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[Continued on next page]

(54) Title: GENERATING SPECIFICATIONS FOR AN ORTHOSIS

(57) Abstract: Example implementations relate to collecting data to generate specifications for an orthosis. In example implementations, data may be collected from a plurality of pressure sensors. Histograms may be generated that characterize collected data. Specifications for an orthosis may be generated based on the histograms.

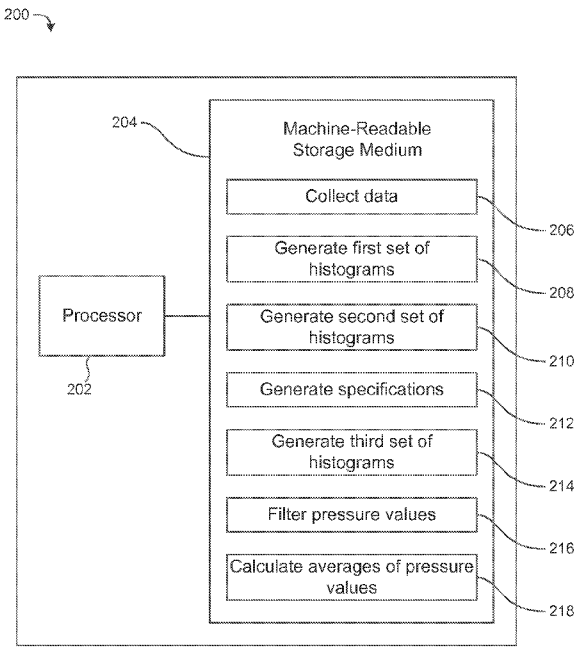


FIG. 2

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GENERATING SPECIFICATIONS FOR AN ORTHOSIS

Background

[0001] Orthotic devices may be used to support, brace, and/or improve functions of parts of the body. For example, people with flat feet may place insoles inside their shoes to provide arch support. Someone recovering from an ankle sprain/fracture may wear an ankle-foot orthosis to control position of the ankle and/or compensate for weakness in certain muscles. To better suit a person's individual needs, a custom orthosis may be made especially for the person.

Brief Description of the Drawings

[0002] The following detailed description references the drawings, wherein:

[0003] FIG. 1 is a block diagram of an example device that includes a machine-readable storage medium encoded with instructions to enable generating specifications for an orthosis;

[0004] FIG. 2 is a block diagram of an example device that includes a machine-readable storage medium encoded with instructions to filter pressure values;

[0005] FIG. 3 is a block diagram of an example system for generating specifications for an orthosis;

[0006] FIG. 4 is a block diagram of an example system for processing data collected by pressure sensors;

[0007] FIG. 5 is a flowchart of an example method for generating support values for an orthosis;

[0008] FIG. 6 is a flowchart of an example method for generating a model for a three-dimensional (3D) printer to print an orthosis; and

[0009] FIG. 7 is a flowchart of an example method for processing data collected by pressure sensors.

Detailed Description

[0010] Orthoses may be worn by people who experience muscle/joint weakness, nerve damage, or poor blood circulation. For example, diabetics who suffer from peripheral neuropathy may wear insoles in their shoes to provide extra

support and cushioning, decreasing irritation by external objects. Custom insoles may be made that better conform to a person's feet. To make a custom insole, a person's foot may be dipped in plaster to form a mold/cast of the person's foot, and an insole may be formed based on the shape of the mold/cast. Some retailers or medical offices may scan a person's foot using a flatbed image scanner that shines light on the foot and determines the shape of the foot by measuring the intensity of light that is reflected back. Data from this scan may be used to create a custom insole.

[0011] Custom insoles created using the aforementioned methods may not be suitable for actual conditions in a person's daily life, as the person's cushioning/ support needs may be different when the person is moving than when the person is standing still. In light of the above, the present disclosure provides for using a diagnostic insole having a plurality of pressure sensors to collect data as a person goes about his/her daily activities. Collecting data over a longer period of time (e.g., hours or days, as opposed to a few seconds in a store or doctor's office) may allow for the creation of a custom insole suited to actual conditions in a person's daily life.

[0012] Referring now to the drawings, FIG. 1 is a block diagram of an example device 100 that includes a machine-readable storage medium encoded with instructions to enable generating specifications for an orthosis. In some implementations, device 100 may be embedded in a diagnostic insole or other limb support structure (e.g., for a hand, shoulder, ankle, or knee). In some implementations, device 100 may be an electronic user device, such as a notebook computer, a desktop computer, a workstation, a tablet computing device, or a mobile phone. In FIG. 1, device 100 includes processor 102 and machine-readable storage medium 104. As used herein, the terms "include", "have", and "comprise" are interchangeable and should be understood to have the same meaning.

[0013] Processor 102 may include a central processing unit (CPU), microprocessor (e.g., semiconductor-based microprocessor), and/or other hardware device suitable for retrieval and/or execution of instructions stored in machine-readable storage medium 104. Processor 102 may fetch, decode, and/ or execute instructions 106, 108, 110, and 112 to enable generating specifications for an orthosis, as described below. As an alternative or in addition to retrieving and/or

executing instructions, processor 102 may include an electronic circuit comprising a number of electronic components for performing the functionality of instructions 106, 108, 110, and/or 112.

[0014] Machine-readable storage medium 104 may be any suitable electronic, magnetic, optical, or other physical storage device that contains or stores executable instructions. Thus, machine-readable storage medium 104 may include, for example, a RAM, an Electrically Erasable Programmable Read-Only Memory (EEPROM), a storage device, an optical disc, and the like. In some implementations, machine-readable storage medium 104 may include a non-transitory storage medium, where the term "non-transitory" does not encompass transitory propagating signals. As described in detail below, machine-readable storage medium 104 may be encoded with a set of executable instructions 106, 108, 110, and 112.

[0015] Instructions 106 may collect data from a plurality of pressure sensors. The plurality of pressure sensors may be in various locations on a diagnostic insole. For example, a diagnostic insole having the plurality of pressure sensors may be placed in a person's shoe, and data may be collected from the plurality of pressure sensors as the person goes about his/her daily routine. Data collected from the plurality of pressure sensors may include pressure values. Each pressure value may indicate an amount of pressure applied to one of the plurality of pressure sensors at a certain time. In some implementations, data may be collected from the plurality of pressure sensors over a plurality of days.

[0016] Although example implementations discussed herein refer to a diagnostic insole, it should be understood that the concepts discussed herein may be applicable to diagnostic support structures for other parts of the body (e.g., hand, shoulder, ankle, knee). Pressure sensors may be placed on a diagnostic insole/other support structure worn by a person as the person goes about his/her normal activities. Data collected by the pressure sensors may be used to create a custom insole or other customized support structure (orthosis) that suits the person's individual needs. Although example implementations discussed herein refer to orthoses worn by humans, it should be understood that the concepts discussed herein may be applicable to orthoses worn by animals.

[0017] Instructions 108 may generate a first set of histograms. A histogram may have a plurality of value ranges ("bins"), and each value range may include data

values in the respective value range. Each histogram in the first set of histograms may correspond to a respective one of the plurality of pressure sensors, and may characterize a distribution of data collected from the respective one of the plurality of pressure sensors. For example, the plurality of pressure sensors may include a pressure sensor in the heel region of a diagnostic insole, and another pressure sensor in the big-toe region of the diagnostic insole. A histogram in the first set of histograms may correspond to the pressure sensor in the heel region, and may have a plurality of bins into which pressure values collected from the heel-region pressure sensor are sorted (e.g., a first bin may have pressure values between 0 and 1.5 pounds per square inch [psi], a second bin may have pressure values greater than 1.5 psi up to 3 psi, etc.). Another histogram in the first set of histograms may correspond to the pressure sensor in the big-toe region, and may have a plurality of bins into which pressure values collected from the big-toe-region pressure sensor are sorted.

[0018] The number of values in a bin of a histogram may be directly proportional to the amount of time the respective pressure sensor sensed an amount of pressure in the value range of the bin. For example, if a person tends to stand/walk/run on the balls of his/her feet, a histogram, in the first set of histograms generated from data collected from a diagnostic insole worn by the person, that corresponds to a pressure sensor in the big-toe region of the diagnostic insole may have a lot of data values in higher-value bins, while lower-value bins may not have as many data values. A histogram, in the first set of histograms, that corresponds to a pressure sensor in the heel region of the diagnostic insole may have a lot of data values in lower-value bins, while higher-value bins may not have as many data values.

[0019] Instructions 110 may generate a second set of histograms. Each histogram in the second set of histograms may correspond to a respective pair of the plurality of pressure sensors, and may characterize a distribution of averages of data collected from the respective pair of the plurality of pressure sensors. Pressure sensors in the plurality of pressure sensors may be paired based on physical proximity; for example, a pressure sensor in the big-toe region of a diagnostic insole may be paired with a pressure sensor in the ball-of-the-foot region of the diagnostic insole, and two pressure sensors in the heel region of the diagnostic insole may be paired together.

[0020] For each pair of pressure sensors, data values corresponding to the same time may be averaged, and a histogram may be generated using the averaged values. For example, a first pressure sensor may collect 100 data values over a period of time, and a second pressure sensor paired with the first pressure sensor may collect 100 data values over the same period of time. Each of the 100 data values collected from the first pressure sensor may reflect an amount of pressure applied to the first pressure sensor at a particular point in time, and each of the 100 data values collected from the second pressure sensor may reflect an amount of pressure applied to the second pressure sensor at those same times. Each of the 100 data values collected from the first pressure sensor may be averaged with the one of the 100 data values collected from the second pressure sensor that corresponds to the same time, such that 100 average values are created. A histogram may be generated using these 100 average values. A histogram corresponding to a pair of pressure sensors may allow pressure values at a location halfway between the pair of sensors to be inferred (e.g., the histogram generated using average values may be used to infer the distribution of data values that would have been collected if another pressure sensor had been placed halfway between the pair of pressure sensors whose data was averaged).

[0021] Instructions 112 may generate, based on the first and second sets of histograms, specifications for an orthosis. The specifications may include thickness and density measurements for various regions of the orthosis. In some implementations, regions of the orthosis where a person tends to put more pressure may be thinner than regions of the orthosis where the person tends to put less pressure. For example, for a person who tends to stand/walk/run on his/her heels, histograms corresponding to pressure sensors (or groups of pressure sensors) in the heel region of a diagnostic insole may have a high concentration of data values in higher value bins, and histograms corresponding to pressure sensors (or groups of pressure sensors) at the other end of the diagnostic insole (where the person's toes are) may have a high concentration of data values in lower value bins. Specifications for a custom insole may indicate that the custom insole should be thinner in the heel region than in the region under/near the toes. The amount of the difference in thickness may be determined based on how much greater data values collected from

the heel region are than data values collected from the region under/ near the toes (e.g., the great the difference in data values, the greater the difference in thickness).

[0022] In some implementations, regions of the orthosis where a person tends to put more pressure may be denser than regions of the orthosis where the person tends to put less pressure. For example, for a person who tends to shift weight toward the outer edges of his/her feet, histograms corresponding to pressure sensors (or groups of pressure sensors) along the outer edge of a diagnostic insole may have a high concentration of data values in higher value bins, and histograms corresponding to pressure sensors (or groups of pressure sensors) along the inner edge of the diagnostic insole may have a high concentration of data values in lower value bins. Specifications for a custom insole may indicate that the custom insole should be denser along the outer edge than along the inner edge (e.g., since the person may feel more comfortable having more cushioning/support along the outer edge, where more weight is shifted). The higher the value ranges are of the bins in which data values are concentrated, the denser an orthosis may be in the relevant region.

[0023] FIG. 2 is a block diagram of an example device 200 that includes a machine-readable storage medium encoded with instructions to filter pressure values. In some implementations, device 200 may be embedded in a diagnostic insole or other limb support structure (e.g., for a hand, shoulder, ankle, or knee). In some implementations, device 200 may be an electronic user device, such as a notebook computer, a desktop computer, a workstation, a tablet computing device, or a mobile phone. In FIG. 2, device 200 includes processor 202 and machine-readable storage medium 204.

[0024] As with processor 102 of FIG. 1, processor 202 may include a CPU, microprocessor (e.g., semiconductor-based microprocessor), and/or other hardware device suitable for retrieval and/or execution of instructions stored in machine-readable storage medium 204. Processor 202 may fetch, decode, and/ or execute instructions 206, 208, 210, 212, 214, 216, and 218. As an alternative or in addition to retrieving and/or executing instructions, processor 202 may include an electronic circuit comprising a number of electronic components for performing the functionality of instructions 206, 208, 210, 212, 214, 216, and/or 218.

[0025] As with machine-readable storage medium 104 of FIG. 1, machine-readable storage medium 204 may be any suitable physical storage device that

stores executable instructions. Instructions 206, 208, 210, and 212 on machine-readable storage medium 204 may be analogous to (e.g., have functions and/or components similar to) instructions 106, 108, 110, and 112, respectively, on machine-readable storage medium 104. Instructions 206 may collect data from a plurality of pressure sensors, and instructions 208 and 210 may generate a first set and a second set of histograms, respectively. Instructions 214 may generate a third set of histograms. Each histogram in the third set of histograms may correspond to a respective triplet of the plurality of pressure sensors, and may characterize a distribution of averages of data collected from the respective triplet of the plurality of pressure sensors. Pressure sensors in the plurality of pressure sensors may be grouped into triplets based on physical proximity. For example, three pressure sensors in the heel region of a diagnostic insole may be grouped together in a triplet. Three pressure sensors in or near the ball-of-the-foot region of the diagnostic insole may be grouped together in another triplet.

[0026] For each triplet of pressure sensors, data values corresponding to the same time may be averaged, and a histogram may be generated using the averaged values. For example, a first pressure sensor may collect 100 data values over a period of time, a second pressure sensor in the same triplet as the first pressure sensor may collect 100 data values over the same period of time, and a third pressure sensor in the same triplet may collect 100 data values over the same period of time. Each of the 100 data values collected from the first pressure sensor may reflect an amount of pressure applied to the first pressure sensor at a particular point in time, and each of the 100 data values collected from each of the second and third pressure sensors may reflect an amount of pressure applied to the second and third pressure sensors, respectively, at those same times. Each of the 100 data values collected from the first pressure sensor may be averaged with the one of the 100 data values collected from the second pressure sensor, and the one of the 100 data values collected from the third pressure sensor, that correspond to the same time, such that 100 average values are created. A histogram may be generated using these 100 average values. A histogram corresponding to a triplet of pressure sensors may allow pressure values at a location in the middle of the triplet of sensors to be inferred (e.g., the histogram generated using average values may be used to infer the distribution of data values that would have been collected if another pressure sensor had been

placed in the middle of the triplet of pressure sensors whose data was averaged). Instructions 212 may generate specifications for an orthosis based on the first, second, and third sets of histograms. The generation of specifications based on averages of data values may allow the resulting orthosis to be better customized for more regions of a person's foot/other body part.

[0027] As discussed above with respect to FIG. 1, data collected from the plurality of pressure sensors may include pressure values. Each pressure value may indicate an amount of pressure applied to one of the plurality of pressure sensors at a certain time. Instructions 216 may filter out pressure values below a threshold value. For example, instructions 216 may filter out pressure values below 0.5 psi. Data below the threshold value may have been collected during times when a person was not putting pressure on his/her feet, for example when the person was sitting or lying down. Filtered-out pressure values may not be used to generate the first and second sets of histograms. If a third set of histograms is generated, filtered-out pressure values may not be used to generate the third set of histograms. The exclusion of filtered-out pressure values from generated histograms may allow the histograms to more accurately characterize pressure values collected when a person is on his/her feet, and thus allow more accurate specifications for an orthosis (e.g., custom insole) to be generated.

[0028] Instructions 218 may calculate, for each of the plurality of pressure sensors, an average of pressure values collected from the respective pressure sensor. For example, if a person wore a diagnostic insole for three days, an average of all pressure values collected over the three days by a particular pressure sensor on the diagnostic insole may be calculated. An average may be calculated for each pressure sensor on the diagnostic insole. In some implementations, filtered-out pressure values may not be included when calculating an average of pressure values for a pressure sensor. Specifications for an orthosis may be generated based on the calculated averages. For example, for a person who tends to stand/walk/run on his/her heels, an average of pressure values collected by a pressure sensor in the heel region of a diagnostic insole may be higher than an average of pressure values collected by a pressure sensor in the big-toe region of the diagnostic insole. Specifications for a custom insole may indicate that the custom insole should be thinner in the heel region than in the big-toe region. The amount of the difference in

thickness may be determined based on how much greater the average pressure value for the pressure sensor in the heel region is than the average pressure value for the pressure sensor in the big-toe region (e.g., the great the difference in average pressure values, the greater the difference in thickness; the higher the average pressure value, the thinner the custom insole in the corresponding region).

[0029] In some implementations, specifications for an orthosis may include support values that correspond to respective thicknesses and/or densities of material. For example, support values may be assigned to various regions of an orthosis based on numerical values of averages of pressure values collected from pressure sensors in the respective regions, relative values of averages of pressure values collected from pressure sensors in the respective regions compared to averages of pressure values collected from pressure sensors in other regions, and/or where data values are concentrated in histograms corresponding to pressure sensors (or groups of pressure sensors) in the respective regions. Higher support values may correspond to lower thickness measurements and/or higher density measurements. In some implementations, a first support value for thickness and a second support value for density may be generated for each region (e.g., determined based on locations of pressure sensors in a diagnostic insole) of an orthosis.

[0030] FIG. 3 is a block diagram of an example system 300 for generating specifications for an orthosis. System 300 may include a plurality of pressure sensors 302, storage module 304, histogram module 306, and specifications module 308. A module may include a set of instructions encoded on a machine-readable storage medium and executable by a processor of system 300. In addition or as an alternative, a module may include a hardware device comprising electronic circuitry for implementing the functionality described below.

[0031] The plurality of pressure sensors 302 may be in various locations on a diagnostic insole or other diagnostic support structure. For example, a diagnostic insole having the plurality of pressure sensors 302 may be placed in a person's shoe, and data may be collected from the plurality of pressure sensors 302 as the person goes about his/her daily routine. Data collected from the plurality of pressure sensors 302 may include pressure values. Each pressure value may indicate an amount of pressure applied to one of the plurality of pressure sensors at a certain time.

[0032] Storage module 304 may store data collected from the plurality of pressure sensors 302. In some implementations, the stored data may include data collected from the plurality of pressure sensors 302 over a plurality of days. In some implementations, storage module 304 may be embedded in a diagnostic insole/ other support structure. In some implementations, storage module 304 may be on a separate device from the diagnostic insole/other support structure. For example, storage module 304 may be on a person's smartphone. Data collected from the plurality of pressure sensors 302 may be wirelessly transmitted to the person's smartphone and stored by storage module 304.

[0033] Histogram module 306 may generate a plurality of histograms based on the stored data. In some implementations, histogram module 306 may be embedded in a diagnostic insole/other support structure. In some implementations, histogram module 306 may be on a separate device from the diagnostic insole/ other support structure (e.g., on a person's smartphone or on a server to which collected/stored data is transmitted). The plurality of histograms may include a first set of histograms and a second set of histograms. Each histogram in the first set of histograms may correspond to a respective one of the plurality of pressure sensors, and may characterize a distribution of data collected from the respective one of the plurality of pressure sensors. The number of values in a bin of a histogram may be directly proportional to the amount of time the respective pressure sensor sensed an amount of pressure in the value range of the bin, as discussed above with respect to FIG. 1. Each histogram in the second set of histograms may correspond to a respective pair of the plurality of pressure sensors 302, and may characterize a distribution of averages of data collected from the respective pair of the plurality of pressure sensors 302. Pressure sensors in the plurality of pressure sensors 302 may be paired based on physical proximity, as discussed above with respect to FIG. 1.

[0034] In some implementations, the plurality of histograms may include a third set of histograms. Each histogram in the third set of histograms may correspond to a respective triplet of the plurality of pressure sensors 302, and may characterize a distribution of averages of data collected from the respective triplet of the plurality of pressure sensors 302. Pressure sensors in the plurality of pressure sensors 302 may be grouped into triplets based on physical proximity, as discussed above with respect to FIG. 2.

[0035] Specifications module 308 may generate, based on the plurality of histograms, specifications for an orthosis. In some implementations, specifications module 308 may be embedded in a diagnostic insole/other support structure. In some implementations, specifications module 308 may be on a separate device from the diagnostic insole/other support structure (e.g., on a person's smartphone or on a server to which collected/stored data is transmitted). The specifications may include thickness and density measurements for various regions of the orthosis. The regions may correspond to locations of pressure sensors in a diagnostic insole/other support structure. In some implementations, regions of the orthosis where a person tends to put more pressure may be thinner and/or denser than regions of the orthosis where the person tends to put less pressure, as discussed above with respect to FIG. 1.

[0036] FIG. 4 is a block diagram of an example system 400 for processing data collected by pressure sensors. System 400 may include a plurality of pressure sensors 402, storage module 404, histogram module 406, specifications module 408, filter module 410, and averages module 412. A module may include a set of instructions encoded on a machine-readable storage medium and executable by a processor of system 400. In addition or as an alternative, a module may include a hardware device comprising electronic circuitry for implementing the functionality described below.

[0037] The plurality of pressure sensors 402 of system 400 may be analogous to the plurality of pressure sensors 302 of FIG. 3. Modules 404, 406, and 408 of system 400 may be analogous to modules 304, 306, and 308 of system 300. Storage module 404 may store data collected from the plurality of pressure sensors 402. The stored data may include pressure values. Each pressure value may indicate an amount of pressure applied to one of the plurality of pressure sensors at a certain time. In some implementations, the stored data may include data collected from the plurality of pressure sensors 402 over a plurality of days.

[0038] Filter module 410 may filter out pressure values below a threshold value. In some implementations, filter module 410 may be embedded in a diagnostic insole/other support structure. In some implementations, filter module 410 may be on a separate device from the diagnostic insole/other support structure (e.g., on a person's smartphone or on a server to which collected/stored data is transmitted). Data below the threshold value may have been collected during times when a person

was not putting pressure on his/her feet, for example when the person was sitting or lying down. Filtered-out pressure values may not be used to generate the plurality of histograms. The exclusion of filtered-out pressure values from generated histograms may allow the histograms to more accurately characterize pressure values collected when a person is on his/her feet, and thus allow more accurate specifications for an orthosis (e.g., custom insole) to be generated.

[0039] Averages module 412 may calculate, for each of the plurality of pressure sensors 402, an average of pressure values collected from the respective pressure sensor. For example, if a person wore a diagnostic insole for two days, an average of all pressure values collected over the two days by a particular pressure sensor on the diagnostic insole may be calculated. An average may be calculated for each pressure sensor on the diagnostic insole. In some implementations, filtered-out pressure values may not be included when calculating an average of pressure values for a pressure sensor. In some implementations, averages module 412 may be embedded in a diagnostic insole/other support structure. In some implementations, averages module 412 may be on a separate device from the diagnostic insole/other support structure (e.g., on a person's smartphone or on a server to which collected/stored data is transmitted). Specifications module 408 may generate specifications for an orthosis based on the calculated averages, as discussed above with respect to FIG. 2. In some implementations, specifications for an orthosis may include support values that correspond to respective thicknesses and/or densities of material, as discussed above with respect to FIG. 2.

[0040] Methods related to collecting data from pressure sensors for purposes of creating a custom orthosis are discussed with respect to FIGS. 5-7. FIG. 5 is a flowchart of an example method 500 for generating support values for an orthosis. Although execution of method 500 is described below with reference to processor 102 of FIG. 1, it should be understood that execution of method 500 may be performed by other suitable devices, such as processor 202 of FIG. 2. Method 500 may be implemented in the form of executable instructions stored on a machine-readable storage medium and/or in the form of electronic circuitry.

[0041] Method 500 may start in block 502, where processor 102 may collect, over a plurality of days, data from a plurality of pressure sensors. The plurality of pressure sensors may be in various locations on a diagnostic insole. For example,

a diagnostic insole having the plurality of pressure sensors may be placed in a person's shoe, and data may be collected from the plurality of pressure sensors as the person goes about his/her daily routine during the plurality of days. Data collected from the plurality of pressure sensors may include pressure values. Each pressure value may indicate an amount of pressure applied to one of the plurality of pressure sensors at a certain time.

[0042] In block 504, processor 102 may generate a first set of histograms. Each histogram in the first set of histograms may correspond to a respective one of the plurality of pressure sensors, and may characterize a distribution of data collected from the respective one of the plurality of pressure sensors. The number of values in a bin of a histogram may be directly proportional to the amount of time the respective pressure sensor sensed an amount of pressure in the value range of the bin, as discussed above with respect to FIG. 1.

[0043] In block 506, processor 102 may generate a second set of histograms. Each histogram in the second set of histograms may correspond to a respective pair of the plurality of pressure sensors, and may characterize a distribution of averages of data collected from the respective pair of the plurality of pressure sensors. Pressure sensors in the plurality of pressure sensors may be paired based on physical proximity, as discussed above with respect to FIG. 1. Although block 506 is shown below block 504 in FIG. 5, it should be understood that elements of block 506 may be performed before or in parallel with elements of block 504.

[0044] In block 506, processor 102 may generate, based on the first and second sets of histograms, support values for an orthosis. A support value may correspond to a particular thickness and/or density of material. In some implementations, support values may be assigned to various regions of an orthosis based on numerical values of averages of pressure values collected from pressure sensors in the respective regions, relative values of averages of pressure values collected from pressure sensors in the respective regions compared to averages of pressure values collected from pressure sensors in other regions, and/or where data values are concentrated in histograms, of the first and second sets of histograms, corresponding to pressure sensors (or groups of pressure sensors) in the respective regions. Higher support values may correspond to lower thickness measurements and/or higher density measurements. In some implementations, a first support value

for thickness and a second support value for density may be generated for each region (e.g., determined based on locations of pressure sensors in a diagnostic insole) of an orthosis.

[0045] FIG. 6 is a flowchart of an example method 600 for generating a model for a three-dimensional (3D) printer to print an orthosis. Although execution of method 600 is described below with reference to processor 202 of FIG. 2, it should be understood that execution of method 600 may be performed by other suitable devices, such as processor 102 of FIG. 1. Some blocks of method 600 may be performed in parallel with and/or after method 500. Method 600 may be implemented in the form of executable instructions stored on a machine-readable storage medium and/or in the form of electronic circuitry.

[0046] Method 600 may start in block 602, where processor 202 may generate a first set of histograms. In block 604, processor 202 may generate a second set of histograms. Blocks 602 and 604 of FIG. 6 may be analogous to blocks 504 and 506, respectively of FIG. 5. Although block 604 is shown below block 602 in FIG. 6, it should be understood that elements of block 604 may be performed before or in parallel with elements of block 602.

[0047] In block 606, processor 202 may generate a third set of histograms. Each histogram in the third set of histograms may correspond to a respective triplet of a plurality of pressure sensors, and may characterize a distribution of averages of data collected from the respective triplet of the plurality of pressure sensors. Pressure sensors in the plurality of pressure sensors may be grouped into triplets based on physical proximity, as discussed above with respect to FIG. 2.

[0048] In block 608, processor 202 may generate support values for an orthosis based on the first, second, and third sets of histograms. In some implementations, support values may be assigned to various regions of an orthosis based on where data values are concentrated in histograms, of the first, second, and third sets of histograms, corresponding to pressure sensors (or groups of pressure sensors) in the respective regions. For example, if a histogram corresponding to a first pressure sensor has a high concentration of data values in high-value bins, a high support value may be generated for a region of an orthosis corresponding to the location of the first pressure sensor. If a histogram corresponding to a second pressure sensor has a high concentration of data values in low-value bins, a low

support value may be generated for a region of the orthosis corresponding to the location of the second pressure sensor. In some implementations, a first support value for thickness and a second support value for density may be generated for each region (e.g., determined based on locations of pressure sensors in a diagnostic insole) of an orthosis.

[0049] In block 610, processor 202 may determine, based on the support values, thickness and density measurements for various regions of the orthosis. A support value may correspond to a particular thickness and/or density of material. Higher support values may correspond to lower thickness measurements and/or higher density measurements.

[0050] In block 612, processor 202 may smooth support values to generate a model for the orthosis. For example, fifteen support values may be generated, each corresponding to a respective region of the orthosis and to a respective thickness and/or density for the respective region. Processor 202 may apply a smoothing function, such as a moving average function, to the fifteen support values to allow a more gradual transition in thickness and/or density between different regions. The generated model may be used by a 3D printer to print the orthosis. Thus, a 3D printer may be used to print the orthosis without scanning a person's foot or a cast/ mold of the person's foot.

[0051] FIG. 7 is a flowchart of an example method 700 for processing data collected by pressure sensors. Although execution of method 700 is described below with reference to processor 202 of FIG. 2, it should be understood that execution of method 700 may be performed by other suitable devices, such as processor 102 of FIG. 1. Some blocks of method 700 may be performed in parallel with and/or after method 500 and/or 600. Method 700 may be implemented in the form of executable instructions stored on a machine-readable storage medium and/or in the form of electronic circuitry.

[0052] Method 700 may start in block 702, where processor 202 may collect data from a plurality of pressure sensors. The plurality of pressure sensors may be in various locations on a diagnostic insole. For example, a diagnostic insole having the plurality of pressure sensors may be placed in a person's shoe, and data may be collected from the plurality of pressure sensors as the person goes about his/her daily routine. Data collected from the plurality of pressure sensors may include

pressure values. Each pressure value may indicate an amount of pressure applied to one of the plurality of pressure sensors at a certain time. In some implementations, data may be collected from the plurality of pressure sensors over a plurality of days.

[0053] In block 704, processor 202 may filter out pressure values below a threshold value. For example, processor 202 may filter out pressure values below 0.3 psi. Data below the threshold value may have been collected during times when a person was not putting pressure on his/her feet, for example when the person was sitting or lying down.

[0054] In block 706, processor 202 may generate a plurality of histograms. The plurality of histograms may include a first set of histograms that characterize a distribution of data collected from respective ones of the plurality of pressure sensors, and a second set of histograms that characterize a distribution of averages of data collected from respective pairs of the plurality of pressure sensors, as discussed above with respect to FIG. 1. Filtered-out pressure values may not be used to generate the first and second sets of histograms. In some implementations, the plurality of histograms may include a third set of histograms that characterize a distribution of averages of data collected from respective triplets of the plurality of pressure sensors, as discussed above with respect to FIG. 2. Filtered-out pressure values may not be used to generate the third set of histograms. The exclusion of filtered-out pressure values from generated histograms may allow the histograms to more accurately characterize pressure values collected when a person is on his/her feet, and thus allow more accurate specifications for an orthosis (e.g., custom insole) to be generated.

[0055] In block 708, processor 202 may calculate, for each of the plurality of pressure sensors, an average of pressure values collected from the respective pressure sensor. For example, if a person wore a diagnostic insole for three days, processor 202 may calculate an average of all pressure values collected over the three days by a particular pressure sensor on the diagnostic insole. Processor 202 may calculate an average for each pressure sensor on the diagnostic insole. In some implementations, filtered-out pressure values may not be included when calculating an average of pressure values for a pressure sensor.

[0056] In block 710, processor 202 may generate support values based on the plurality of histograms and the calculated averages. In some implementations,

support values may be assigned to various regions of an orthosis based on numerical values of averages of pressure values collected from pressure sensors in the respective regions, relative values of averages of pressure values collected from pressure sensors in the respective regions compared to averages of pressure values collected from pressure sensors in other regions, and/or where data values are concentrated in histograms corresponding to pressure sensors (or groups of pressure sensors) in the respective regions. Support values may correspond to respective thicknesses and/or densities of material, as discussed above with respect to FIG. 2. In some implementations, a first support value for thickness and a second support value for density may be generated for each region (e.g., determined based on locations of pressure sensors in a diagnostic insole) of an orthosis.

[0057] The foregoing disclosure describes using a diagnostic insole/other support structure having a plurality of pressure sensors to collect data as a person goes about his/her daily activities. Example implementations described herein enable the creation of a custom orthosis suited to actual conditions in a person's daily life.

I claim:

1. A machine-readable storage medium encoded with instructions executable by a processor, the machine-readable storage medium comprising:

instructions to collect data from a plurality of pressure sensors;

instructions to generate a first set of histograms, wherein each histogram in the first set of histograms:

corresponds to a respective one of the plurality of pressure sensors, and

characterizes a distribution of data collected from the respective one of the plurality of pressure sensors;

instructions to generate a second set of histograms, wherein each histogram in the second set of histograms:

corresponds to a respective pair of the plurality of pressure sensors, and

characterizes a distribution of averages of data collected from the respective pair of the plurality of pressure sensors; and

instructions to generate, based on the first and second sets of histograms, specifications for an orthosis.

2. The machine-readable storage medium of claim 1, further comprising instructions to generate a third set of histograms, wherein:

each histogram in the third set of histograms corresponds to a respective triplet of the plurality of pressure sensors;

each histogram in the third set of histograms characterizes a distribution of averages of data collected from the respective triplet of the plurality of pressure sensors; and

specifications for the orthosis are generated based on the first, second, and third sets of histograms.

3. The machine-readable storage medium of claim 1, wherein the collected data comprises pressure values, each pressure value indicating an amount of pressure applied to one of the plurality of pressure sensors at a certain time, the

machine-readable storage medium further comprising instructions to filter out pressure values below a threshold value, and wherein filtered-out pressure values are not used to generate the first and second sets of histograms.

4. The machine-readable storage medium of claim 1, wherein data is collected from the plurality of pressure sensors over a plurality of days.

5. The machine-readable storage medium of claim 1, wherein the collected data comprises pressure values, each pressure value indicating an amount of pressure applied to one of the plurality of pressure sensors at a certain time, the machine-readable storage medium further comprising instructions to calculate, for each of the plurality of pressure sensors, an average of pressure values collected from the respective pressure sensor, wherein specifications for the orthosis are generated based on the calculated averages.

6. The machine-readable storage medium of claim 1, wherein the specifications comprise thickness and density measurements for various regions of the orthosis.

7. A system comprising:

a plurality of pressure sensors;

a storage module to store data collected from the plurality of pressure sensors;

a histogram module to generate a plurality of histograms based on the stored data, the plurality of histograms comprising:

a first set of histograms, wherein each histogram in the first set of histograms:

corresponds to a respective one of the plurality of pressure sensors, and

characterizes a distribution of data collected from the respective one of the plurality of pressure sensors; and

a second set of histograms, wherein each histogram in the second set of histograms:

corresponds to a respective pair of the plurality of pressure sensors, and

characterizes a distribution of averages of data collected from the respective pair of the plurality of pressure sensors; and

a specifications module to generate, based on the plurality of histograms, specifications for an orthosis.

8. The system of claim 7, wherein:

the plurality of histograms further comprises a third set of histograms;

each histogram in the third set of histograms corresponds to a respective triplet of the plurality of pressure sensors; and

each histogram in the third set of histograms characterizes a distribution of averages of data collected from the respective triplet of the plurality of pressure sensors.

9. The system of claim 7, wherein the stored data comprises pressure values, each pressure value indicating an amount of pressure applied to one of the plurality of pressure sensors at a certain time, the system further comprising:

a filter module to filter out pressure values below a threshold value, wherein filtered-out pressure values are not used to generate the plurality of histograms; and

an averages module to calculate, for each of the plurality of pressure sensors, an average of pressure values collected from the respective pressure sensor, wherein the specifications module is further to generate specifications for the orthosis based on the calculated averages.

10. The system of claim 7, wherein the stored data comprises data collected from the plurality of pressure sensors over a plurality of days.

11. A method comprising:

collecting, over a plurality of days, data from a plurality of pressure sensors;

generating a first set of histograms, wherein each histogram in the first set of histograms:

corresponds to a respective one of the plurality of pressure sensors, and

characterizes a distribution of data collected from the respective one of the plurality of pressure sensors;

generating a second set of histograms, wherein each histogram in the second set of histograms:

corresponds to a respective pair of the plurality of pressure sensors, and

characterizes a distribution of averages of data collected from the respective pair of the plurality of pressure sensors; and

generating, based on the first and second sets of histograms, support values for an orthosis.

12. The method of claim 11, further comprising generating a third set of histograms, wherein:

each histogram in the third set of histograms corresponds to a respective triplet of the plurality of pressure sensors;

each histogram in the third set of histograms characterizes a distribution of averages of data collected from the respective triplet of the plurality of pressure sensors; and

support values for the orthosis are generated based on the first, second, and third sets of histograms.

13. The method of claim 11, further comprising determining, based on the support values, thickness and density measurements for various regions of the orthosis.

14. The method of claim 11, further comprising smoothing support values to generate a model for the orthosis, wherein the generated model is used by a three-dimensional (3D) printer to print the orthosis.

15. The method of claim 11, wherein the collected data comprises pressure values, each pressure value indicating an amount of pressure applied to one of the plurality of pressure sensors at a certain time, the method further comprising:

filtering out pressure values below a threshold value, wherein filtered-out pressure values are not used to generate the first and second sets of histograms; and

calculating, for each of the plurality of pressure sensors, an average of pressure values collected from the respective pressure sensor, wherein the support values are generated based on the calculated averages.

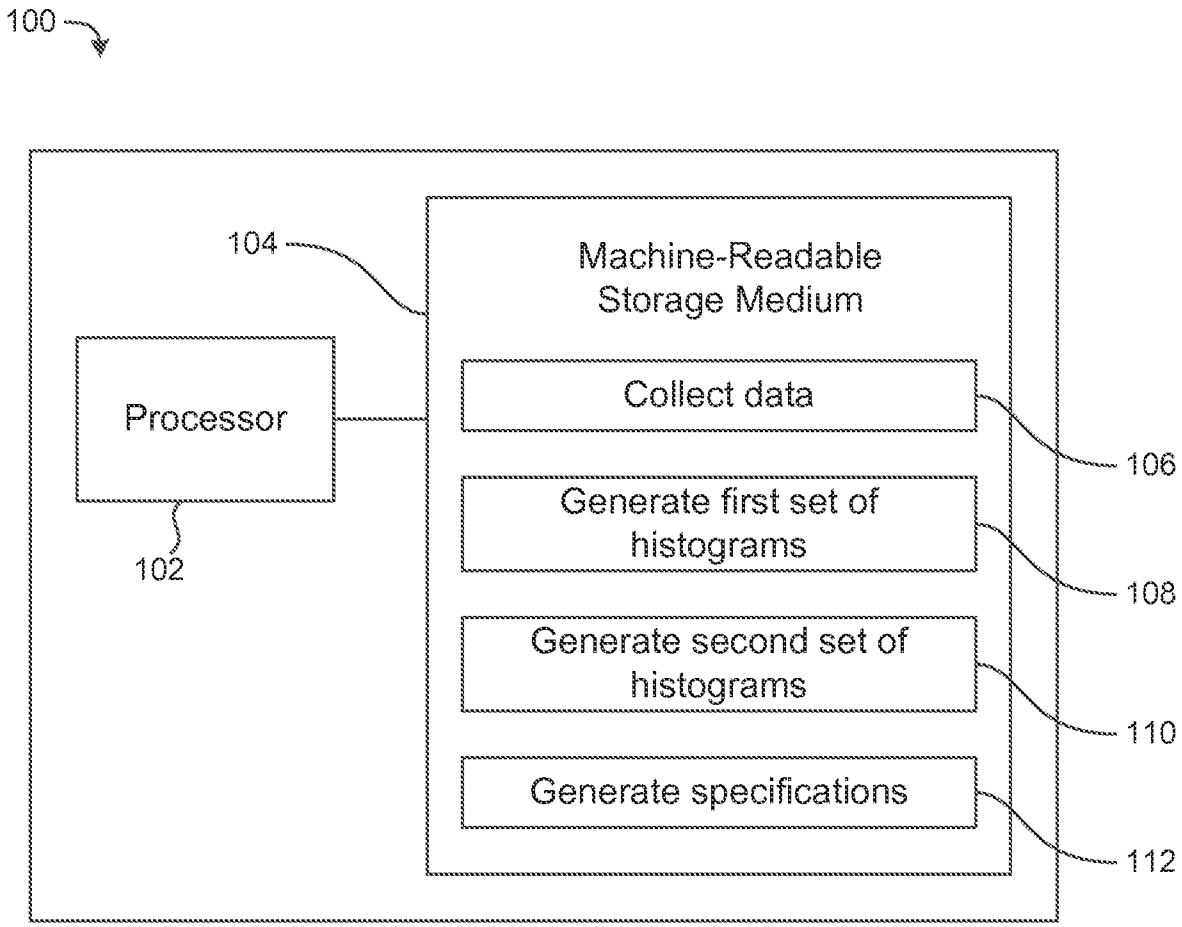

100
104
Machine-Readable Storage Medium
Processor
102
Collect data
106
Generate first set of histograms
108
Generate second set of histograms
110
Generate specifications
112

FIG. 1

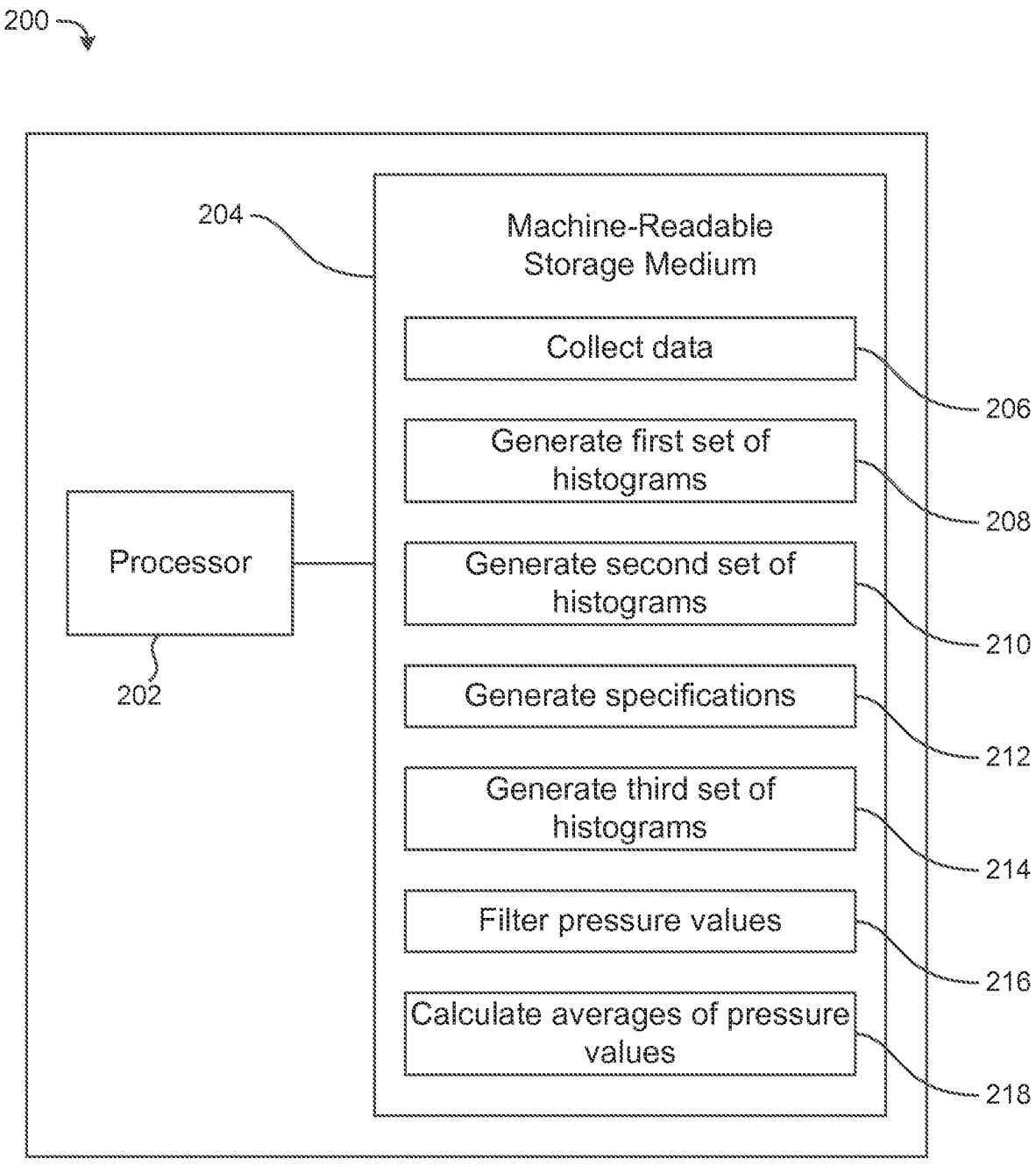

200
204
Machine-Readable Storage Medium
Collect data
206
Generate first set of histograms
208
Processor
Generate second set of histograms
210
202
Generate specifications
212
Generate third set of histograms
214
Filter pressure values
216
Calculate averages of pressure values
218

FIG. 2

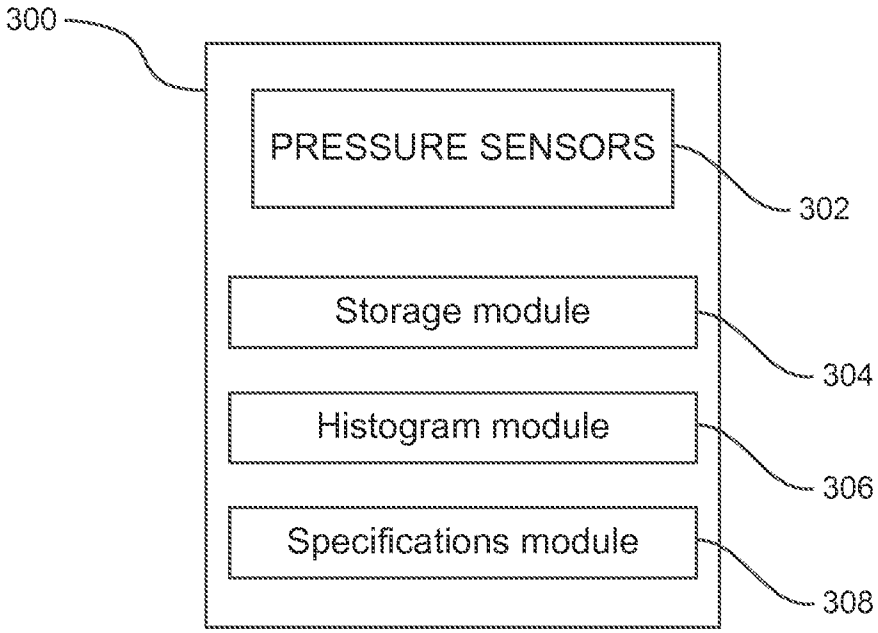

300
PRESSURE SENSORS
302
Storage module
304
Histogram module
306
Specifications module
308

FIG. 3

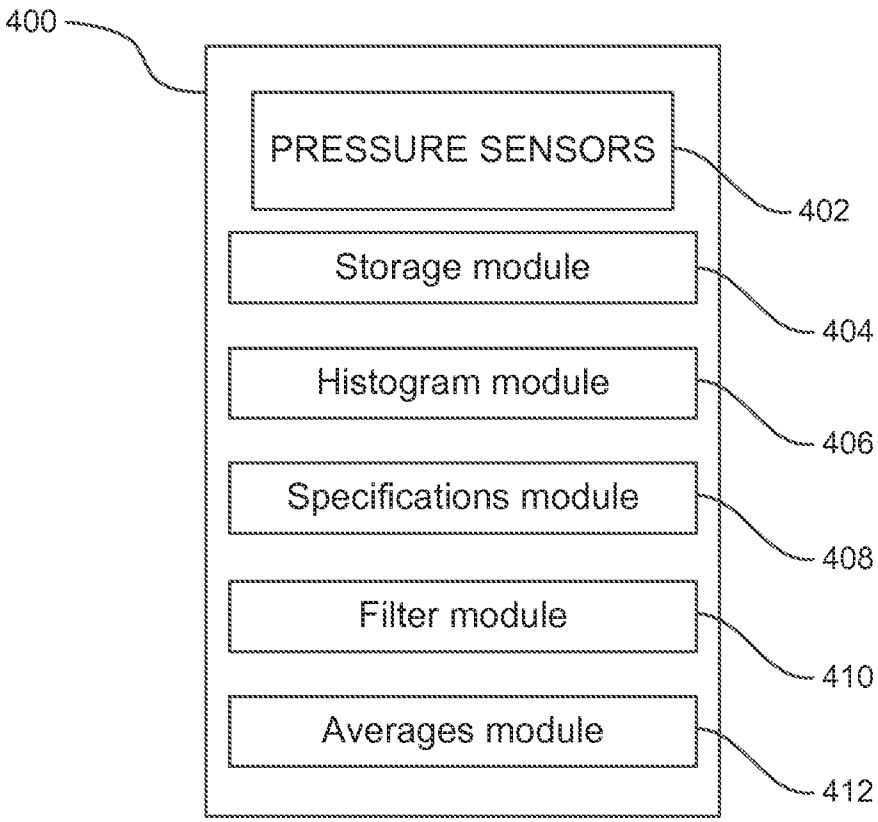

400
PRESSURE SENSORS
402
Storage module
404
Histogram module
406
Specifications module
408
Filter module
410
Averages module
412

FIG. 4

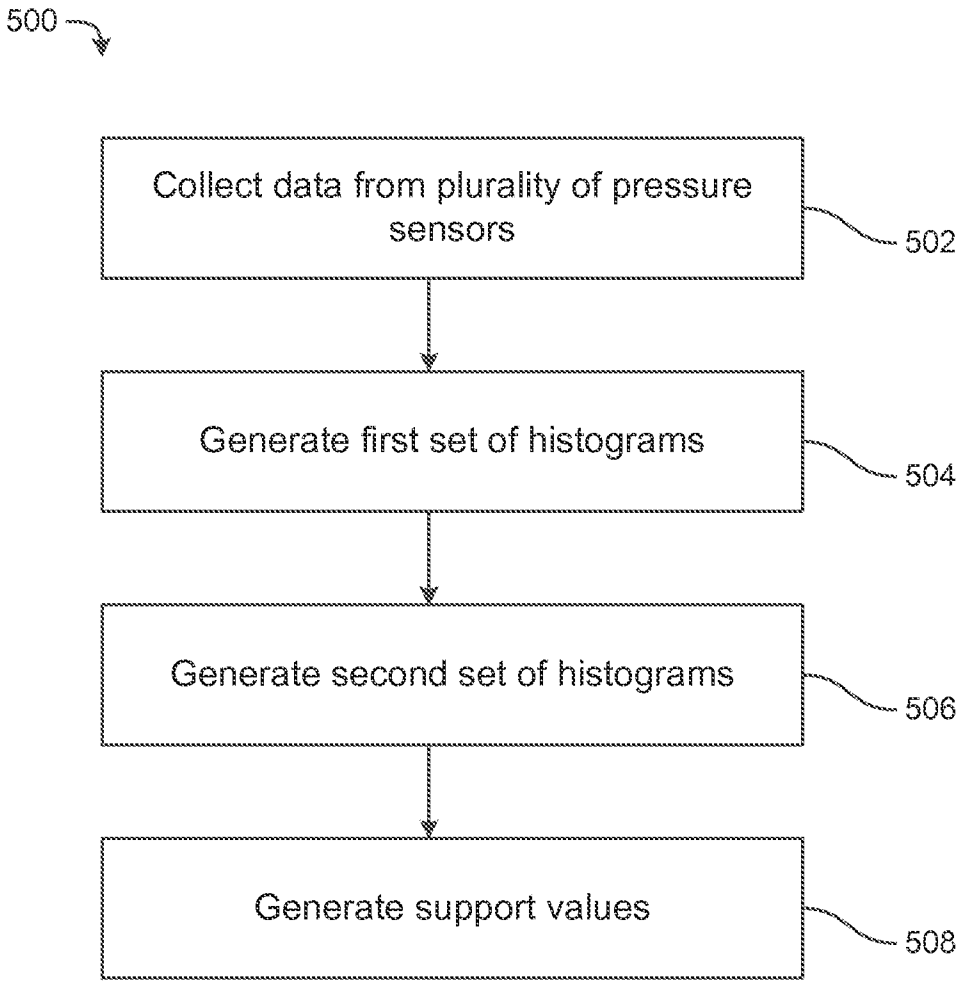

500
Collect data from plurality of pressure sensors
502
Generate first set of histograms
504
Generate second set of histograms
506
Generate support values
508

FIG. 5

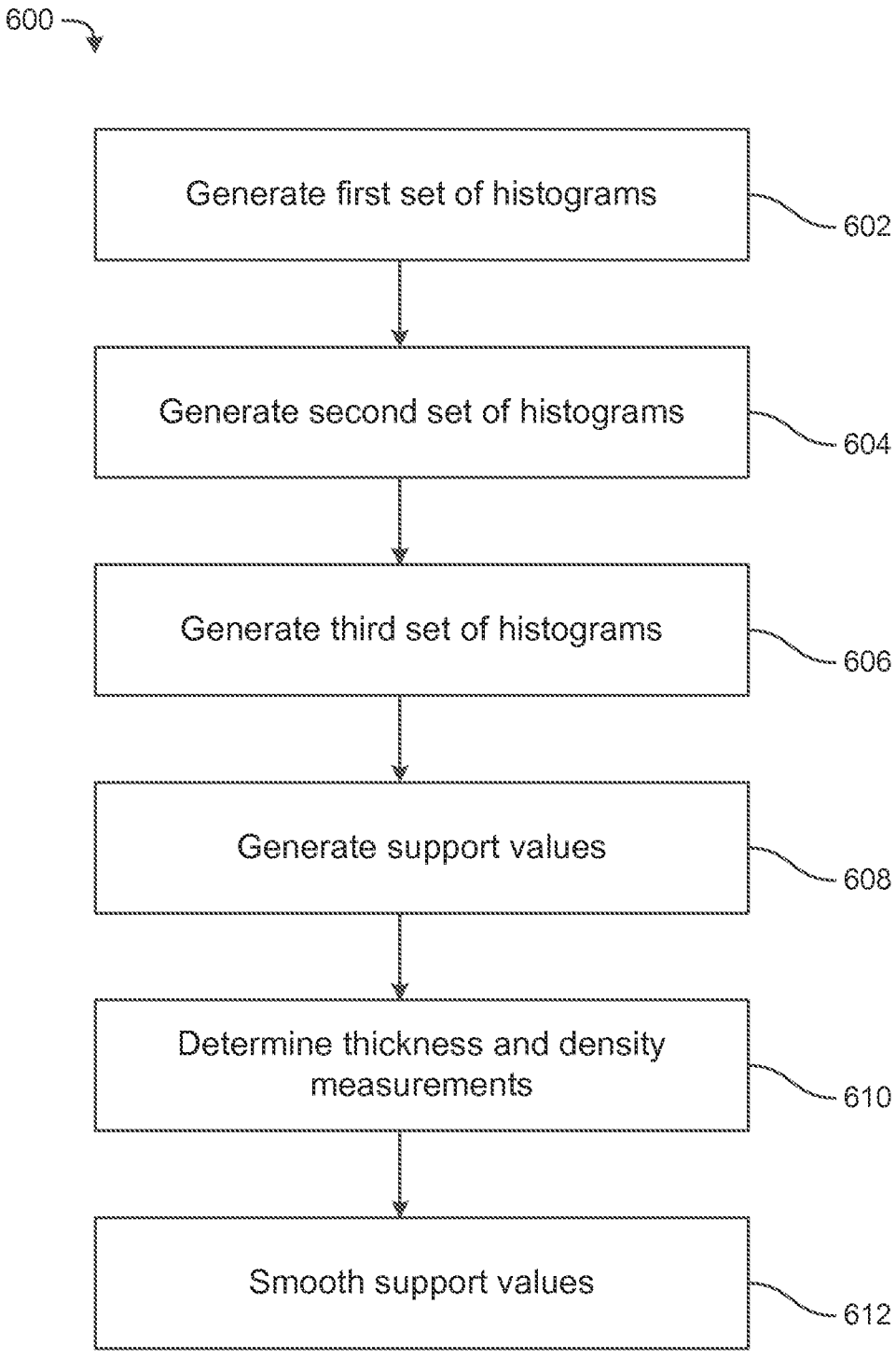

600
Generate first set of histograms
602
Generate second set of histograms
604
Generate third set of histograms
606
Generate support values
608
Determine thickness and density measurements
610
Smooth support values
612

FIG. 6

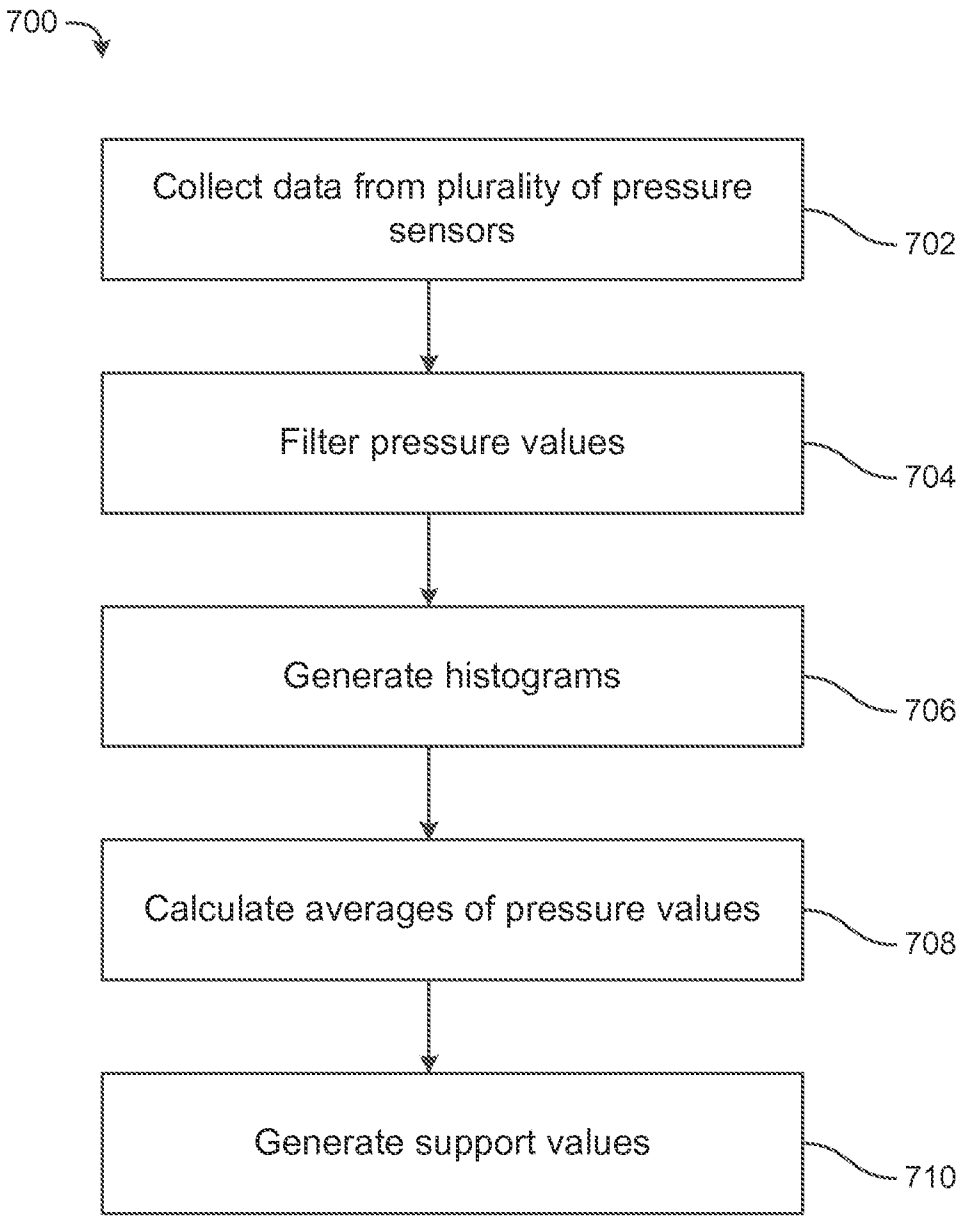

700
Collect data from plurality of pressure sensors
702
Filter pressure values
704
Generate histograms
706
Calculate averages of pressure values
708
Generate support values
710

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2014/044337

A. CLASSIFICATION OF SUBJECT MATTER

G06F 19/00(2011.01)i, A61F 2/76(2006.01)i, A61F 3/00(2006.01)i, A43B 13/38(2006.01)i

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)
G06F 19/00; A43B 13/38; G01D 9/00; G01K 13/00; A61B 5/103; A61F 2/76; A61F 3/00

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
eKOMPASS(KIPO internal) & Keywords: insole, pressure, sensor, distribution, histogram, and similar terms.

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2011-0214501 A1 (JANICE MARIE ROSS et al.) 08 September 2011 See paragraphs [0073], [0091] and [0107]-[0108]; claim 1; and figures 1, 10 and 19.	1-15
Y	US 2006-0070260 A1 (PETER R. CAVANAGH et al.) 06 April 2006 See paragraphs [0044]-[0045]; and figures 9A and 11.	1-15
A	US 6,183,425 B1 (ROBERT T. WHALEN et al.) 06 February 2001 See column 9, line 30 - column 10, line 11; and figures 6-9.	1-15
A	US 6,505,522 B1 (JEAN-PIERRE WILSSENS) 14 January 2003 See column 5, line19 - column 6, line 28; and figure 3.	1-15
A	US 2008-0109183 A1 (RAHMAT A. SHOURESHI et al.) 08 May 2008 See paragraphs [0018]-[0026]; and figure 1.	1-15

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

* Special categories of cited documents:
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"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
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"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	Date of mailing of the international search report
25 February 2015 (25.02.2015)	**25 February 2015 (25.02.2015)**

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.
PCT/US2014/044337

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