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(54) Title: BAROMETRIC INSTRUMENT AND METHOD

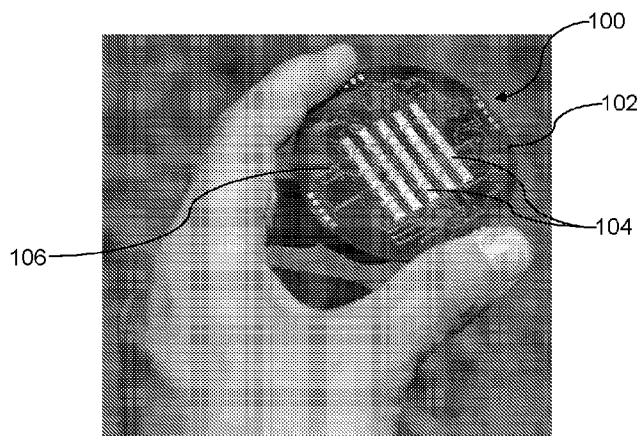


Figure 1A

(57) Abstract: The present disclosure generally relates to a barometric instrument (100) and method (200). The barometric instrument (100) comprises: a base (102); a plurality of pressure sensors (104) distributed on the base (102), each pressure sensor (104) representing a sensor position and configured for measuring a set of atmospheric pressure values at the respective sensor position; a gimbal assembly coupled to the base (102) for maintaining the pressure sensors (104) horizontally; and a processor (106) communicatively linked to the pressure sensors (104), the processor (106) configured for determining atmospheric pressure distribution on the sensor positions based on the measured sets of atmospheric pressure values, the atmospheric pressure distribution comprising a pressure gradient directed horizontally along the sensor positions.



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BAROMETRIC INSTRUMENT AND METHOD

Technical Field

5 The present disclosure generally relates to a barometric instrument and method. More particularly, the present disclosure describes various embodiments of a barometric instrument and a barometric method for determining pressure gradient and atmospheric pressure distribution based on measured sets of atmospheric pressure values.

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Background

Our daily activities are often influenced by the weather conditions for the day and we can mitigate risk of disruption to our activities by forecasting weather conditions.

15 Weather forecasting is performed by calculating probability of changes in the weather based on current weather parameters such as temperature, humidity, wind, clouds, rain, and so on. Although the weather parameters can be measured by various environment sensors, the sensors cannot forecast future weather conditions from the measured weather parameters. Other existing weather forecasting

20 technology rely on satellites (References [1], [2], and [3]) and weather observatories to estimate weather conditions by measuring the distribution of atmospheric pressure.

Satellites are able to sense weather conditions globally from images of visible light, infrared light, water vapor, and temperature. Atmospheric pressure can be estimated

25 from the images. If location information such as latitude and longitude coordinates at the desired place of observation is known, the atmospheric pressure at the place of observation can be estimated by tracking clouds referenced from the images. To effectively track the clouds require simulation of the cloud flows and to estimate the different types of clouds. Such simulation is highly complex and would be difficult to

30 forecast weather against every place in real-time. Additionally, atmospheric pressure cannot be estimated at the place of observation if there are insufficient clouds for tracking. The satellites are also unlikely to provide real-time updates because the update interval for the images is about one hour.

Another method for estimating atmospheric pressure without tracking clouds is using weather information of weather observatories or stations located around the world (Reference [6]). Measurement data from sensors of the weather observatories are shared online and individuals can search for local weather information based on their own locations. However, the update intervals for the weather observatories are inconsistent and may not be able to provide real-time updates. In addition, it is more difficult to obtain weather information at seaside locations because the number of weather sensors put on the seaside locations are fewer than on mainland.

Another method to forecast weather is to rely on Doppler radar (References [4] and [5]). Doppler radar uses ultrasound waves on moving clouds to measure wind speed and direction, which are useful to estimate distribution of atmospheric pressure. However, this method cannot estimate wind behaviors without clouds.

As described above, some existing methods for weather forecasting are based on atmospheric pressure distribution estimated from satellite images or weather observations. These methods estimate the atmospheric pressure distribution at wide areas such as entire cities or states or even globally. However, these methods are difficult to implement if there is limited cloud cover in the satellite images or if real-time updates are required.

United States patent publication 20120084005 describes a weather variation forecast information providing system that measures and processes atmospheric pressure data to calculate an atmospheric pressure gradient vector. The system requires three or more atmospheric pressure measuring devices to be arranged at different positions in a local region and at several hundred meters apart. The system thus requires a large-scale network of atmospheric pressure measuring devices to be set up across distances, thereby restricting practical applications of the system.

Therefore, in order to address or alleviate at least one of the aforementioned problems and/or disadvantages, there is a need to provide an improved barometric instrument and method.

Summary

According to a first aspect of the present disclosure, there is a barometric instrument comprising: a base; a plurality of pressure sensors distributed on the base, each pressure sensor representing a sensor position and configured for measuring a set of atmospheric pressure values at the respective sensor position; a gimbal assembly coupled to the base for maintaining the pressure sensors horizontally; and a processor communicatively linked to the pressure sensors, the processor configured for determining atmospheric pressure distribution on the sensor positions based on the measured sets of atmospheric pressure values, the atmospheric pressure distribution comprising a pressure gradient directed horizontally along the sensor positions.

According to a second aspect of the present disclosure, there is a barometric method performed by a barometric instrument. The method comprises: maintaining a plurality of pressure sensors horizontally on a base of the barometric instrument, the pressure sensors distributed on the base and each pressure sensor representing a sensor position; measuring, by each pressure sensor, a set of atmospheric pressure values at the respective sensor position; and determining, by a processor communicatively linked to the pressure sensors, atmospheric pressure distribution on the sensor positions based on the measured sets of atmospheric pressure values, the atmospheric pressure distribution comprising a pressure gradient directed horizontally along the sensor positions.

An advantage of the present disclosure is that the pressure gradient and atmospheric pressure distribution can be determined by the barometric instrument without large-scale weather systems such as weather observatories or satellite networks. Near-future weather information in the local region of the barometric instrument may be forecasted by recognizing surrounding weather conditions from the pressure gradient and atmospheric pressure distribution at the local region, so as to help the local population to better plan their activities and potentially improve the quality of life.

A barometric instrument and method according to the present disclosure are thus disclosed herein. Various features, aspects, and advantages of the present disclosure will become more apparent from the following detailed description of the
5 embodiments of the present disclosure, by way of non-limiting examples only, along with the accompanying drawings.

Brief Description of the Drawings

10 Figure 1A and Figure 1B are illustrations of a barometric instrument.

Figure 2 is a flowchart illustration of a barometric method.

Figure 3A and Figure 3B are illustrations of an experimental study in an indoor wind
15 tunnel setting.

Figure 4 is an illustration of an experimental study in an outdoor environment setting.

Figure 5A is an illustration of the atmospheric pressure values measured by the
20 barometric instrument.

Figure 5B is an illustration of sensor positions of the barometric instrument.

Figure 5C is an illustration of generating filtered atmospheric pressure values.
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Figure 5D to Figure 5F are illustrations of the filtered atmospheric pressure values.

Figure 6 is an illustration of a method for determining pressure gradient and
30 atmospheric pressure distribution.

Figure 7A and Figure 7B are illustrations of direction charts from an experimental study.

Figure 8A to Figure 8C are illustrations of applications of the barometric instrument.

Detailed Description

5 In the present disclosure, depiction of a given element or consideration or use of a particular element number in a particular figure or a reference thereto in corresponding descriptive material can encompass the same, an equivalent, or an analogous element or element number identified in another figure or descriptive material associated therewith. The use of "/" herein, in a figure, or in associated text
10 is understood to mean "and/or" unless otherwise indicated. The recitation of a particular numerical value or value range herein is understood to include or be a recitation of an approximate numerical value or value range.

For purposes of brevity and clarity, descriptions of embodiments of the present
15 disclosure are directed to a barometric instrument and method, in accordance with the drawings. While aspects of the present disclosure will be described in conjunction with the embodiments provided herein, it will be understood that they are not intended to limit the present disclosure to these embodiments. On the contrary, the present disclosure is intended to cover alternatives, modifications and
20 equivalents to the embodiments described herein, which are included within the scope of the present disclosure as defined by the appended claims. Furthermore, in the following detailed description, specific details are set forth in order to provide a thorough understanding of the present disclosure. However, it will be recognized by an individual having ordinary skill in the art, i.e. a skilled person, that the present
25 disclosure may be practiced without specific details, and/or with multiple details arising from combinations of aspects of particular embodiments. In a number of instances, known systems, methods, procedures, and components have not been described in detail so as to not unnecessarily obscure aspects of the embodiments of the present disclosure.

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References to "an embodiment / example", "another embodiment / example", "some embodiments / examples", "some other embodiments / examples", and so on, indicate that the embodiment(s) / example(s) so described may include a particular

feature, structure, characteristic, property, element, or limitation, but that not every embodiment / example necessarily includes that particular feature, structure, characteristic, property, element or limitation. Furthermore, repeated use of the phrase “in an embodiment / example” or “in another embodiment / example” does
5 not necessarily refer to the same embodiment / example.

In representative or exemplary embodiments of the present disclosure, there is a barometric instrument 100 as shown in Figure 1A and Figure 1B. Broadly, the barometric instrument 100 is a scientific device or tool for obtaining measurements
10 related to atmospheric pressure. The barometric instrument 100 includes a base 102 and a plurality of pressure sensors 104 distributed on the base 102. The base 102 thus provides a support body for supporting the pressure sensors 104. Each pressure sensor 104 represents a sensor position and is configured for measuring a set of atmospheric pressure values at the respective sensor position.

The barometric instrument 100 further includes a gimbal assembly coupled to the base 102 for maintaining the pressure sensors 104 horizontally. The gimbal assembly includes a set of gimbals rotatably or pivotably coupled to the base 102. As used herein, a gimbal is defined as a pivoted structure that allows the rotation of
20 an object about a single axis. The base 102 and gimbal assembly are angularly moveable relative to each other such that the base 102 can be maintained or stabilized horizontally, i.e. maintained in a horizontal orientation at a common altitude level, when the barometric instrument 100 is being manipulated or moved. The base 102 whereon the pressure sensors 104 are supported is weighted to facilitate said
25 maintaining of the base 102 in the horizontal orientation, as will be readily understood by the skilled person. The barometric instrument 100 optionally includes a cover, e.g. a waterproof one, attached to the base 102 for protecting the pressure sensors 104 from weather elements such as rain.

The barometric instrument 100 further includes a processor 106 communicatively
30 linked to the pressure sensors 104. The processor 106 is configured for determining atmospheric pressure distribution on the sensor positions on the base 102 based on the measured sets of atmospheric pressure values. The atmospheric pressure

distribution includes a pressure gradient directed horizontally along the sensor positions on the base 102. Specifically, the pressure gradient is directed horizontally across the distribution of sensor positions represented by the plurality of pressure sensors 104, and the pressure gradient may be coincident with one or more, or none, of the sensor positions.

With reference to Figure 2, there is a barometric method 200 performed by the barometric instrument 100. The method 200 includes a step 202 of maintaining the plurality of pressure sensors 104 horizontally on the base 102. As described above, the pressure sensors 104 are distributed on the base 102, each pressure sensor 104 represents a sensor position, and said maintaining is achieved by the gimbal assembly. The method 200 further includes a step 204 of measuring, by each pressure sensor 104, a set of atmospheric pressure values at the respective sensor position. The method 200 further includes a step 206 of determining, by the processor 106 communicatively linked to the pressure sensors, atmospheric pressure distribution on the sensor positions on the base 102 based on the measured sets of atmospheric pressure values, wherein the atmospheric pressure distribution includes the pressure gradient directed horizontally along the sensor positions on the base 102. Specifically, the atmospheric pressure distribution is determined by estimation from the pressure gradient. The processor 106 includes suitable logic / algorithm for performing various steps of the method 200 and in response to non-transitory instructions operative or executed by the processor 106.

In embodiments as shown in Figure 1A and Figure 1B, the pressure sensors 104 are distributed in an ordered arrangement, such as an array on the base 102. The array has a plurality of rows and an identical plurality of columns. Specifically, there are 25 pressure sensors 104 arranged in 5 rows and 5 columns. In another embodiment, the pressure sensors 104 may be arranged differently, such as in a rectangular array with different number of rows and columns. In another embodiment, the pressure sensors 104 may be arranged in a circular array, wherein the pressure sensors 104 are positioned radially outward from a center position. In some other embodiments, the pressures sensors 104 are distributed randomly on the base 102. It will be appreciated by the skilled person that the number and arrangement of the pressure

sensors 104 affect the accuracy of the pressure gradient of the atmospheric pressure distribution determined based on the measured sets of atmospheric pressure values. The number and arrangement of the pressure sensors 104 distributed on the base 102 are adjustable according to the desired accuracy.

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It is known that atmospheric pressure at an altitude level is the pressure exerted by the weight of air in the atmosphere above the altitude level. Atmospheric pressure varies continuously across regions. Air currents descend in a region of higher atmospheric pressure (high-pressure region) and ascent in a region of lower atmospheric pressure (low-pressure region). The airflow or wind direction between the high-pressure region and low-pressure region is dependent on the altitude and wind blows at different altitudes simultaneously. For example, at ground level, the air flows from the high-pressure region to low-pressure region while at higher altitudes, the air flows in the opposite direction, i.e. from the low-pressure region to high-pressure region. Additionally, airflows at intermediate altitudes are complex and exhibit different behaviors.

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Atmospheric pressure decrease from the high-pressure region to low-pressure region and the rate of decrease is represented by the pressure gradient. The pressure gradient results in wind generation and the steeper the pressure gradient, the stronger the wind. In addition, the direction of the wind can be estimated from the pressure gradient. Although wind is generated by the pressure gradient, wind does not affect atmospheric pressure. The barometric instrument 100 can thus be used under windy conditions or in still air to determine the pressure gradient and atmospheric pressure distribution based on measured sets of atmospheric pressure values. The pressure gradient and atmospheric pressure distribution on the sensor positions represented by the pressure sensors 104 can be analyzed to forecast near-future weather information at the local region where the barometric instrument 100 is located.

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In embodiments as shown in Figure 1A and Figure 1B, the barometric instrument 100 has 25 pressure sensors 104 arranged in an array of 5 rows and 5 columns. The type of pressure sensors 104 should ideally be sensitive to faint variations in

atmospheric pressure. A non-limiting example of the type of pressure sensors 104 would be the MPL3115A2 type or model. The MPL3115A2 pressure sensors 104 can measure within the range of 20 kPa to 110 kPa with a relative accuracy of ± 50 Pa and resolution of 1.5 Pa. There may be some noise ranging between -400 Pa and 400 Pa because the MPL3115A2 pressure sensors 104 measure the atmospheric pressure by piezoresistive effect. The MPL3115A2 pressure sensors 104 are able to measure other parameters such as temperature and altitude.

Each pressure sensor 104 represents a sensor position on the base 102 and may include a hole 108 at each sensor position. The pressure sensors 104 are aligned to the holes 108, and each hole 108 may coincide with or be offset from the center of the respective pressure sensor 104. Each pressure sensor 104 has dimensions of approximately 3 mm by 5 mm and the interval spacing between the pressure sensors 104 is approximately 5.5 mm. The array of 25 pressure sensors 104 is disposed on an area having dimensions of approximately 25 mm by 27 mm. Referring to Figure 1A, the barometric instrument 100 shown in comparison to a hand is sufficiently small to be a handheld instrument and/or a wearable instrument, such as worn on a wristwatch device.

The pressure sensors 104 communicate the measured sets of atmospheric pressure values via an Inter-Integrated Circuit (I2C) computer bus. In one embodiment, the method 200 includes another step of repeating said measuring of the sets of atmospheric pressure values at predefined intervals. For example, the pressure sensors 104 measure the sets of atmospheric pressure values at predefined intervals of 400 ms (milliseconds), although the predefined intervals may be adjustable on the barometric instrument 100. The processor 106 takes approximately 0.6 ms to receive the set of atmospheric pressure values measured by one pressure sensor 104, and approximately 12 ms in total to receive and aggregate the sets of atmospheric pressure values measured by all 25 pressure sensors 104. Thus, the processor 106 collects all the measured sets of atmospheric pressure values within 400 ms before the pressure sensors 104 repeat the measurements.

Some experimental studies were conducted to evaluate the performance of the barometric instrument 100 and method 200. A first experimental study was conducted in an indoor wind tunnel setting 300 as shown in Figure 3A, and a second experimental study was conducted in an outdoor environment setting 400 as shown in Figure 4. The indoor wind tunnel setting 300 presents a simulated environment for said evaluation while the outdoor environment setting 400 presents actual conditions where the barometric instrument 100 is used.

With reference to Figure 3A, the indoor wind tunnel setting 300 includes a wind tunnel 302 which generates airflow or wind in an enclosed space for studying the effects of moving air across the barometric instrument 100 placed horizontally in the center of the wind tunnel 302. A benefit of the wind tunnel 302 is that the wind and pressure conditions are stable. The wind tunnel 302 generated wind by cooling fans 304 used for computers. The fans 304 are attached at one end of the wind tunnel 302 and generated wind through the wind tunnel 302. The wind speed can be controlled by adjusting the rotation speed of the fans 304 which is in turn dependent on the voltage supplied to the fans 304. A wind gauge was used to measure the wind speed and direction. The maximum wind speed achieved by the fans 304 was 14 km/h.

For the first experimental study in the indoor wind tunnel setting 300, the fans 304 generated wind in the wind tunnel 302 at a wind speed of 12 km/h. Measurements were not taken for an initial period of 30 minutes to calibrate and stabilize the barometric instrument 100. Atmospheric pressure values were then measured for a first period of 30 s (seconds) after the initial period. After the first period, the wind speed was decreased to 10 km/h within an interval of 10 s. Atmospheric pressure values were then measured for a second period of 30 s at the wind speed of 10 km/h. After the second period, the wind speed was decreased to 8 km/h within an interval of 10 s. Atmospheric pressure values were then measured for a third period of 30 s at the wind speed of 8 km/h.

Figure 3B illustrates a chart of the sets of atmospheric pressure values averaged from all the pressure sensors 104 during the first, second, and third periods of the

first experimental study. The vertical axis represents the atmospheric pressure values and the horizontal axis represents the number of the averaged sets of atmospheric pressure values. Each unit along the horizontal axis represents 10 s, summing to 110 s for the entire duration of the first experimental study. Given that the pressure sensors 104 measure every 400 ms, the number of sets atmospheric pressure values obtained is approximately 275. It can be seen that the atmospheric pressure values in each period of 30 s are similar. However, in the intervals of 10 s between the periods during which the wind speed decreased, the averaged atmospheric pressure values increased significantly. Thus, when the wind speed decreased, the atmospheric pressure values increased. The atmospheric pressure values remained stable when the wind speed was stable. Although the presence of wind may affect the pressure sensors 104, this is applicable to all the pressure sensors 104 as they are subjected to the same wind. As such, the atmospheric pressure values measured by the pressure sensors 104 tended to be similar. It can be concluded from the first experimental study that the pressure sensors 104 have similar sensor characteristics and are not significantly different from one another, and that it would be feasible to use the barometric instrument 100 in actual outdoor environment.

With reference to Figure 4, the outdoor environment setting 400 includes a table 402 of dimensions 120 cm x 120 cm, and the barometric instrument 100 was placed horizontally on the center of the table 402. The horizontal orientation of the barometric instrument 100 on the table 402 was verified by a spirit level. There was no other obstacle or object on the table 402 that would have undesirably casted a shadow on the pressure sensors 104. A camera 404 was placed in front of the table 402 to capture images of the sky, and an anemometer 406 was placed on the ground nearby the table 402 to measure the surrounding wind speed and direction. The camera 404 and anemometer 406 were placed away from the table 402 to avoid having their shadows casted on the pressure sensors 104.

For the second experimental study in the outdoor environment setting 400, measurements were not taken for an initial period of 30 minutes to calibrate and stabilize the barometric instrument 100. Atmospheric pressure values were then

measured for a first period of 30 minutes after the initial period. Simultaneously during the first period, the camera 404 captured sky images and the anemometer 406 measured surrounding wind speed and direction.

5 Notably, there was data from the sky images and surrounding wind speed and direction, the data was insufficient to accurately determine the pressure gradient and atmospheric pressure distribution. Particularly, the surrounding wind direction was opposite or different from the trajectory of cloud movement. The cloud movements were also in different directions depending on altitude. As such, it was difficult to
10 determine the pressure gradient and atmospheric pressure distribution from the data obtained by the camera 404 and anemometer 406. It was also ascertained from the first experimental study that any influence from surrounding wind can be disregarded since the surrounding wind affect all the pressure sensors 104.

15 Figure 5A illustrates graphs 500 of the raw sets of atmospheric pressure values measured from all the pressure sensors 104 during the first period of the second experimental study. The vertical axis represents the atmospheric pressure values and the horizontal axis represents the number of sets of atmospheric pressure values. Each unit along the horizontal axis represents 200 s, summing to the first
20 period of 30 minutes for the entire duration of the first experimental study. Given that the pressure sensors 104 measure every 400 ms, the number of sets atmospheric pressure values measured by each pressure sensor 104 is approximately 4500. Each of the 25 graphs 500 shows the raw set of atmospheric pressure values measured from a respective one of the 25 pressure sensors 104 and the graphs 500
25 are in the same arrangement as the sensor positions on the base 102. The sensor positions represented by the pressure sensors 104 are expressed as $S(x,y)$ cells from $S(0,0)$ to $S(4,4)$, as shown in Figure 5B. The graphs 500 in Figure 5A represent a raw group $P(1)$ of atmospheric pressure values.

30 As the second experimental study was conducted in the outdoor environment setting 400, the atmospheric pressure values are affected by actual weather conditions such as atmospheric pressure changes, temperature and humidity. These conditions introduce noise in the measured atmospheric pressure values. A smoothing filter

was applied to filter and reduce / remove noise from the measured atmospheric pressure values. Accordingly, during use of the barometric instrument 100, the step 206 of the method 200 includes generating at least one group of sets of atmospheric pressure values filtered from the measured sets of atmospheric pressure values.

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Figure 5C illustrates an example of generating of at least one group $P(n)$, where n is an integer from 2, of sets of atmospheric pressure values filtered from the measured sets of atmospheric pressure values, i.e. from the raw group $P(1)$. Each group $P(n)$, i.e. $P(2)$, $P(3)$, $P(4)$, and possibly more, is generated from the raw group $P(1)$. For each group $P(n)$, each set of atmospheric pressure values thereof is generated based on a plurality of the measured sets of atmospheric pressure values of the raw group $P(1)$. Specifically, for each group $P(n)$, each cell or set of atmospheric pressure values is the average of $n \times n$ cells of the raw group $P(1)$. A cell of a group $P(n)$ is part of the $n \times n$ cells of the raw group $P(1)$. An $S(i,j)$ cell in a group $P(n)$ can be calculated from the raw group $P(1)$ by the following equation.

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$$S(i,j) = \frac{1}{n * n} \sum_{y=0}^{n-1} \sum_{x=0}^{n-1} S(i + x, j + y)$$

Figure 5D illustrates graphs 502 of the sets of atmospheric pressure values of the group $P(2)$ generated from the raw group $P(1)$. Each of the graphs 502 shows the cell or set of atmospheric pressure values generated from 2×2 cells of the raw group $P(1)$. Each cell of the group $P(2)$ is generated from 4 cells of the raw group $P(1)$, such that the group $P(2)$ has 4×4 or 16 cells or sets of atmospheric pressure values in total.

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Figure 5E illustrates graphs 504 of the sets of atmospheric pressure values of the group $P(3)$ generated from the raw group $P(1)$. Each of the graphs 504 shows the cell or set of atmospheric pressure values generated from 3×3 cells of the raw group $P(1)$. Each cell of the group $P(3)$ is generated from 9 cells of the raw group $P(1)$, such that the group $P(3)$ has 3×3 or 9 cells or sets of atmospheric pressure values in total.

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Figure 5F illustrates graphs 506 of the sets of atmospheric pressure values of the group P(4) generated from the raw group P(1). Each of the graphs 506 shows the cell or set of atmospheric pressure values generated from 4 x 4 cells of the raw group P(1). Each cell of the group P(4) is generated from 16 cells of the raw group P(1), such that the group P(4) has 2 x 2 or 4 cells or sets of atmospheric pressure values in total.

Comparing the raw group P(1) to the generated groups P(2) to P(4), it can be seen that each group has of the groups P(2) to P(4) has fewer sets of atmospheric pressure values than the raw group P(1) of the measured sets of atmospheric pressure values. Additionally, the groups P(2) to P(4) are consecutive and a first group has more sets of atmospheric pressure values than a second group consecutive to the first group. Each set of atmospheric pressure values of the first and second groups is generated based on first and second pluralities of the measured sets of atmospheric pressure values, respectively, wherein the first plurality is fewer than the second plurality. For example, a first group P(2) and a second group P(3), which is consecutive to the first group P(2), have 16 and 9 sets of atmospheric pressure values, respectively. Each set of atmospheric pressure values of the first group P(2) is generated based on 4 measured sets of atmospheric pressure values, and each set of atmospheric pressure values of the second group P(3) is generated based on 9 measured sets of atmospheric pressure values.

Referring to the raw group P(1) and graphs 500 in Figure 5A, it can be seen that the raw sets of atmospheric pressure values measured in the outdoor environment setting 400 were irregular, whereas the atmospheric pressure values measured in the indoor wind tunnel setting 300 were stable. Moreover, statistical calculations on the graphs 500 indicate a minimum correlation coefficient of 0.10 between the S(0,0) cell and the other cells. The irregular sets of atmospheric pressure values of the raw group P(1) were likely due to influences from actual weather conditions which introduced noise in the atmospheric pressure values.

The generated groups P(2) to P(4) have reduced or even removed noise in their sets of atmospheric pressure values, as can be seen in the graphs 502, 504, and 506, respectively. Similar statistical calculations on the graphs 502, 504, and 506 indicate minimum correlation coefficients of 0.78, 0.94, and 0.98, respectively. The minimum correlation coefficients improved significantly after the raw sets of atmospheric pressure values were filtered to reduce or even remove noise, and the minimum correlation coefficient for each group P(2) to P(4) was significantly higher than that for the raw group P(1). The high correlation coefficients indicate that each cell of the groups P(2) to P(4) exhibit similar behavior as in the first experimental study in the indoor wind tunnel setting 300. The high correlation coefficients were further verified in repeated experimental studies. Accordingly, it would be feasible to use the barometric instrument 100 in actual outdoor environment to determine the pressure gradient and atmospheric pressure distribution from filtered atmospheric pressure values of the groups P(2) to P(4).

The step 206 of the method 200 of determining the atmospheric pressure distribution includes identifying a minimum and a maximum of the sets of atmospheric pressure values of each of the groups P(2) to P(4) for determining the pressure gradient. In one embodiment, as each of the groups P(2) to P(4) has better correlation coefficient relative to P(1), the pressure gradient is determined based on the minimum and maximum sets of atmospheric pressure values of one of the groups P(2) to P(4). The atmospheric pressure distribution is subsequently determined by estimation from the pressure gradient.

In another embodiment, all the groups P(2) to P(4) are used in determining the pressure gradient and atmospheric pressure distribution. Specifically, said determining of the pressure gradient in the step 206 includes determining an intermediary pressure gradient for each of the groups P(2) to P(4) based on the minimum and maximum sets of atmospheric pressure values of the respective one of the groups P(2) to P(4). The pressure gradient is then determined by aggregation / combination of the intermediary pressure gradients of the groups P(2) to P(4). Various algorithms may be employed for the aggregation. For example, the pressure gradient may be determined by vector addition of the intermediary pressure

gradients. The atmospheric pressure distribution is subsequently determined by estimation from the resultant pressure gradient. The intermediary pressure gradients improve the accuracy of the resultant pressure gradient and atmospheric pressure distribution as more sets of atmospheric pressure values are considered.

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A computerized method 600 implemented on the processor 106 for determining the pressure gradient and atmospheric pressure distribution is described with reference to Figure 6. The method 600 includes a first stage 602 of processing the raw group P(1). Specifically, in the first stage 602, groups P(2) to P(4) are generated from the raw group P(1), wherein each of the groups P(2) to P(4) has sets of atmospheric pressure values filtered from the measured sets of atmospheric pressure values of the raw group P(1) to reduce / remove noise.

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The method 600 includes a second stage 604 of determining the intermediary pressure gradients of the groups P(2) to P(4). Specifically, in the second stage 604, for each of the groups P(2) to P(4), the sets of atmospheric pressure values are ranked. A number of minimum or lowest-ranked and a number of maximum or highest-ranked sets of atmospheric pressure values for each of the groups P(2) to P(4) are identified. In one embodiment, there is one minimum and one maximum set of atmospheric pressure values for each of the groups P(2) to P(4). In another embodiment, there are different numbers of minimum and maximum sets for the different groups P(2) to P(4). For a particular group P(n), (N-n) sets of minimum atmospheric pressure values and (N-n) sets of maximum atmospheric pressure values are identified, wherein N = 5 corresponding to the number of rows / columns in the array of pressure sensors 104. Using group P(2) as an example, 3 sets of the lowest atmospheric pressure values and 3 sets of the highest atmospheric pressure values are identified. Following that, for each of the groups P(2) to P(4), a minimum center position is calculated based on the sensor positions corresponding to the set(s) of lowest atmospheric pressure values, and a maximum center position is calculated based on the sensor positions corresponding to the set(s) of highest atmospheric pressure values. An intermediary pressure gradient 110 is generated for each of the groups P(2) to P(4) as a straight vector from the maximum center position to the minimum center position.

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The method 600 includes a third stage 604 of determining the pressure gradient 112. Specifically, in the third stage 604, the intermediary pressure gradients 110 of the groups P(2) to P(4) are aggregated / combined, such as by vector addition, to generate the pressure gradient 112. The atmospheric pressure distribution is subsequently determined by estimation from the pressure gradient 112. The atmospheric pressure distribution is represented as an image map 114 generated by estimation from the pressure gradient 112. The pressure gradient 112 is shown on the image map 114 and is directed from an aggregated maximum center position to an aggregated minimum center position. The pressure gradient 112 and image map 114 can be analyzed for forecasting near-future weather information at the local region where the barometric instrument 100 is located.

A third experimental study was conducted to evaluate the performance of the barometric instrument 100 and method 200, specifically the accuracy of the pressure gradient 112. The third experimental study was conducted in two phases outdoors similar to the outdoor environment setting 400. In the first phase, two barometric instruments 100 were placed horizontally on a table in the same orientation, i.e. pointing in the same horizontal direction. In the second phase, two barometric instruments 100 were placed horizontally on the table in different orientations, i.e. pointing in different horizontal directions. The first and second phases were conducted at different dates at the same place. Multiple measurements of the atmospheric pressure values were repeated for both phases. The pressure gradients 112 from each barometric instrument 100 in each phase were then averaged.

Figure 7A illustrates a direction chart 700 from the first phase of the third experimental study. Figure 7B illustrates a direction chart 702 from the second phase of the third experimental study. Each of the direction charts 700 and 702 show the average pressure gradients 112a and 112b determined from the first barometric instrument 100a and second barometric instrument 100b, respectively. The average pressure gradients 112a and 112b are shown relative to a forward axis 704. The pressure gradients 112a and 112b from the first phase are pointing at approximately 0° and 31.7° relative to the forward axis 704, respectively, forming a gap of 31.7°

between the pressure gradients 112a and 112b. The pressure gradients 112a and 112b from the second phase are pointing at approximately 76.7° and 45° relative to the forward axis 704, forming a gap of 31.7° between the pressure gradients 112a and 112b.

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The pressure gradients 112a and 112b determined by the barometric instruments 100a and 100b, respectively, for both the first and second phases tended to be close to each other, with a gap or error margin of approximately 30° . Both barometric instruments 100a and 100b showed that the pressure gradients 112a and 112b are
10 similar to each other regardless of whether the barometric instruments 100a and 100b are placed in same or different orientations. The results of the third experimental study showed that the pressure gradient determined by the barometric instrument 100 is sufficiently accurate.

15 The pressure gradient determined by the barometric instrument 100 through the method 200 is a weather condition calculated from atmospheric pressure values measured by the pressure sensors 104 of the barometric instrument 100. The pressure gradient is neither a result of properties of the pressure sensors 104 nor from wind effects, as evaluated in the second experimental study in the outdoor
20 environment setting 400. The pressure gradient is determined from calculations performed on the measured atmospheric pressure values, as described above.

One possible way of improving the accuracy of the pressure gradient is to supplement the determined pressure gradient with a predefined threshold value.

25 Another way to improve the accuracy is to further reduce noise in the atmospheric pressure values. More contrivance components in the barometric instrument 100 may be required to achieve further noise reduction. The pressure sensors 104 of the barometric instrument 100 measure the atmospheric pressure values by piezoresistive effect which causes noise. In embodiments described above, a
30 smoothing filter may be applied to compress, filter, and reduce / remove noise from the measured atmospheric pressure values. In some other embodiments, other methods may be used for noise reduction, as will be readily understood by the skilled

person. Some non-limiting examples include a Fourier transform algorithm and an expectation–maximization algorithm.

5 The accuracy of the pressure gradient may be affected by individual properties of the pressure sensors 104, such as shape and sensor position on the base 102. The accuracy may be improved by improving the quality of the barometric instrument 100, particularly of the array of pressure sensors 104. For example, adjusting the sensor positions on the base 102 and better precision in the manufacturing process of distributing the pressure sensors 104 on the base 102 may improve the quality of the
10 barometric instrument 100.

As described in various embodiments above, the barometric instrument 100 is configured to determine pressure gradient and atmospheric pressure distribution through the method 200. Data associated with location of the barometric instrument
15 100 and the pressure gradient and atmospheric pressure distribution at the location may be stored on a memory or storage device of the barometric instrument 100 for monitoring and tracking. Alternatively or additionally, the data is communicable from the barometric instrument 100 to a remote computer system for storing thereon.

20 The pressure gradient and atmospheric pressure distribution are determined by the barometric instrument 100, which can be handheld-sized, without large-scale weather systems such as weather observatories or satellite networks. Near-future weather information in the local region of the barometric instrument 100 may be forecasted by recognizing surrounding weather conditions from the pressure gradient
25 and atmospheric pressure distribution at the local region. Specifically, the pressure gradient extends from a high-pressure area to a low-pressure area at the local region, and the pressure gradient has a middle point which can be referred to as a border. Movements of the border means changes to the atmospheric pressure distribution at the local region, and analysis of the border movement can estimate the progress of
30 the atmospheric pressure distribution changes. Forecasting near-future weather information helps the local population to better plan their activities and potentially improves the quality of life.

In one example, clouds are difficult to form in the high-pressure area than in the low-pressure area. By analyzing the proportion and progress of the high-pressure and low-pressure areas from the atmospheric pressure distribution changes, near-future weather information can be forecasted. The barometric instrument 100 can thus forecast whether the current weather conditions at the local region will be maintained or weather changes are expected. In another example, the barometric instrument 100 can detect specific signs before a weather disaster, such as cyclones / typhoons / hurricanes / tornados, occurs. For typhoons, the center of a typhoon has the lowest pressure and the cloud of the typhoon rotates about the center. Based on the rotation direction of the typhoon, the pressure gradient and gap between the high-pressure area and low-pressure area change accordingly. The peculiar pattern of these changes can be seen on an image map representing the atmospheric pressure distribution. It may be possible that the barometric instrument 100 is able to estimate occurrence of impending typhoons earlier than current weather forecast systems.

The barometric instrument 100 may be used in various other applications. The barometric instrument 100 may include an attachment mechanism coupled to the gimbal assembly for attaching the barometric instrument 100 to a body, such as a miniature aircraft. In one example, the barometric instrument 100 may be used as an anemometer or wind sensor. As evaluated in the first experimental study in the indoor wind tunnel setting 300, the atmospheric pressure values increased when the wind speed decreased. This relationship may be extrapolated to configure the barometric instrument 100 as an anemometer or wind sensor for measuring wind speed and direction. A conventional ultrasonic wind sensor requires more space for airflow between sensors and is larger than the barometric instrument 100. The barometric instrument 100 is small enough to be installed in places with space constraints.

In another example with reference to Figure 8A, the barometric instrument 100 may be used for paragliding 800. Paragliding 800 involves the use of a glider aircraft 802 and a parachute 804 attached to the glider aircraft 802. Flight of the glider aircraft 802 relies on wind power without powered motors. One technique in paragliding 800

is soaring flight which is achieved by utilizing wind directed upwards. In order to maintain flight during paragliding 800, the user or driver of the glider aircraft 802, the driver needs to find areas where there is wind, and it can be difficult for a beginner to find such areas. The barometric instrument 100 may be used in cooperation with the glider aircraft 802 to determine the pressure gradient which helps to estimate the wind direction. The barometric instrument 100 may be attached to the glider aircraft 802 and alignable to the glider aircraft 802, such that the pressure gradient and consequently the wind direction are determined relative to the glider aircraft 802.

Similar to the glider aircraft and with reference to Figure 8B, the barometric instrument 100 may be attached to a flight drone 806, such as of an airplane or quadcopter / quadrotor type. The flight drone 806 is an autonomous robot capable of flight without controlling by human hands. The flight drone 806 flies by utilizing wind power without powered motors which would be difficult operate continuously in order to maintain flight. Utilizing wind power for flight addresses the difficulty associated with powered motors and the use of the barometric instrument 100 helps to estimate the wind direction for guiding the flight drone 806. One benefit of using flight drones 806 is that smaller platforms or temporary base stations can be built under space constraints for launching the flight drones 806 for various purposes. For example, the flight drones 806 may be configured to improve mobile connectivity during disasters, for weather observation at sea, or for spraying pesticide on fields in mountainous regions. The flight drone 806 may also be installed with other components such as gyro sensors and accelerometers to complement their flight.

In another example with reference to Figure 8C, the barometric instrument 100 may be used for estimate the location of the ignition point or origin of a fire. A firefighter may wear a helmet 808 whereon the barometric instrument 100 is attached. The barometric instrument 100 may be alignable to the helmet 808, such that the pressure gradient is determined relative to the helmet 808. The origin or source of a fire in a building may be difficult to locate by cameras because of smoke from the fire which affect visibility. Although thermal sensors and/or thermography may be used to help detect the fire origin, it takes time to locate the fire origin because of changing temperatures caused by water discharged for fire extinguishment. The fire increases

the temperature all around and affects atmospheric pressure. Particularly, corridors of the building have similar structures as the wind tunnel 302 used in the first experimental study. In a similar manner, the barometric instrument 100 can locate the areas with high atmospheric pressure, as the area around the fire has high atmospheric pressure. The barometric instrument 100 can thus be used to estimate the fire source location where the fire started in the building and help people to avoid this location.

In the foregoing detailed description, embodiments of the present disclosure in relation to a barometric instrument and method are described with reference to the provided figures. The description of the various embodiments herein is not intended to call out or be limited only to specific or particular representations of the present disclosure, but merely to illustrate non-limiting examples of the present disclosure. The present disclosure serves to address at least one of the mentioned problems and issues associated with the prior art. Although only some embodiments of the present disclosure are disclosed herein, it will be apparent to a person having ordinary skill in the art in view of this disclosure that a variety of changes and/or modifications can be made to the disclosed embodiments without departing from the scope of the present disclosure. Therefore, the scope of the disclosure as well as the scope of the following claims is not limited to embodiments described herein.

References

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Claims

1. A barometric instrument comprising:

a base;

a plurality of pressure sensors distributed on the base, each pressure sensor representing a sensor position and configured for measuring a set of atmospheric pressure values at the respective sensor position;

a gimbal assembly coupled to the base for maintaining the pressure sensors horizontally; and

a processor communicatively linked to the pressure sensors, the processor configured for determining atmospheric pressure distribution on the sensor positions based on the measured sets of atmospheric pressure values, the atmospheric pressure distribution comprising a pressure gradient directed horizontally along the sensor positions.

2. The instrument according to claim 1, said determining of the atmospheric pressure distribution comprising generating at least one group of sets of atmospheric pressure values filtered from the measured sets of atmospheric pressure values.

3. The instrument according to claim 2, wherein for each group, each set of atmospheric pressure values thereof is generated based on a plurality of the measured sets of atmospheric pressure values.

4. The instrument according to claim 2 or 3, wherein each group has fewer sets of atmospheric pressure values than of the measured sets of atmospheric pressure values.

5. The instrument according to any one of claims 2 to 4, wherein the groups are consecutive and a first group has more sets of atmospheric pressure values than a second group consecutive to the first group.

6. The instrument according to claim 5, wherein each set of atmospheric pressure values of the first and second groups is generated based on first and

second pluralities of the measured sets of atmospheric pressure values, respectively, and wherein the first plurality is fewer than the second plurality.

7. The instrument according to any one of claims 2 to 6, said determining of the atmospheric pressure distribution further comprising identifying a minimum and a maximum of the sets of atmospheric pressure values of each group for determining the pressure gradient.

8. The instrument according to claim 7, wherein the atmospheric pressure distribution is determined from the pressure gradient determined based on the minimum and maximum sets of atmospheric pressure values of one of the groups.

9. The instrument according to claim 7, said determining of the pressure gradient comprising determining an intermediary pressure gradient for each group based on the minimum and maximum sets of atmospheric pressure values of the respective group.

10. The instrument according to claim 9, wherein the atmospheric pressure distribution is determined from the pressure gradient aggregated from the intermediary pressure gradients.

11. The instrument according to any one of claims 1 to 10, wherein the pressure sensors are distributed in an array on the base.

12. The instrument according to any one of claims 1 to 11, further comprising an attachment mechanism coupled to the gimbal assembly for attaching the instrument to a body, wherein the instrument is alignable to the body such that the pressure gradient is determined relative to the body.

13. The instrument according to any one of claims 1 to 12, wherein the instrument is a handheld instrument and/or a wearable instrument.

14. A barometric method performed by a barometric instrument, the method comprising:

maintaining a plurality of pressure sensors horizontally on a base of the barometric instrument, the pressure sensors distributed on the base and each pressure sensor representing a sensor position;

measuring, by each pressure sensor, a set of atmospheric pressure values at the respective sensor position; and

determining, by a processor communicatively linked to the pressure sensors, atmospheric pressure distribution on the sensor positions based on the measured sets of atmospheric pressure values, the atmospheric pressure distribution comprising a pressure gradient directed horizontally along the sensor positions.

15. The method according to claim 14, said determining of the atmospheric pressure distribution comprising generating at least one group of sets of atmospheric pressure values filtered from the measured sets of atmospheric pressure values.

16. The method according to claim 15, wherein for each group, each set of atmospheric pressure values thereof is generated based on a plurality of the measured sets of atmospheric pressure values.

17. The method according to claim 15 or 16, said determining of the atmospheric pressure distribution further comprising identifying a minimum and a maximum of the sets of atmospheric pressure values of each group for determining the pressure gradient.

18. The method according to any one of claims 15 to 17, said determining of the pressure gradient comprising determining an intermediary pressure gradient for each group based on the minimum and maximum sets of atmospheric pressure values of the respective group.

19. The method according to claim 18, wherein the atmospheric pressure distribution is determined from the pressure gradient aggregated from the intermediary pressure gradients.

- 5 20. The method according to any one of claims 14 to 20, further comprising repeating said measuring of the sets of atmospheric pressure values at predefined intervals.

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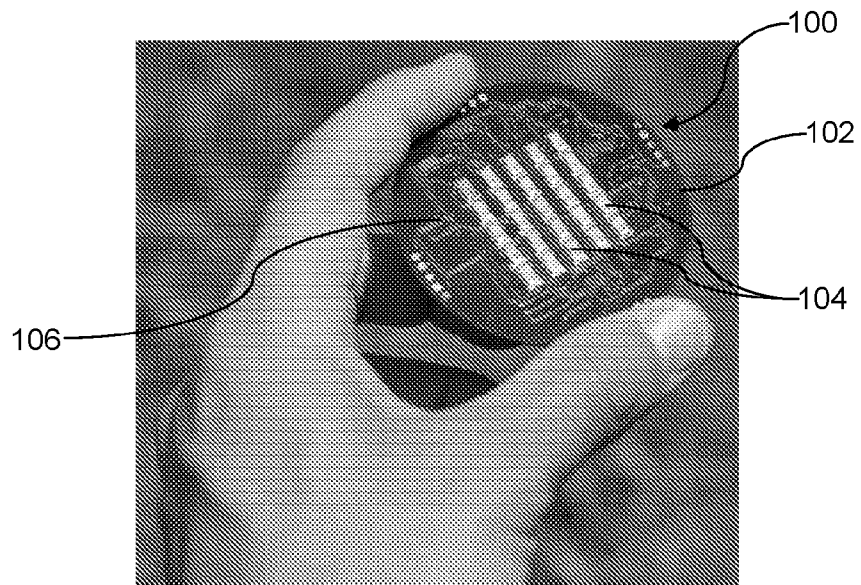


Figure 1A

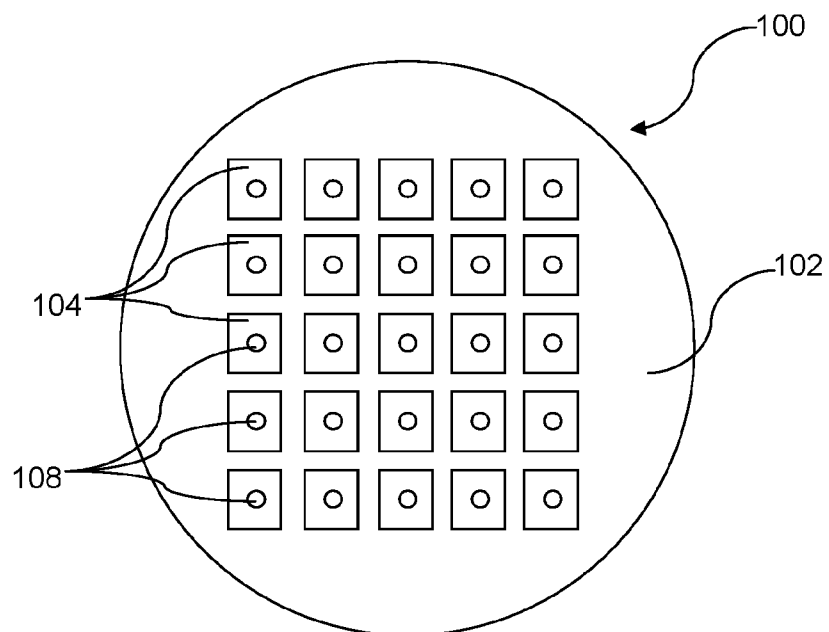


Figure 1B

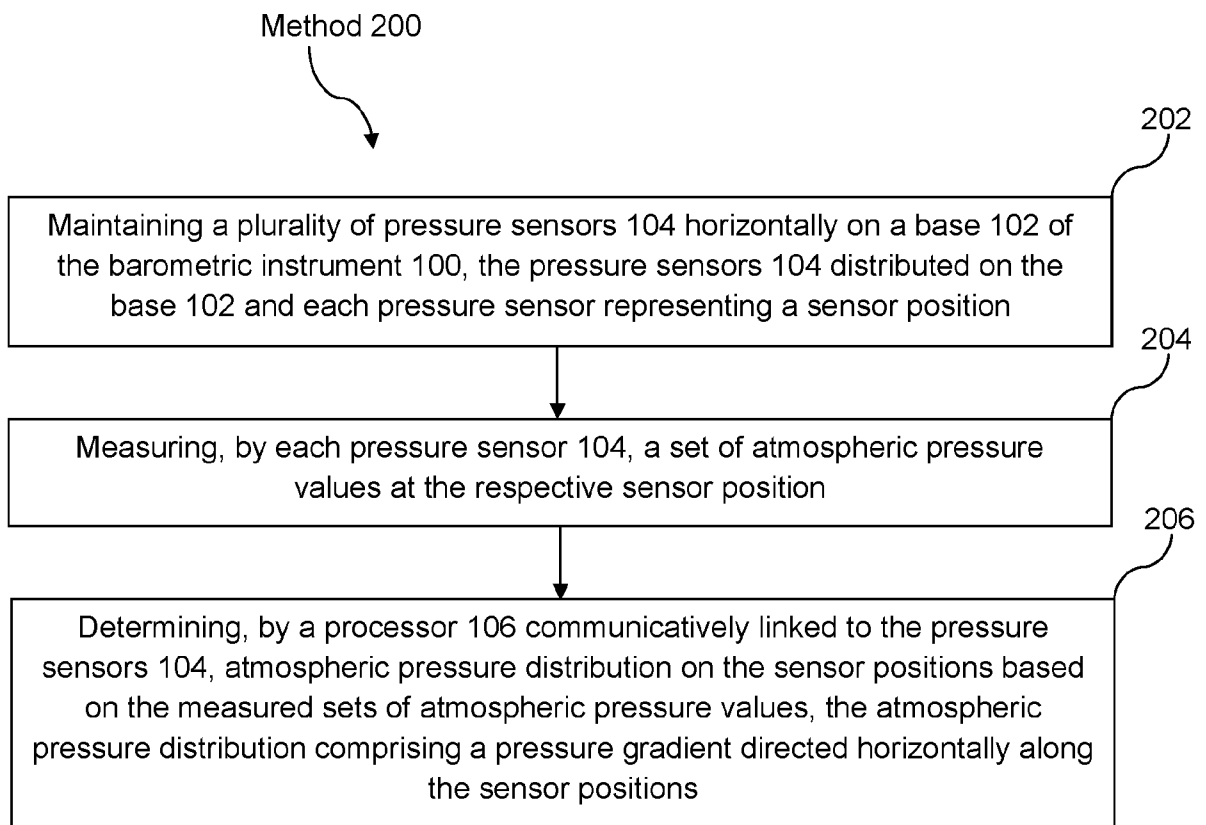


Figure 2

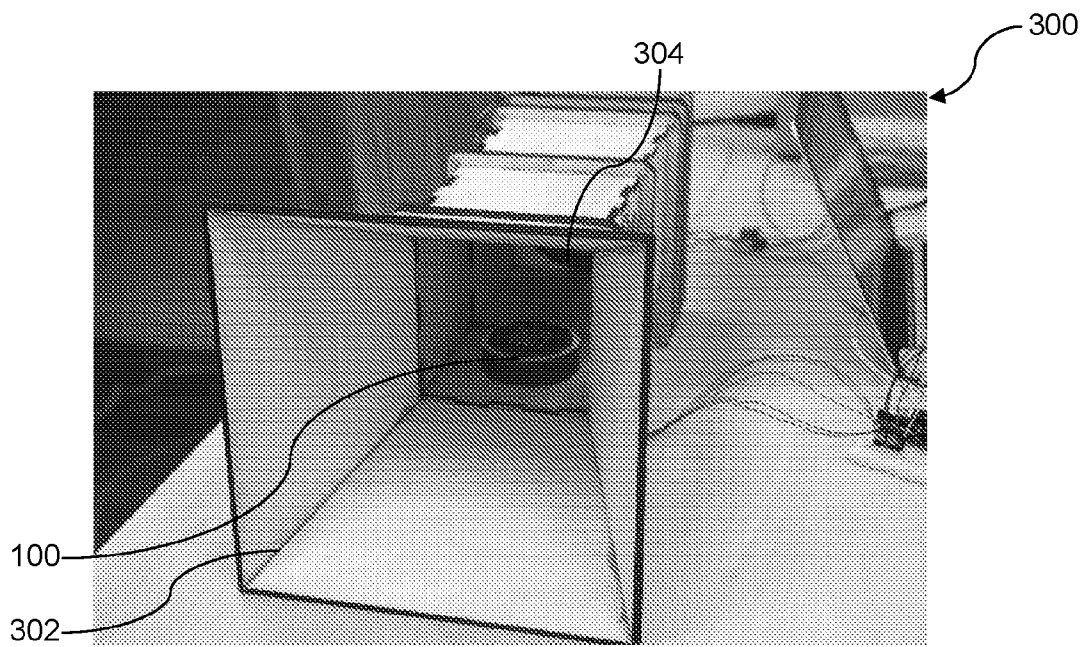


Figure 3A

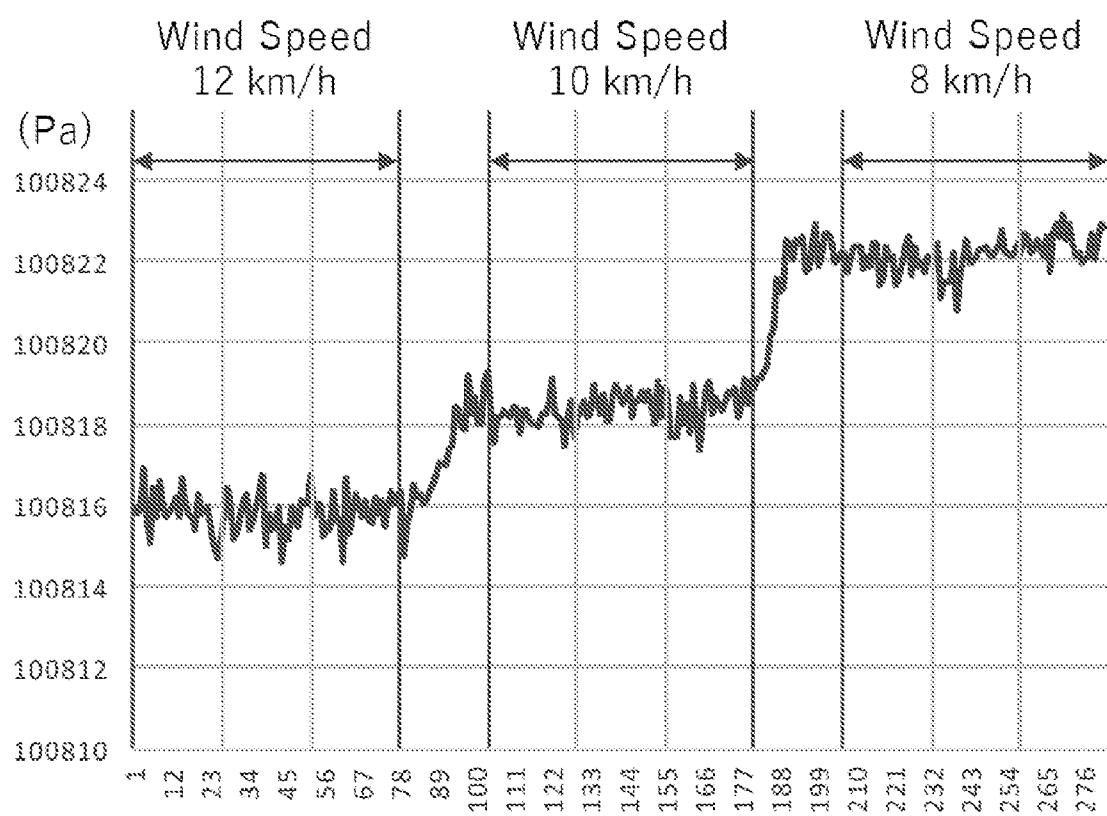


Figure 3B



Figure 4

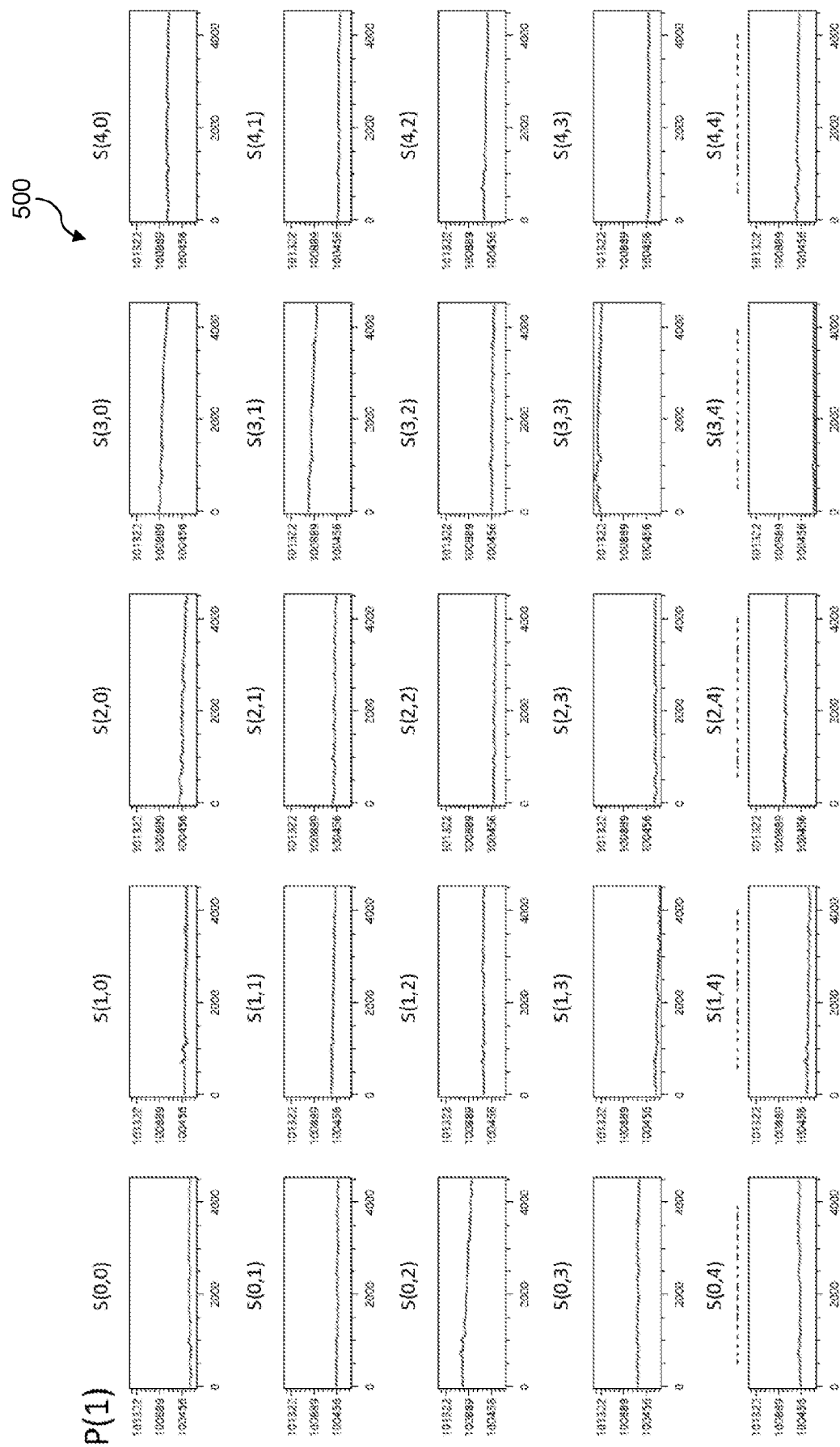


Figure 5A

104

$S(0,0)$	$S(1,0)$	$S(2,0)$	$S(3,0)$	$S(4,0)$
$S(0,1)$	$S(1,1)$	$S(2,1)$	$S(3,1)$	$S(4,1)$
$S(0,2)$	$S(1,2)$	$S(2,2)$	$S(3,2)$	$S(4,2)$
$S(0,3)$	$S(1,3)$	$S(2,3)$	$S(3,3)$	$S(4,3)$
$S(0,4)$	$S(1,4)$	$S(2,4)$	$S(3,4)$	$S(4,4)$

Figure 5B

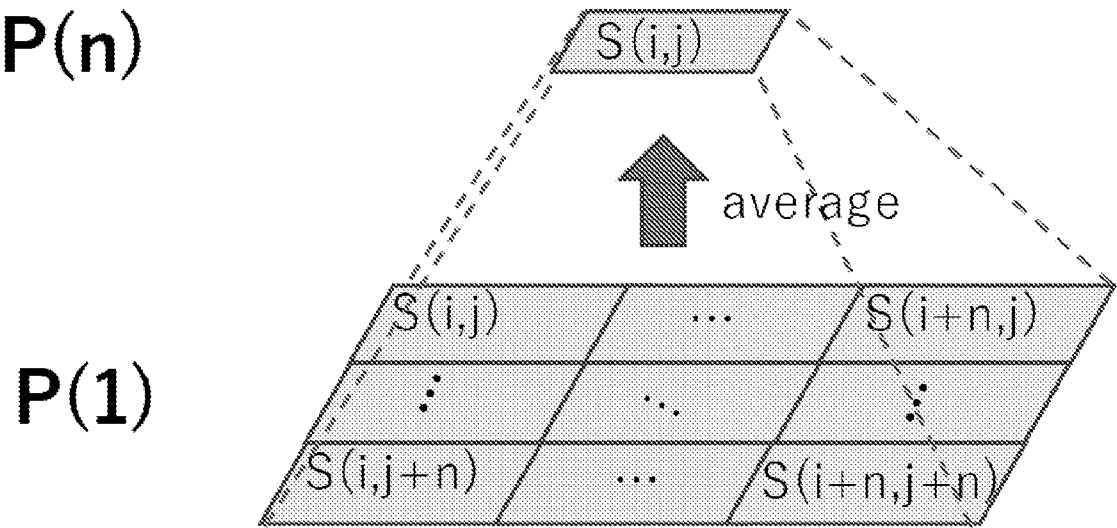


Figure 5C

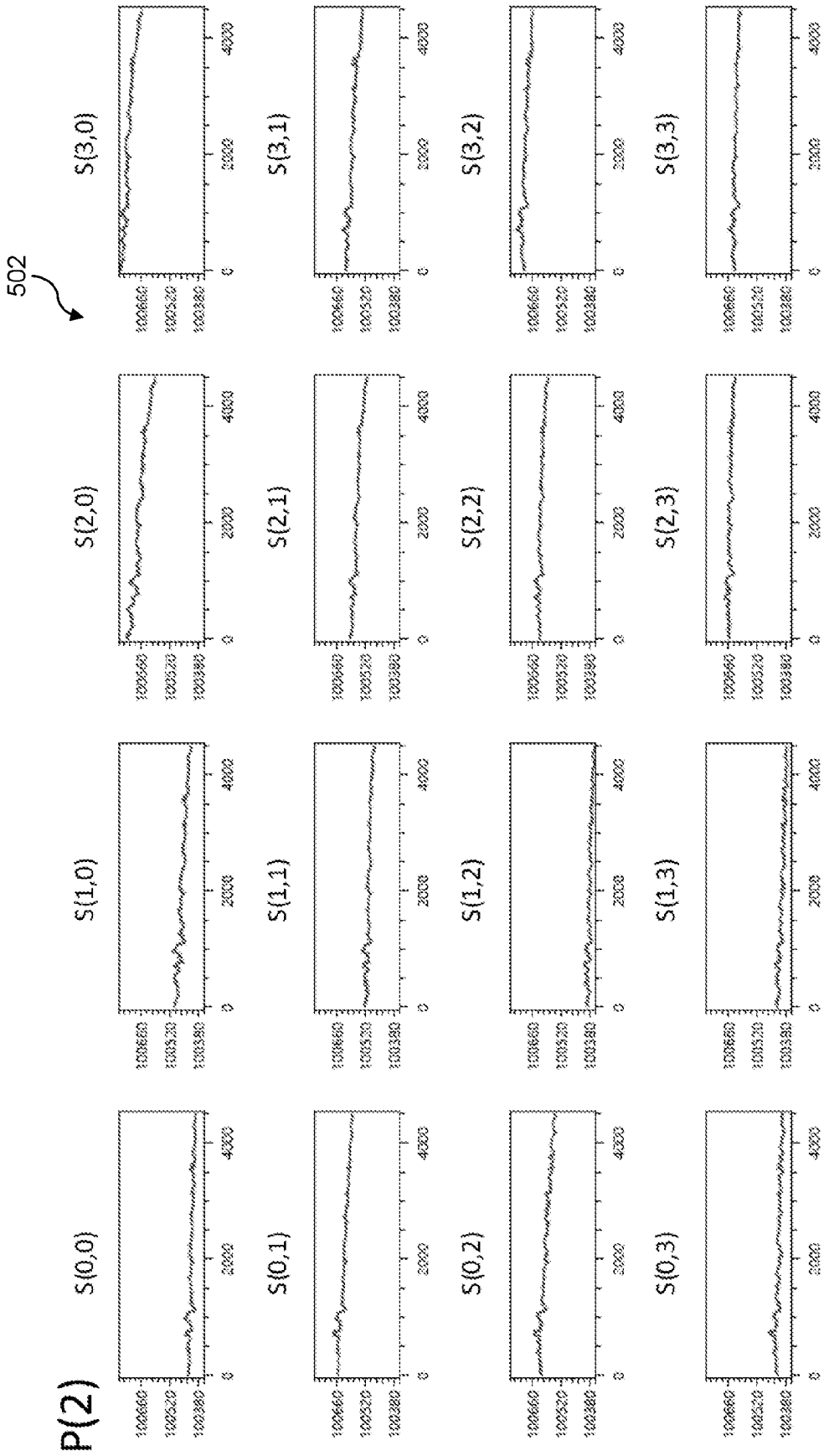


Figure 5D

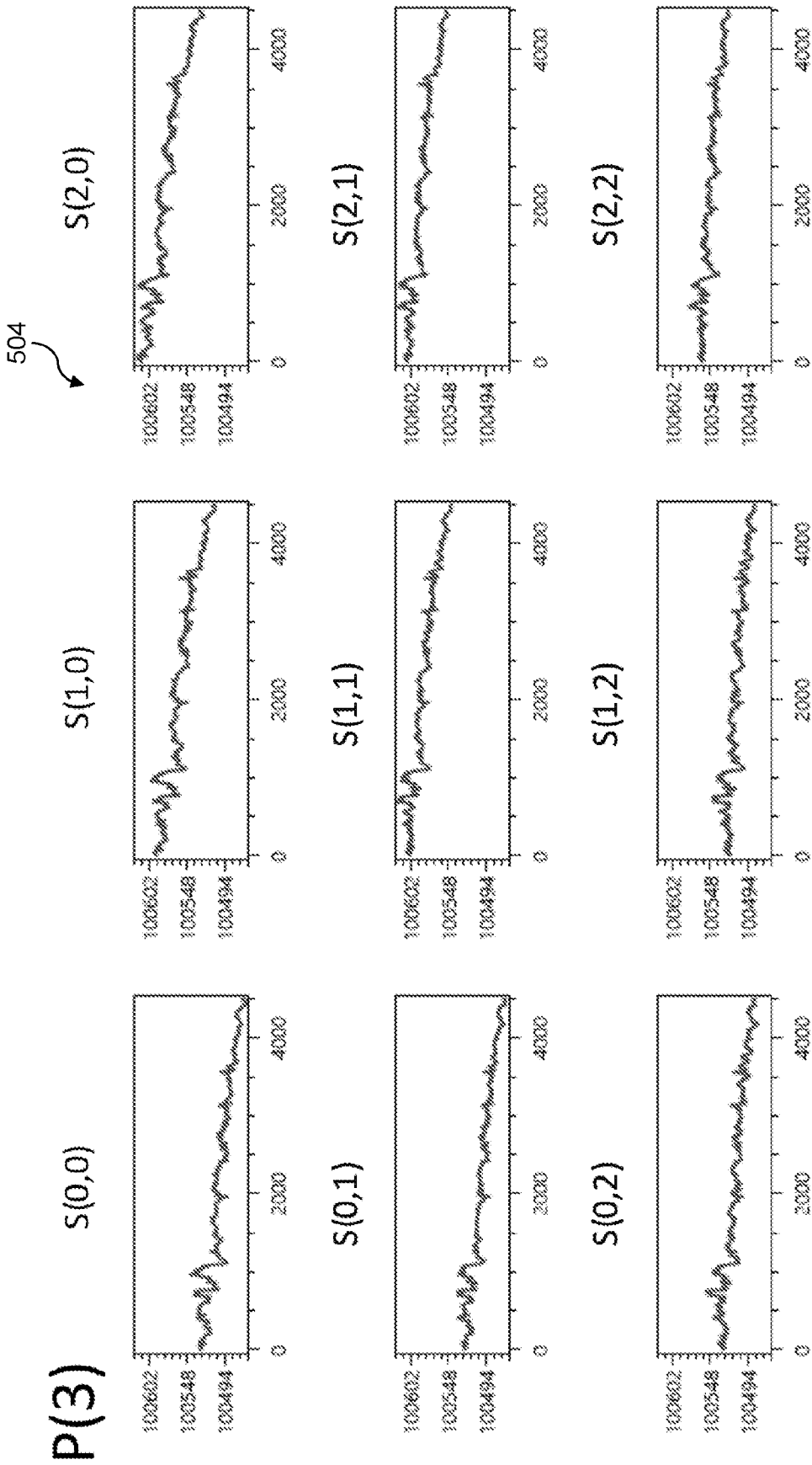


Figure 5E

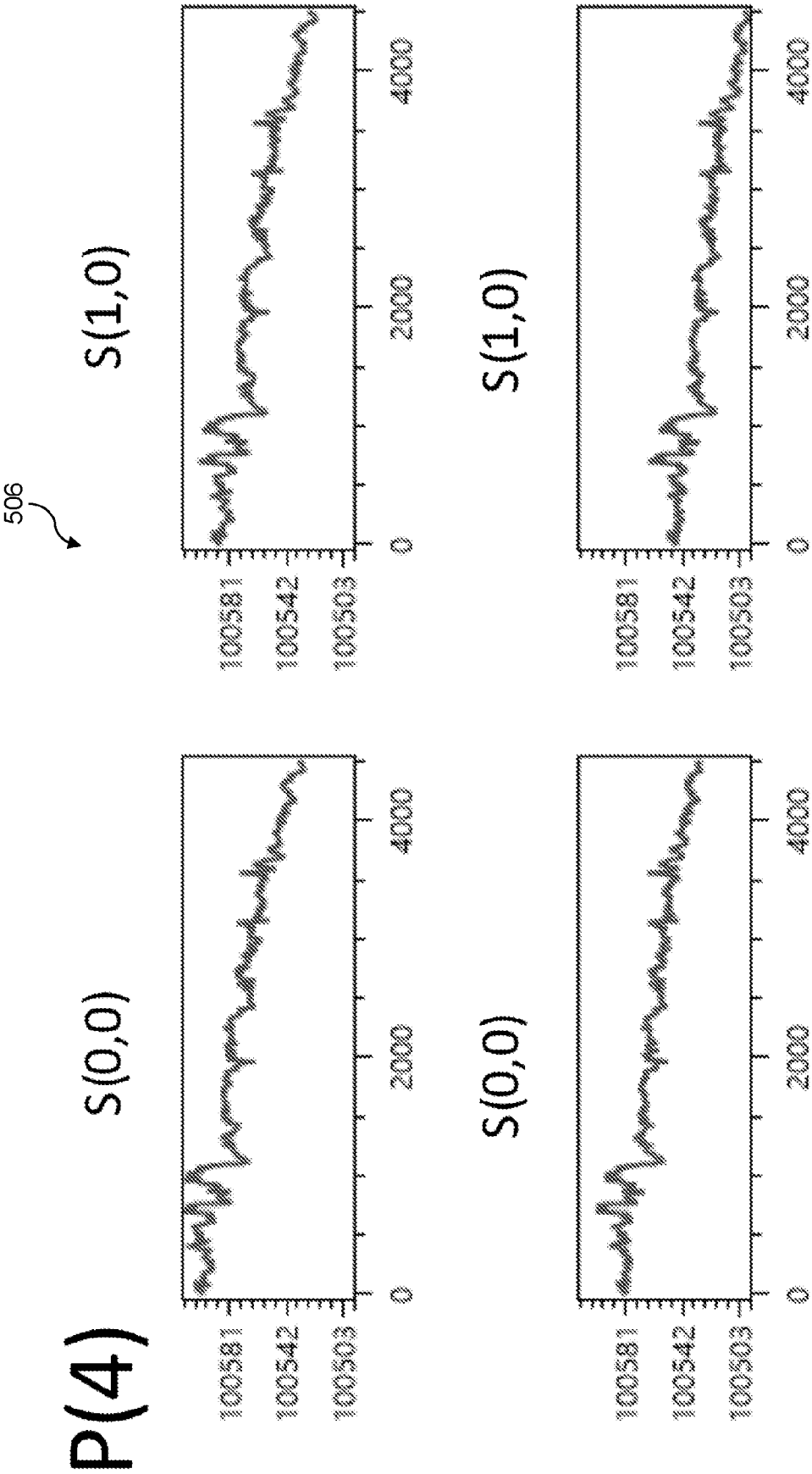


Figure 5F

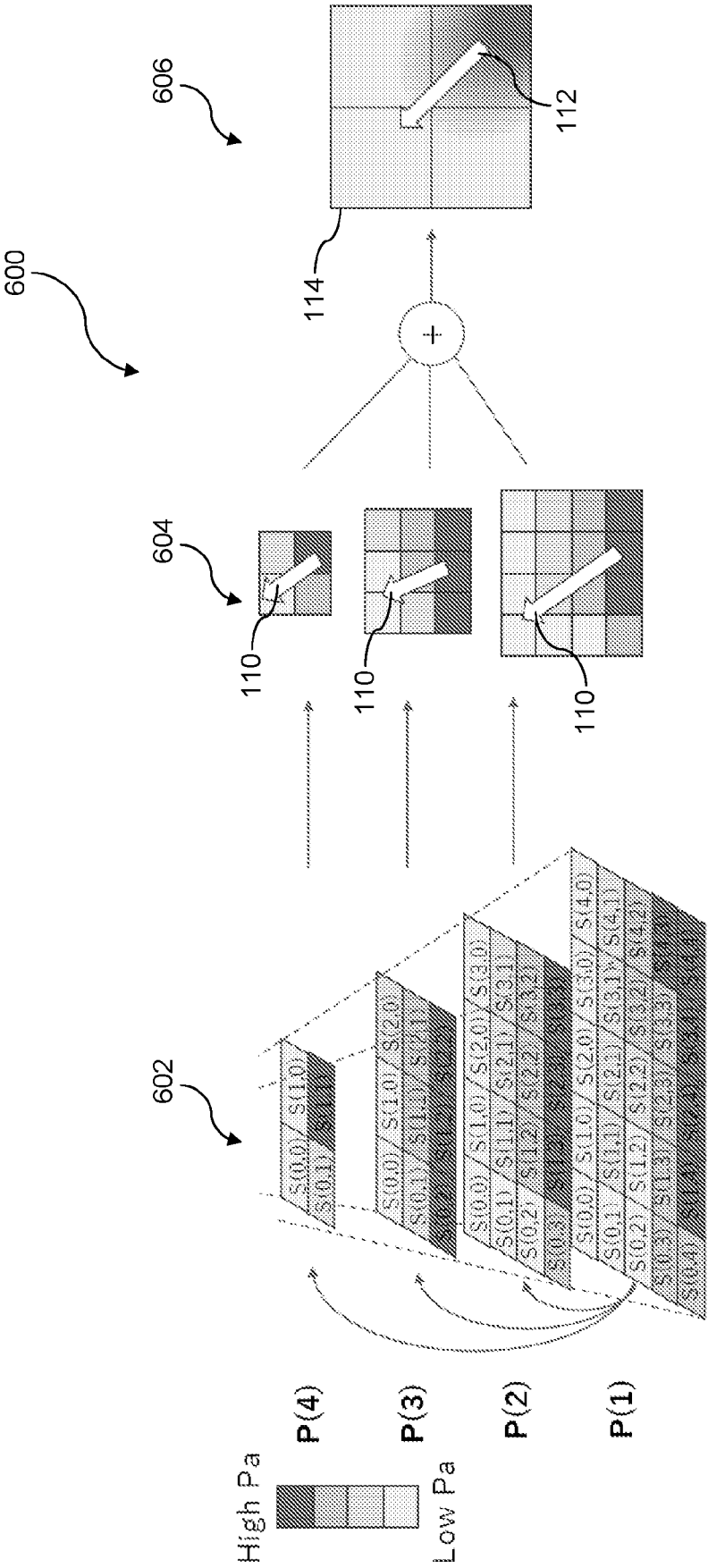


Figure 6

11/13

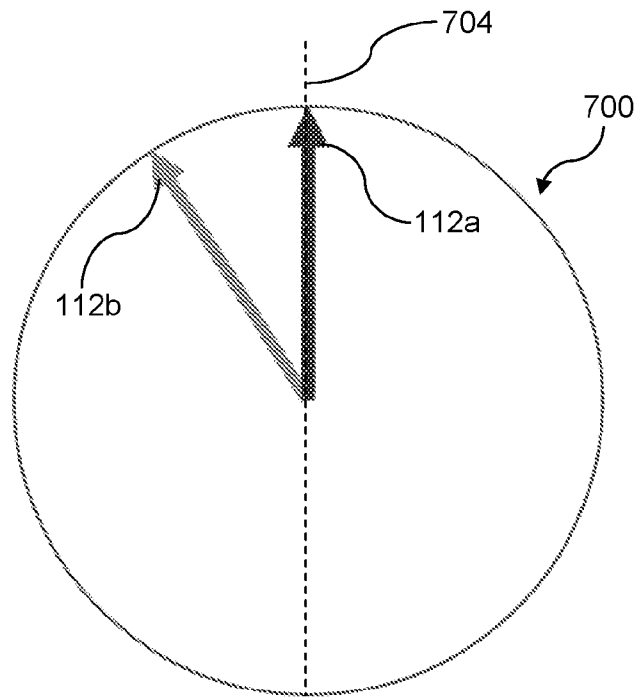


Figure 7A

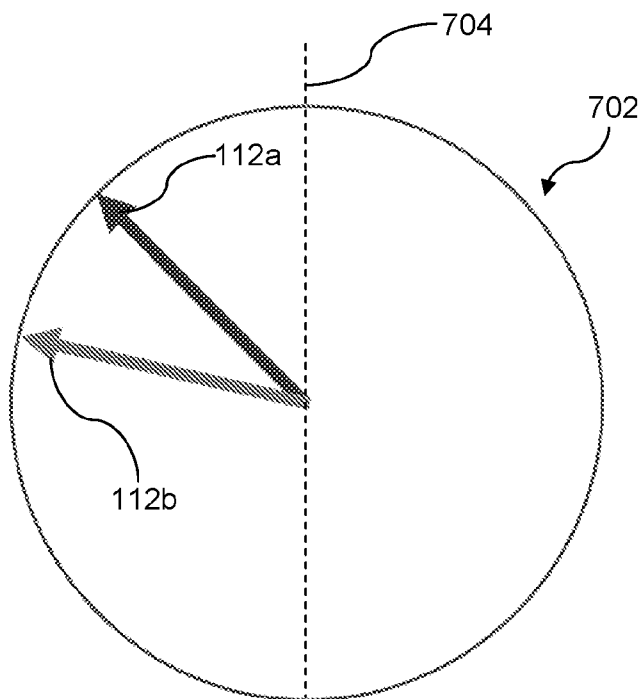


Figure 7B

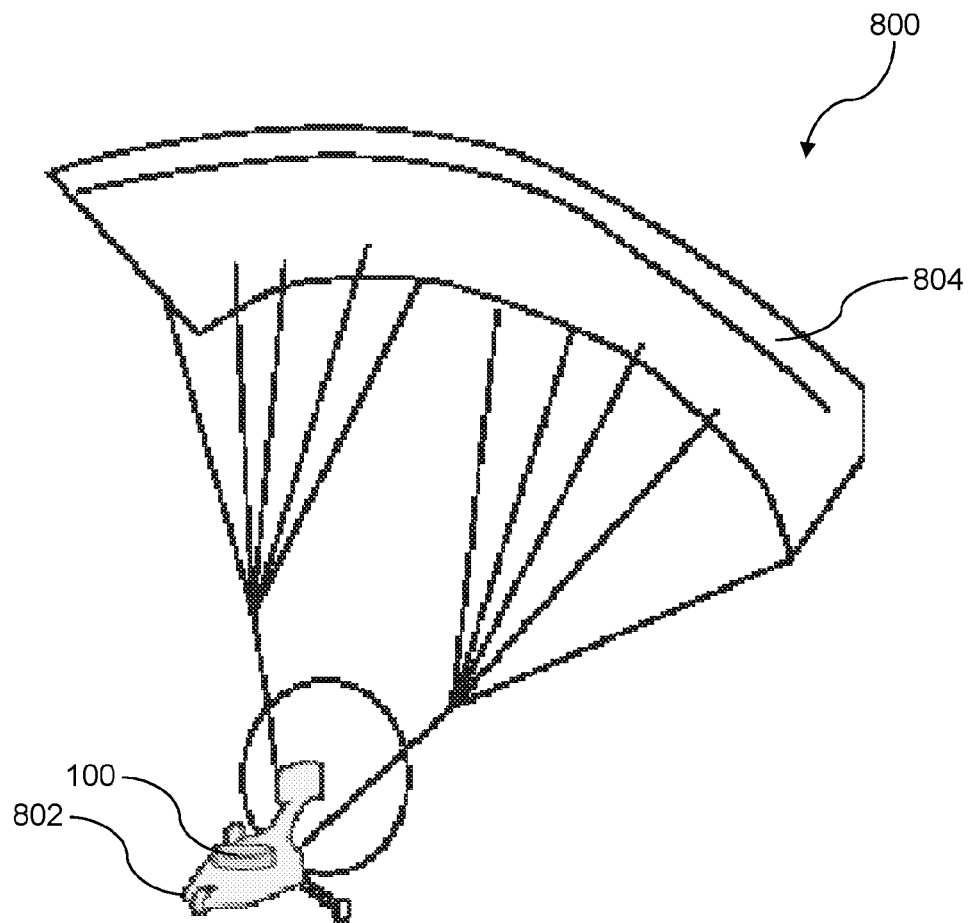


Figure 8A

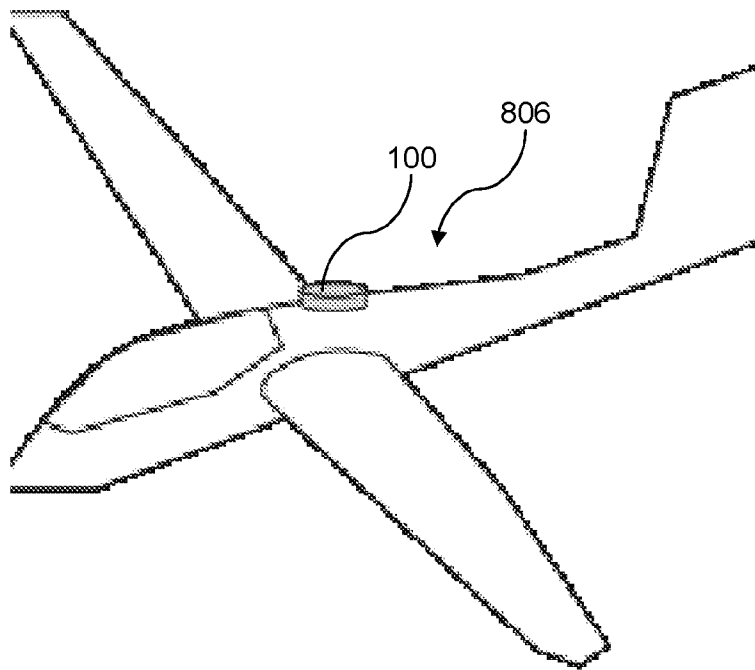


Figure 8B

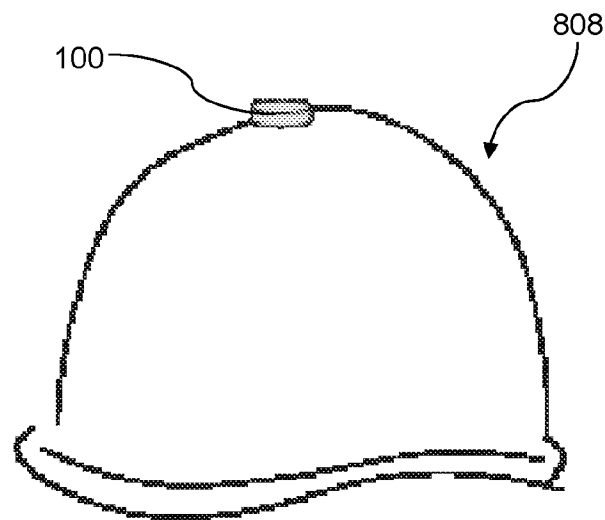


Figure 8C

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2018/050387

A. CLASSIFICATION OF SUBJECT MATTER

G01W 1/10 (2006.01) G01L 7/00 (2006.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G01W, G01L

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)

Databases: Fampat, Incopat, IEEE Xplore, CNKI

Search terms: weather forecast, barometric, atmospheric, air, pressure, sensor, pressure gradient, pressure distribution, 天气预报, 天气预测, 气压, 压力, 压强, 阶差, 梯度, 分布, 大气压, 传感器 and related terms

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 2437083 A2 (SEIKO EPSON CORPORATION) 4 April 2012 Fig. 5, Paras. [0078]-[0080], [0083], [0090]	1-4, 7-8, 11-17, 20
A	CN 105334346 A (SOUTHEAST UNIVERSITY) 17 February 2016 Whole document particularly Fig. 8 of the original non-English language document (a machine translation is enclosed only for your reference)	
A	Wikipedia: Smoothing. 25 February 2008 [Retrieved on 2018-09-14 from https://web.archive.org/web/*/https://en.wikipedia.org/wiki/Smoothing] Whole document particularly Algorithm section	
A	CODELUPPI R. ET AL., A sensor network for real-time windsail aerodynamic control. <i>Proceedings ELMAR-2010</i> , 21 October 2010, pages 314-344 [Retrieved on 2018-09-13] Whole document particularly Figs. 1(A), 6(B)	

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

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"P" document published prior to the international filing date but later than the priority date claimed

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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

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Date of the actual completion of the international search

14/09/2018

(day/month/year)

Date of mailing of the international search report

02/10/2018

(day/month/year)

Name and mailing address of the ISA/SG



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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2018/050387

Note: This Annex lists known patent family members relating to the patent documents cited in this International Search Report. This Authority is in no way liable for these particulars which are merely given for the purpose of information.

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
EP 2437083 A2	04/04/2012	TW 201217826 A CN 102445715 A JP 2012078237 A KR 20120035127 A US 2012/0084005 A1	01/05/2012 09/05/2012 19/04/2012 13/04/2012 05/04/2012
CN 105334346 A	17/02/2016	NONE	