited documents:	"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	
"A" document defining the general state of the art which is not considered to be of particular relevance		
"E" earlier document 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		
Date of the actual completion of the international search	Date of mailing of the international search report	
28 September 2017 (28.09.2017)	19 October 2017 (19.10.2017)	
Name and mailing address of the ISA/RU: Federal Institute of Industrial Property, Berezhkovskaya nab., 30-1, Moscow, G-59, GSP-3, Russia, 125993 Facsimile No: (8-495) 531-63-18, (8-499) 243-33-37	Authorized officer A.Tokarev Telephone No. (8-495) 531-65-15	