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(54) **SYSTEM AND METHOD FOR DETERMINING AIR QUALITY CHARACTERISTIC OF ENCLOSED VOLUME**

(57) Disclosed is a heating, ventilation and air-conditioning (HVAC) system for determining a characteristic air quality recovery score of a pollutant in an enclosed volume, comprising a processor configured to obtain pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times; identify an event comprising a sub-range of datapoints from the plurality of datapoints, the event comprising at least one datapoint which satisfies a predetermined criterion of maxima or minima; determine that the event is of a decay event type which follows a pollutant decay pattern; determine a pollutant decay characteristic from the event; and determine the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic. Further disclosed is a method for operating the HVAC system, and a processor for the HVAC system.

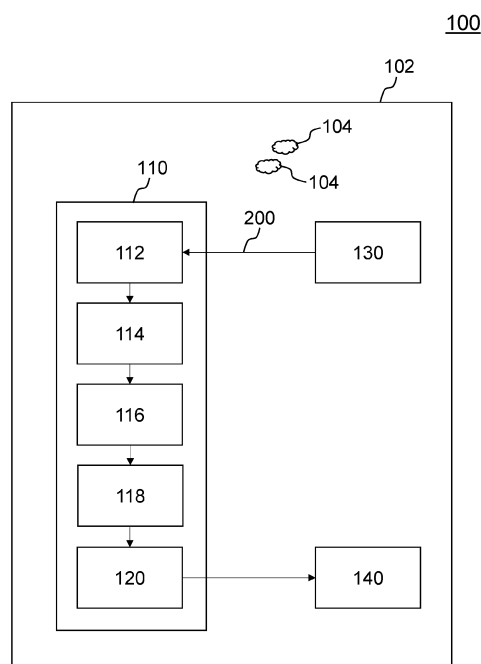


FIG. 1

Description

BACKGROUND

[0001] The present disclosure relates to a heating, ventilation and air-conditioning (HVAC) system, a processor for the HVAC system, and a method of operating the HVAC system for determining an air quality related characteristic of an enclosed volume.

[0002] The following discussion of the background art is intended to facilitate an understanding of the present disclosure only. It should be appreciated that the discussion is not an acknowledgement or admission that any of the material referred to was published, known or is part of the common general knowledge of the person skilled in the art in any jurisdiction as of the priority date of the disclosure.

[0003] Conventional pollutant sensors, such as carbon dioxide sensors, may be employed for determining pollutant levels in indoor air quality management systems and/or HVAC devices. Such conventional pollutant sensors are currently used to provide information on air exchange rates within an enclosed volume.

[0004] However, continuous monitoring of the number of air exchanges rates within the enclosed volume is challenging since variables such as doors, windows, variable ventilation rates and the number of occupants may skew the results.

[0005] In addition, such sensors do not provide information on the impact of the air exchanges rates on the overall air quality of the enclosed volume. This results in ambiguity regarding the quality of air within the enclosed volume, and its impact on the occupants of the enclosed volume.

[0006] Accordingly, there exists a need for an improved system that seeks to address at least one of the aforementioned issues.

SUMMARY

[0007] The disclosure was conceptualised to provide an improved HVAC system for determining an air quality related characteristic of an enclosed volume in real-time or near real-time. To this end, the improved system provides a user information on the impact of the air exchanges rates on the overall air quality of the enclosed volume. It was found that this may be determined based on a characteristic air quality recovery score of a pollutant in the enclosed volume. In particular, the improved system provides the characteristic air quality recovery score, indicative of the pollutant decay rate in the enclosed volume. The improved system further allows the adjustment of at least one operating parameter of the system based on said characteristic air quality recovery score. Since the pollutant requires time to disperse from the enclosed volume, the provision of the characteristic air quality recovery score provides the user with a better indication of the clearance of the pollutant from the en-

closed volume, to prevent the pollutant concentration from reaching undesirable levels, for example, unsafe levels. This may be helpful for the user to determine safe occupancy rates of the enclosed volume.

[0008] According to one aspect of the disclosure, there is provided a HVAC system for determining a characteristic air quality recovery score of a pollutant in an enclosed volume. The HVAC system comprises a processor configured to obtain pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times. The processor is also capable of being configured to identify an event comprising a sub-range of datapoints from the plurality of datapoints, the event comprising at least one datapoint which satisfies a pre-determined criterion of maxima or minima, and determine that the event is of a decay event type which follows a pollutant decay pattern. The processor may further be configured to determine a pollutant decay characteristic from the event; and determine the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic.

[0009] In various embodiments, determining that the event is of the decay event type which follows the pollutant decay pattern may comprise, determining a first increase in the pollutant concentration of the pollutant from a current pollutant data.

[0010] In various embodiments, determining the characteristic air quality recovery score based on the pollutant decay characteristic may comprise, calculating a plurality of event air quality recovery scores, and determining the characteristic air quality recovery score based on the plurality of event air quality recovery scores. In some embodiments, determining the characteristic air quality recovery score may comprise, calculating a statistical measure of the plurality of event air quality recovery scores.

[0011] In various embodiments, determining the pollutant decay characteristic from the event may comprise, determining a first point having a first maximum value, the first point corresponding to the determined first increase in the pollutant concentration of the pollutant from the current pollutant data. Determining the pollutant decay characteristic from the event may further comprise determining a second point having a first minimum value, the second point corresponding to a first decrease detected in the pollutant concentration of the pollutant from the first point.

[0012] In various embodiments, determining an event air quality recovery score of the pollutant based on the pollutant decay characteristic may comprise calculating a first parameter based on the first point having the first maximum and the second point having the first minimum.

[0013] In various embodiments, determining the pollutant decay characteristic from the event may further comprise, determining a third point having a second maximum, the third point corresponding to a second increase determined in the pollutant concentration of

the pollutant from the second point. Determining the pollutant decay characteristic from the event may further comprise determining a fourth point having a second minimum, the fourth point corresponding to a second decrease determined in the pollutant concentration of the pollutant from the third point.

[0014] In various embodiments, determining the event air quality recovery score of the pollutant based on the pollutant decay characteristic may further comprise, calculating a second parameter based on the third point having the second maximum and the fourth point having the second minimum, and calculating a mean of the first parameter and the second parameter.

[0015] In various embodiments, the system may further comprise at least one sensor for detecting an occupancy of the enclosed volume; wherein the processor is in data communication with the at least one sensor. The processor may be configured to obtain, from the at least one sensor, the occupancy of the enclosed volume. The processor may be configured to compare the characteristic air quality recovery score with a predetermined threshold air quality recovery score; and adjust at least one operating parameter of the system based on said comparison of the air quality recovery score with the predetermined threshold air quality recovery score, and/or the occupancy of the enclosed volume.

[0016] In various embodiments, the system may further comprise a scheduler for storing schedule data indicative of a scheduled use of the enclosed volume. The processor is in data communication with the scheduler. The processor may be configured to obtain, from the scheduler, a time of the scheduled use of the enclosed volume based on the scheduled data. The processor may be configured to determine a time slot, indicative of a time difference between a current time and the time of the scheduled use of the enclosed volume, and calculate a duration required for the pollutant concentration to reach a predetermined threshold, based on the characteristic air quality recovery score. The processor may be further configured to determine if the duration is within the time slot; and adjust the at least one operating parameter of the system based on the determination that the duration is within the time slot.

[0017] In various embodiments, adjusting the at least one operating parameter of the system may comprise adjusting an air flow of a ventilation device. The ventilation device may be configured to inject fresh air into the enclosed volume and/or to increase a clearance rate of the pollutant from the enclosed volume.

[0018] In various embodiments, the pollutant may be carbon dioxide.

[0019] According to another aspect of the disclosure, there is provided an enclosed volume comprising the HVAC system according to various embodiments of the disclosure.

[0020] According to yet another aspect of the disclosure, there is provided a control device for a HVAC system, the control device comprising a processor con-

figured to determine a characteristic air quality recovery score of a pollutant in an enclosed volume. The processor is in data communication with a memory having instructions stored therein. The instructions, when executed by the processor, causes the processor to obtain pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times. The processor further identifies an event comprising a sub-range of datapoints among the plurality of datapoints, the event comprising at least one datapoint which satisfies a predetermined criterion of maxima or minima. The processor further determines that the event is of a decay event type which follows a pollutant decay pattern, and determines a pollutant decay characteristic from the event. The processor further determines the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic.

[0021] According to yet another aspect of the disclosure, there is provided a method for determining a characteristic air quality recovery score of a pollutant in an enclosed volume. The method comprises providing a processor for obtaining pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times. The method further comprises identifying an event comprising a sub-range of datapoints among the plurality of datapoints, the event comprising at least one datapoint which satisfies a predetermined criterion of maxima or minima, and determining that the event is of a decay event type which follows a pollutant decay pattern. The method further comprises determining a pollutant decay characteristic from the event, and determining the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic.

[0022] In various embodiments, determining that the event is of the decay event type which follows the pollutant decay pattern may comprise determining a first increase in the pollutant concentration of the pollutant from a current pollutant data.

[0023] In various embodiments, determining the characteristic air quality recovery score based on the pollutant decay characteristic may comprise calculating a plurality of event air quality recovery scores, and determining the characteristic air quality recovery score based on the plurality of event air quality recovery scores. In some embodiments, determining the characteristic air quality recovery score may further comprise, calculating a statistical measure of the plurality of event air quality recovery scores.

[0024] In various embodiments, determining the pollutant decay characteristic from the event may comprise determining a first point having a first maximum, the first point corresponding to the determined first increase in the pollutant concentration of the pollutant from the current pollutant data. Determining the pollutant decay characteristic from the event may further comprise determining a second point having a first minimum, the second

point corresponding to a first decrease determined in the pollutant concentration of the pollutant from the first point.

[0025] In various embodiments, determining an event air quality recovery score of the pollutant based on the pollutant decay characteristic may comprise calculating a first parameter based on the first point having the first maximum and the second point having the first minimum.

[0026] In various embodiments, determining the pollutant decay characteristic from the event may further comprise determining a third point having a second maximum, the third point corresponding to a second increase determined in the pollutant concentration of the pollutant from the second point. Determining the pollutant decay characteristic from the event may further comprise determining a fourth point having a second minimum, the fourth point corresponding to a second decrease determined in the pollutant concentration of the pollutant from the third point.

[0027] In various embodiments, determining the event air quality recovery score of the pollutant based on the pollutant decay characteristic may further comprise calculating a second parameter based on the third point having the second maximum and the fourth point having the second minimum, and calculating a mean of the first parameter and the second parameter.

[0028] In various embodiments, the method may further comprise obtaining, from at least one sensor, an occupancy of the enclosed volume, the at least one sensor configured to detect the occupancy of the enclosed volume. The method may further comprise comparing, by the processor, the characteristic air quality recovery score with a predetermined threshold air quality recovery score. The method may further comprise adjusting, by the processor, at least one operating parameter of a HVAC system based on said comparison of the characteristic air quality recovery score with the predetermined threshold air quality recovery score, and/or the detected occupancy of the enclosed volume.

[0029] In various embodiments, the method may further comprise obtaining, from a scheduler, a time of the scheduled use of the enclosed volume based on the scheduled data, the scheduler configured to store schedule data indicative of a scheduled use of the enclosed volume. The method may further comprise determining, by the processor, a time slot, indicative of a time difference between a current time and the time of the scheduled use of the enclosed volume, and calculating, by the processor, a duration required for the pollutant concentration to reach a predetermined threshold, based on the characteristic air quality recovery score. The method may further comprise determining, by the processor, if the duration is within the time slot; and adjusting, by the processor, the at least one operating parameter of the HVAC system based on the determination that the duration is within the time slot.

[0030] In various embodiments, adjusting the at least one operating parameter of the HVAC system may comprise adjusting an air flow of a ventilation device, the

ventilation device configured to inject fresh air into the enclosed volume and/or to increase a clearance rate of the pollutant from the enclosed volume.

[0031] According to yet another aspect of the disclosure, there is provided a computer program product, comprising software instructions which when executed on the processor, causes the processor to execute the steps of the method for determining a characteristic air quality recovery score of a pollutant in an enclosed volume.

BRIEF DESCRIPTION OF DRAWINGS

[0032] The disclosure will be better understood with reference to the detailed description when considered in conjunction with the non-limiting examples and the accompanying drawings, in which:

FIG. 1 shows an exemplary schematic illustration of a HVAC system 100, including a processor 110 for determining a characteristic air quality recovery score of a pollutant 104 in an enclosed volume 102; FIG. 2 shows an exemplary graph of the pollutant data 200 comprising a plurality of datapoints indicative of the concentration of the pollutant 104 over different times;

FIG. 3 shows another exemplary schematic illustration of a HVAC system 300, including the processor 110 for determining a characteristic air quality recovery score of the pollutant 103 in the enclosed volume 102;

FIG. 4 shows an exemplary schematic illustration of a control device 400 for a HVAC system, the control device 400 comprising a processor 420 configured to determine a characteristic air quality recovery score of a pollutant in the enclosed volume;

FIG. 5 shows an exemplary flowchart of a method 500 for determining a characteristic air quality recovery score of a pollutant in an enclosed volume; FIG. 6 shows another exemplary flowchart of a method 600 for determining a characteristic air quality recovery score of a pollutant in an enclosed volume; and

FIG. 7 shows another exemplary flowchart of a method 700 for determining a characteristic air quality recovery score of a pollutant in an enclosed volume.

DETAILED DESCRIPTION

[0033] The following detailed description refers to the accompanying drawings that show, by way of illustration, specific details and embodiments in which the disclosure may be practiced. These embodiments are described in sufficient detail to enable those skilled in the art to practice the disclosure. Other embodiments may be utilized and structural, and logical changes may be made without departing from the scope of the disclosure. The various

embodiments are not necessarily mutually exclusive, as some embodiments can be combined with one or more other embodiments to form new embodiments.

[0034] Features that are described in the context of an embodiment may correspondingly be applicable to the same or similar features in the other embodiments. Features that are described in the context of an embodiment may correspondingly be applicable to the other embodiments, even if not explicitly described in these other embodiments. Furthermore, additions and/or combinations and/or alternatives as described for a feature in the context of an embodiment may correspondingly be applicable to the same or similar feature in the other embodiments.

[0035] In the context of various embodiments, the articles "a", "an" and "the", and the term "at least one" as used with regard to a feature or element include a reference to one or more of the features or elements. As used herein, the term "and/or" includes any and all combinations of one or more of the associated listed items.

[0036] In the context of various embodiments, the terms "first", "second", "third", "fourth" are merely used as notations to denote the order of the features or elements as they appear in the disclosure.

[0037] Throughout the description, the term "HVAC system", as used herein, refers to systems for indoor air quality, temperature and/or humidity management. The HVAC system may control air quality through air exchanges, e.g. ventilation and/or filtration. The HVAC system may further include cooling and/or heating devices for temperature and humidity management.

[0038] Throughout the description, the term "enclosed volume", as used herein, refers to an enclosed space or area which contains air having a pollutant concentration.

[0039] Throughout the description, the term "pollutant(s)", as used herein, may refer to any substance that has undesirable effects or adversely affects the quality of the air within the enclosed volume. In various embodiments, the pollutant may include one or more types of pollutant. In some embodiments, the pollutant may be a gas, and in an embodiment, the pollutant may be carbon dioxide. It is contemplated that the pollutant may be a chemical, and/or particulate matter.

[0040] Throughout the description, the term "pollutant decay pattern", may refer to a pattern, e.g. shape, in the pollutant data that is indicative of the decay of the pollutant from the enclosed volume. In various embodiments, the pollutant decay pattern may include points having a maximum and a minimum.

[0041] Throughout the description, the term "air quality recovery score", as used herein, may refer to an indicator, e.g. alphanumeric value, that provides a user an indication of the decay of the pollutant from the enclosed volume. In various embodiments, the air quality recovery score may refer to the decay rate of the pollutant from the enclosed volume. Accordingly, the term "event air quality recovery score", may refer to an individual score obtained from the at least two points which follows the pollutant

decay pattern, and the term "characteristic air quality recovery score", may refer to an overall score indicative of the overall decay rate of the pollutant from the enclosed volume, which may be based on a plurality of event air quality recovery scores.

[0042] Throughout the description, the term "obtain", as used herein, refers to the processor which actively obtains, or passively receives data, e.g. pollutant data, occupancy data, schedule data, from one or more sensors and/or a scheduler. The processor may also obtain various data types from another processor or a communication interface, e.g. a user interface. The processor may also receive or obtain the various data types via a memory, a register, and/or an analog-to-digital port.

[0043] Throughout the description, the term "maxima datapoint(s)", as used herein, refers to a plurality of points having a maximum, indicative of an increase in pollutant concentration from previous pollutant data concentrations. Accordingly, the term "minima datapoint(s)", as used herein, refers to a plurality of points having a minimum, indicative of a reduction in pollutant concentration from the maxima datapoint(s). In various embodiments, the maxima and minima datapoints may refer to local maxima and minima datapoints, or global maxima and minima datapoints.

[0044] Throughout the description, the phrase "point having a maximum or minimum", as used herein, refers to a point derived from the plurality of datapoints corresponding to the pollutant data, which has an extremum of a maximum or minimum. The extremum points may be derived directly from the pollutant data, or may be derived via mathematical optimization of a function of the pollutant data, e.g. curve fitting or interpolation of the pollutant data array. In some embodiments, the extremum point having the maximum or minimum may be a measured datapoint. In some other embodiments, the extremum point having the maximum or minimum may be calculated, and determined to be between the measured datapoints, for example, by curve fitting or interpolation of the pollutant data array, where said point may be between two measured datapoints.

[0045] Throughout the description, the term "maximum or minimum" may refer to extremum points. The term "maximum" may include a maximum, e.g. largest value, an infimum, a limit superior or a sample maximum. Accordingly, the term "minimum" may refer to a minimum, e.g. smallest value, a supremum, a limit inferior or a sample minimum.

[0046] Throughout the description, the term "sensor(s)", include hardware sensors, software sensor, and combinations of hardware and software sensors.

[0047] Throughout the description, the term "processor", refers to a circuit, including analog circuits or components, digital circuits or components, hybrid circuits or components. Any other kind of implementation of the respective functions which will be described in more detail below may also be understood as a "circuit" in accordance with an alternative embodiment. A digital

circuit may be understood as any kind of logic implementing entity, which may be a special purpose circuitry or a processor executing software stored in a memory, or a firmware. The processor may also include a single stand-alone computer, a single dedicated server, multiple dedicated servers, and/or a virtual server running on a larger network of servers and/or cloud-based service.

[0048] FIG. 1 shows an exemplary schematic illustration of a HVAC system 100, including a processor 110 for determining a characteristic air quality recovery score of a pollutant 104 in an enclosed volume 102. FIG. 2 shows an exemplary graph of the pollutant data 200 comprising a plurality of datapoints indicative of the concentration of the pollutant 104 over different times.

[0049] In some embodiments, the enclosed volume may be an enclosed space of an area, such as a space of a building or a room. It is contemplated that the enclosed volume may be a cabin of a vehicle.

[0050] Referring to FIGS. 1 and 2, the HVAC system 100 includes a processor 110 configured to obtain 112, pollutant data 200 comprising a plurality of datapoints indicative of the pollutant 104 concentration over different times. The pollutant data 200 may be measured by a sensor 130 suitable for measuring the pollutant concentration of the pollutant 104 in the enclosed volume 102. In some embodiments, the pollutant 104 may be carbon dioxide, and accordingly, the sensor 130 may be a carbon dioxide sensor. The processor 110 may be in data communication with the sensor 130, and may therefore obtain the pollutant data 200 via a predefined wireless communication protocol. Examples of the pre-defined wireless communication protocols include: global system for mobile communication (GSM), enhanced data GSM environment (EDGE), wideband code division multiple access (WCDMA), code division multiple access (CDMA), time division multiple access (TDMA), wireless fidelity (Wi-Fi), voice over Internet protocol (VoIP), worldwide interoperability for microwave access (Wi-MAX), Wi-Fi direct (WFD), an ultra-wideband (UWB), infrared data association (IrDA), Bluetooth, ZigBee, SigFox, LPWan, LoRa-Wan, GPRS, 3G, 4G, LTE, and 5G communication systems. Alternatively, the processor 110 may obtain the pollutant data 200 via wired means.

[0051] In various embodiments, the pollutant data 200 obtained over different times, may refer to pollutant data 200 measured over a predetermined period. The predetermined period may range from 1 hour to 30 days, and in some embodiments, may be 15 days. Alternatively, the pollutant data 200 may be continuously measured by the sensor 130, and may be transmitted to the processor 110 at a predetermined interval, or upon request by the processor 110.

[0052] Based on the pollutant data 200, the processor 110 identifies 114, an event 210 comprising a sub-range of datapoints from the pollutant data 200, determined based on the identification of at least one datapoint with satisfies a predetermined criterion of maxima 212 or minima 214. Event 210 determination may include the

identification of a plurality of points having a maximum, indicative of an increase in pollutant concentration from current pollutant data 202, or a plurality of points having a minimum, indicative of a reduction in pollutant concentration from the maxima or from a current pollutant data 202.

[0053] In various embodiments, the current pollutant data 202 may include data indicative of a constant pollutant concentration within the enclosed volume 102. In some embodiments, the current pollutant data 202 may include a pollutant concentration which is safe for occupants in the enclosed volume 102.

[0054] The processor 110 is further configured to determine 116, if the event 210 is of a decay event type which follows a pollutant decay pattern 220, 230. In various embodiments, the processor 110 may determine the decay event type, by determining a first increase 204 in the pollutant concentration from the current pollutant data 202. In various embodiments, the decay event type may be determined if the increase in pollutant concentration exceeds a predetermined threshold level, for example, a threshold representative of a pollutant concentration which may be undesirable, for example, unsafe to occupants in the enclosed volume. In various embodiments, the decay event type may include at least one point having a maximum, and at least one point having a minimum. The pollutant decay pattern 220, 230 may therefore be a pattern indicative of an elevation in pollutant concentration, followed by the clearance or reduction of the pollutant 104 from the enclosed volume.

[0055] The processor 110 is further configured to determine 118, a pollutant decay characteristic from the decay event type. Referring to FIG. 2, determination 118 of the pollutant decay characteristic from a first pollutant decay pattern 220 may include, determining a first point 222 having a first maximum, corresponding to the first increase 204 which may be above the predetermined threshold level. Determination 118 of the pollutant decay characteristic from the first pollutant decay pattern 220 may further include, determining a second point 224 having a first minimum corresponding to a first decrease determined in the pollutant concentration of the pollutant 104 from the first point 222. In various embodiments, the first point 222 may be determined prior to the second point 224, e.g. $t_{\text{first point, max}} < t_{\text{second point, min}}$. In other words, the processor 110 determines 118, a consecutive maximum point, e.g. first point 222, and minimum point, e.g. second point 224, which follows the first pollutant decay pattern 220.

[0056] In various embodiments, the first point 222 and second point 224 having the maximum and minimum, respectively, may be determined directly from the measured plurality of datapoints, or may be determined via mathematical optimization of the plurality of datapoints, e.g. curve fitting or interpolation to identify extremum points. While FIG. 2 shows the determination of the first point 222 having a first local maximum and the second point 224 having a first local minimum, embodiments are

not limited thereto and the determination of the first point and second point may be based on the determination of a global maximum and minimum, based on the plurality of datapoints, e.g. via calculus of variations on the pollutant data 200 array.

[0057] The processor 110 may be further configured to determine an event air quality recovery score of the pollutant 104 for the first decay event type having the first pollutant decay pattern 220, by calculating a first parameter based on the first point 222 having the first maximum and the second point 224 having the first minimum. In various embodiments, the first parameter may be a gradient of the first point 222 and the second point 224; the gradient of smooth data based on the first point 222 and the second point 224; gradient of a curve fitted on the data based on the first point 222 and the second point 224; and/or exponent of a fitted exponential decay function based on the first point 222 and the second point 224. In other words, the first parameter may be a parameter indicative of the rate of pollutant 104 decay or clearance, based on the first pollutant decay pattern 220.

[0058] In various embodiments, the processor 110 may be further configured to determine 116, one or more decay event types which follow the pollutant decay pattern 220, 230, from the event 210 comprising the sub-range of datapoints. For example, the processor 110 may further determine a second decay event type which follows a second pollutant decay pattern 230. The second decay event type may be determined based on a second increase in pollutant concentration of the pollutant 104 from the second point 224. In some embodiments, the second increase may be a pollutant concentration which exceeds the predetermined threshold level.

[0059] In various embodiments, the processor 110 may be further configured to determine 118, the pollutant decay characteristic from the second decay event type having the second pollutant decay pattern 230. As shown in FIG. 2, the processor 110 may determine a third point 232 having a second maximum, which may correspond to the second increase determined in the pollutant concentration of the pollutant 104 from the second point 222. Determining 118, the pollutant decay characteristic from the second decay event type may further include determining a fourth point 234 having a second minimum, corresponding to a second decrease determined in the pollutant concentration of the pollutant 104 from the third point 232. In various embodiments, the third point 232 may be determined prior to the fourth point 234, e.g.

$$t_{\text{third point, max}} < t_{\text{fourth point, min}}$$

[0060] Accordingly, the processor 110 may determine 118, consecutive maximum and minimum points of each decay event type having the pollutant decay pattern 220, 230. Said maximum or minimum points of each decay event type may be local or global extremum points, and may in some embodiments, be determined as points obtained directly from the measured pollutant data 200. In some other embodiments, the maximum or mini-

mum points be determined via mathematical optimization of the pollutant data 200 array. For example, the third point 232 may not correspond to the next measured maximum point from the second point 224, but may instead, correspond to another maximum point between the measured plurality of datapoints, e.g. determined via curve fitting or interpolation (not shown in FIG. 2).

[0061] In various embodiments, the processor 110 may be further configured to determine the event air quality recovery score of the pollutant 104 for the second decay event type having the second pollutant decay pattern 230, by calculating a second parameter based on the third point 232 having the second maximum, and the fourth point 234 having the second minimum. The second parameter may be indicative of the rate of pollutant 104 decay or clearance, based on the second pollutant decay pattern 230. In various embodiments, the second parameter may be a gradient; a gradient of smoothed data; a gradient of a curve fitted on the data; and/or exponent of a fitted exponential decay function, based on the third point 232 and the fourth point 234.

[0062] In various embodiments, determining the event air quality recovery score of the event 210 comprising the sub-range of datapoints may include, determining each event air quality recovery score for each decay event type which follows the pollutant decay pattern 220, 230. In some embodiments, the event air quality recovery score may include, determining a mean of the first parameter and the second parameter. It is contemplated that the event air quality recovery score may be based on the determination of a statistical measure, e.g. median, mode, of each parameter of each decay event type which follows the pollutant decay pattern.

[0063] Referring to FIG. 1, the processor 110 is further configured to determine 120, the characteristic air quality recovery score of the pollutant 104 based on the pollutant decay characteristic. In various embodiments, determining 120 the characteristic air quality recovery score may include, calculating a plurality of event air quality recovery scores, each event air quality recovery score corresponding to each decay event type having the pollutant decay pattern 220, 230, and determining, the characteristic air quality recovery score based on said plurality of event air quality recovery scores. In some embodiments, determining 120, the characteristic air quality recovery score may further include, calculating a statistical measure of the plurality of event air quality recovery scores. For example, the characteristic air quality recovery score may be a mean or a median of the plurality of event air quality recovery scores. It is contemplated that the characteristic air quality recovery score may be based on other statistical measures, e.g. mode, percentiles, variance, of the plurality of event air quality recovery scores.

[0064] Accordingly, the characteristic air quality recovery score of the pollutant 104 may represent an overall rate of decay of the pollutant 104 from the enclosed volume 102, and may be based on each decay event type having the pollutant decay pattern 220, 230. In some

embodiments, a high score may indicate that the air exchange rate in the enclosed volume 102 is sufficient for effectively dispersing the pollutant 104 from the enclosed volume 102; and a low score may indicate that the air exchange rate in the enclosed volume 102 may not be sufficient for dispersing said pollutant 104, indicating that one or more operating parameters of the HVAC system 100 may have to be adjusted.

[0065] Referring to FIG. 1, the characteristic air quality recovery score may be displayed on a display of the processor 110, or may be displayed on another processor 140. In various embodiments, the characteristic air quality recovery score may be presented as a graphical symbol indicative of the rate of decay of the pollutant 104 from the enclosed volume 102.

[0066] FIG. 3 shows an exemplary schematic illustration of a HVAC system 300, including the processor 110 for determining a characteristic air quality recovery score of the pollutant 103 in the enclosed volume 102, in accordance with some embodiments of the disclosure. The HVAC system 300 may be based on the HVAC system 100 described with reference to FIG. 1, and repeated description will be omitted for brevity.

[0067] The HVAC system 300 may further include, at least one sensor 310 for detecting an occupancy of the enclosed volume 102. The at least one sensor 310 may be an occupancy and/or vacancy sensor, configured to detect the presence of the occupants in the enclosed volume 102 and to recognize when a person enters or leaves the enclosed volume 102. The processor 110 may be in data communication with the at least one sensor 310, and may be configured to obtain 312, the occupancy, e.g. the number of occupants, of the enclosed volume 102.

[0068] The processor 110 may be further configured to compare 314, the characteristic air quality recovery score with a predetermined threshold air quality recovery score. In various embodiments, the predetermined threshold air quality recovery score may be a score representative of a desired rate of decay of the pollutant 104, which may be a rate optimized for safe occupancy of the enclosed volume 102 based on the occupancy of the enclosed volume 102. For example, the predetermined threshold air quality recovery score may be higher, e.g. faster decay of the pollutant 104, if the enclosed volume 102 has a greater occupancy rate, to prevent the pollutant concentration from reaching undesirable levels, for example, unsafe levels.

[0069] As shown in FIG. 3, the HVAC system 300 may further include a ventilation device 340 configured to adjust an amount of fresh air injected into the enclosed volume 102 and/or to adjust the amount of pollutant 104 cleared from the enclosed volume 102. The ventilation device 340 may be a blower and/or an air filter device.

[0070] Based on the comparison 314 of the characteristic air quality recovery score with the predetermined threshold air quality recovery score, and/or the occupancy of the enclosed volume 102, the processor 110

may be operable to adjust 316, at least one operating parameter of the ventilation device 340. In some embodiments, the processor 110 may adjust an air flow of the ventilation device 330, to increase the amount of fresh air injected into the enclosed volume 102, and/or to increase a clearance rate of the pollutant 104 from the enclosed volume 102. Said adjustment may be done when the characteristic air quality recovery score is less than the predetermined threshold air quality recovery score, and/or if the occupancy of the enclosed volume 102 exceeds a predetermined threshold occupancy. The predetermined threshold occupancy may be indicative of the maximum number of occupants in the enclosed volume 102 at which the pollutant concentration may be maintained at a safe level. In some other embodiments, the processor 110 may adjust the air flow of the ventilation device 330, to decrease the amount of fresh air injected into the enclosed volume 102, and/or to decrease the clearance rate of the pollutant 104 from the enclosed volume 102. Said adjustment may be done when the characteristic air quality recovery score is greater than the predetermined threshold air quality recovery score, and/or the occupancy of the enclosed volume 102 is less than the predetermined threshold occupancy. This may lead to energy savings when there are few or no occupants in the enclosed volume 102.

[0071] Referring to FIG. 3, the HVAC system 300 may further include a scheduler 320, which stores schedule data indicative of a scheduled use of the enclosed volume 102, and may be in data communication with the processor 110.

[0072] The processor 110 may be further configured to obtain 322, from the scheduler 320, a time of the next scheduled use of the enclosed volume 102 based on the schedule data. The processor 110 may be further configured to determine 324, a time slot indicative of a time difference between a current time and the time of the next scheduled use of the enclosed volume 102, and to calculate 326, based on the characteristic air quality recovery score, a duration required for the pollutant concentration to reach a predetermined threshold. In various embodiments, the predetermined threshold may be the pollutant concentration optimized for safe occupancy of the enclosed volume 102. In some embodiments, the predetermined threshold may be the predetermined threshold pollutant concentration for determining 116, decay event types which follow a pollutant decay pattern 220, 230.

[0073] Based on the calculated 326 duration, the processor 110 may be further configured to determine 328, if said duration is within the time slot. The processor 110 may be configured to adjust 330, at least one operating parameter of the HVAC system 300 based on the determination 328, that the duration falls within the time slot.

[0074] In various embodiments, adjusting 330 the least one operating parameter may include adjusting the air flow of the ventilation device 340. For example, if the duration falls within the time slot, the ventilation device

340 may be configured to inject fresh air into the enclosed volume 102, and/or to increase the clearance rate of the pollutant 104 from the enclosed volume 102, thereby reducing the pollutant concentration within the enclosed volume 102 prior to the next scheduled use of the enclosed volume 102. This may prevent the pollutant concentration of the pollutant 104 from reaching undesirable levels, for example, unsafe levels.

[0075] According to another aspect of the disclosure, there is provided an enclosed volume comprising the HVAC device 100, 300 described with reference to FIGS. 1 to 3 of the disclosure.

[0076] FIG. 4 shows an exemplary schematic illustration of a control device 400 for a HVAC system, the control device 400 comprising a processor 420 configured to determine a characteristic air quality recovery score of a pollutant in the enclosed volume, in accordance with another aspect of the disclosure. The control device 400 may be configured for the HVAC system 100, 300 described with reference to FIGS. 1 to 3 of the disclosure, and repeated descriptions are omitted for brevity.

[0077] Referring to FIG. 4, the control device 400 includes a processor 420 in data communication with a memory 410 having instructions stored therein. The instructions, when executed by the processor 420, causes the processor 420 to obtain pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times (step 422). The processor 420 further identifies an event comprising a sub-range of datapoints among the plurality of datapoints, the event comprising at least one datapoint which satisfies a predetermined criterion of maxima or minima (step 424), and determines that the event is of a decay event type which follows a pollutant decay pattern (step 426). The processor 420 further determines a pollutant decay characteristic from the event (step 428); and determines the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic (step 430).

[0078] In various embodiments, the processor 420 may be configured to execute steps 422 to 430 in accordance with the processor 110 described in relation to the HVAC system 100, 300 of FIGS. 1 to 3.

[0079] FIG. 5 shows an exemplary flowchart of a method 500 for determining a characteristic air quality recovery score of a pollutant in an enclosed volume, in accordance with another aspect of the disclosure. The method 500 may be configured for operating the HVAC system 100, 300 described with reference to FIGS. 1 to 3, and repeated descriptions will be omitted for brevity.

[0080] Referring to FIG. 5, method 500 includes providing a processor for executing the followings steps of obtaining, pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times (step 502). Method 500 further includes identifying an event comprising a sub-range of datapoints among the plurality of datapoints, the event comprising at least one datapoint

which satisfies a predetermined criterion of maxima or minima (step 504), and determining that the event is of a decay event type which follows a pollutant decay pattern (step 506). Method 500 further includes determining a pollutant decay characteristic from the event (step 508); and determining the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic (step 510).

[0081] In various embodiments of method 500, determining that the event is of the decay event type which follows the pollutant decay pattern may include, determining a first increase in the pollutant concentration of the pollutant from a current pollutant data.

[0082] In various embodiments of method 500, determining the characteristic air quality recovery score based on the pollutant decay characteristic may include, calculating a plurality of event air quality recovery scores, and determining the characteristic air quality recovery scores based on the plurality of event air quality recovery scores. In some embodiments of method 500, determining the characteristic air quality recovery score may include calculating a statistical measure of the plurality of event air quality recovery scores.

[0083] In various embodiments, determining the pollutant decay characteristic from the event may include, determining a first point having a first maximum, the first point corresponding to the determined first increase in the pollutant concentration of the pollutant from the current pollutant data. Determining the pollutant decay characteristic from the event may further include, determining a second point having a first minimum, the second point corresponding to a first decrease determined in the pollutant concentration of the pollutant from the first point. In various embodiments, determining an event air quality recovery score of the pollutant based on the pollutant decay characteristic may further include, calculating a first parameter based on the first point having the first maximum and the second point having the first minimum.

[0084] In various embodiments of method 500, determining the pollutant decay characteristic from the event may further include, determining a third point having a second maximum, the third point corresponding to a second increase determined in the pollutant concentration of the pollutant from the second point. Determining the pollutant decay characteristic from the event may further include, determining a fourth point having a second minimum, the fourth point corresponding to a second decrease determined in the pollutant concentration of the pollutant from the third point. In various embodiments of method 500, determining the event air quality recovery score of the pollutant based on the pollutant decay characteristic may further include, calculating a second parameter based on the third point having the second maximum and the fourth point having the second minimum, and calculating a mean of the first parameter and the second parameter.

[0085] FIG. 6 shows an exemplary flowchart of a method 600 for determining a characteristic air quality recovery

ery score of a pollutant in an enclosed volume, in accordance with some embodiments of the disclosure. Method 600 may be executed on a processor 110 of the HVAC system 100, 300 discussed with reference to FIGS. 1 to 3. Method 600 may be based on method 500 discussed with reference to FIG. 5 and repeated descriptions will be omitted.

[0086] Referring to FIG. 6, method 600 may further include, obtaining, from at least one sensor, an occupancy of the enclosed volume, the at least one sensor configured to detect the occupancy of the enclosed volume (step 602). Method 600 may further include comparing, by the processor, the characteristic air quality recovery score with a predetermined threshold air quality recovery score (step 604). In various embodiments, method 600 may further include adjusting, by the processor, at least one operating parameter of a HVAC system based on said comparison of the characteristic air quality recovery score with the predetermined threshold air quality recovery score, and/or the detected occupancy of the enclosed volume (step 606).

[0087] In various embodiments of method 600, adjusting the at least one operating parameter of the system 100, 300 may include, adjusting an air flow of a ventilation device, the ventilation device configured to inject fresh air into the enclosed volume and/or to increase a clearance rate of the pollutant from the enclosed volume. Said ventilation device may refer to ventilation device 340 discussed with reference to the HVAC system 300 of FIG. 3.

[0088] FIG. 7 shows an exemplary flowchart of a method 700 for determining a characteristic air quality recovery score of a pollutant in an enclosed volume, in accordance with some other embodiments of the disclosure. Method 700 may be based on method 500 discussed with reference to FIG. 5 and repeated descriptions will be omitted.

[0089] Referring to FIG. 7, method 700 may include, obtaining, from a scheduler, a time of the scheduled use of the enclosed volume based on the scheduled data, the scheduler configured to store schedule data indicative of a scheduled use of the enclosed volume (step 702). Method 700 may also include determining, by the processor, a time slot, indicative of a time difference between a current time and the time of the scheduled use of the enclosed volume (step 704), and calculating, by the processor, a duration required for the pollutant concentration to reach the predetermined baseline value, based on the characteristic air quality recovery score (step 706). Method 700 may further include determining, by the processor, if the duration is within the time slot (step 708), and adjusting, by the processor, the at least one operating parameter of the HVAC system based on the determination that the duration is within the time slot (step 710).

[0090] In various embodiments of method 700, adjusting the at least one operating parameter of the system 100, 300 may include, adjusting an air flow of a ventilation

device, the ventilation device configured to inject fresh air into the enclosed volume and/or to increase a clearance rate of the pollutant from the enclosed volume. Accordingly, a buildup of pollutant in the enclosed volume may be prevented prior to the next scheduled use, and the pollutant concentration of the pollutant in the enclosed volume may not reach an undesired level, for example, a level which is unsafe for occupants of the enclosed volume.

[0091] Various embodiments of the disclosure further provide a computer program product, comprising software instructions which when executed on a processor, causes the processor to execute steps 502 to 710 of method 500, 600, 700 described with reference to FIGS. 5 to 7.

[0092] The present disclosure thus provides an improved HVAC system for determining an air quality related characteristic of an enclosed volume in real-time or near real time, by providing a user with information indicative of the impact of the air exchange rates on the pollutant concentration of the pollutant in the enclosed volume. In particular, the improved system is configured to provide a user with a characteristic air quality recovery score of a pollutant in the enclosed volume, which is indicative of the rate of decay of the pollutant from the enclosed volume. The improved system further provides the adjustment of at least one operating parameter of said system to prevent the pollutant concentration from reaching undesirable levels, for example, unsafe levels.

[0093] While the disclosure has been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that various changes in form and detail may be made therein without departing from the scope of the disclosure as defined by the appended claims. The scope of the disclosure is thus indicated by the appended claims.

Claims

1. A heating, ventilation and air-conditioning (HVAC) system for determining a characteristic air quality recovery score of a pollutant in an enclosed volume, comprising a processor configured to:

obtain pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times;

identify an event comprising a sub-range of datapoints from the plurality of datapoints, the event comprising at least one datapoint which satisfies a predetermined criterion of maxima or minima;

determine that the event is of a decay event type which follows a pollutant decay pattern;

determine a pollutant decay characteristic from the event; and

determine the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic, optionally, wherein the pollutant is carbon dioxide.

2. The system of claim 1, wherein determining that the event is of the decay event type which follows the pollutant decay pattern comprises determining a first increase in the pollutant concentration of the pollutant from a current pollutant data.

3. The system of claim 2, wherein determining the characteristic air quality recovery score based on the pollutant decay characteristic comprises:

calculating a plurality of event air quality recovery scores; and
determining the characteristic air quality recovery score based on the plurality of event air quality recovery scores.

4. The system of claim 3, wherein determining the characteristic air quality recovery score comprises calculating a statistical measure of the plurality of event air quality recovery scores.

5. The system of claim 3, wherein determining the pollutant decay characteristic from the event comprises:

determining a first point having a first maximum, the first point corresponding to the determined first increase in the pollutant concentration of the pollutant from the current pollutant data; and
determining a second point having a first minimum, the second point corresponding to a first decrease determined in the pollutant concentration of the pollutant from the first point.

6. The system of claim 5, wherein determining an event air quality recovery score of the pollutant based on the pollutant decay characteristic comprises calculating a first parameter based on the first point having the first maximum and the second point having the first minimum.

7. The system of claim 6, wherein determining the pollutant decay characteristic from the event further comprises:

determining a third point having a second maximum, the third point corresponding to a second increase determined in the pollutant concentration of the pollutant from the second point; and
determining a fourth point having a second minimum, the fourth point corresponding to a second decrease determined in the pollutant concentration of the pollutant from the third point, and,

optionally,
wherein determining the event air quality recovery score of the pollutant based on the pollutant decay characteristic further comprises:

calculating a second parameter based on the third point having the second maximum and the fourth point having the second minimum; and
calculating a mean of the first parameter and the second parameter.

8. The system of claim 1, further comprising at least one sensor, for detecting an occupancy of the enclosed volume, wherein the processor is in data communication with the at least one sensor, and is further configured to:

obtain, from the at least one sensor, the occupancy of the enclosed volume;
compare the characteristic air quality recovery score with a predetermined threshold air quality recovery score; and
adjust at least one operating parameter of the system based on said comparison of the characteristic air quality recovery score with the predetermined threshold air quality recovery score, and/or the occupancy of the enclosed volume.

9. The system of claim 8, further comprising a scheduler for storing schedule data indicative of a scheduled use of the enclosed volume, wherein the processor is in data communication with the scheduler, and is further configured to:

obtain, from the scheduler, a time of the scheduled use of the enclosed volume based on the scheduled data;
determine a time slot, indicative of a time difference between a current time and the time of the scheduled use of the enclosed volume;
calculate a duration required for the pollutant concentration to reach a predetermined threshold, based on the characteristic air quality recovery score;
determine if the duration is within the time slot; and
adjust the at least one operating parameter of the system based on the determination that the duration is within the time slot, and,
optionally,
wherein adjusting the at least one operating parameter of the system comprises adjusting an air flow of a ventilation device, the ventilation device configured to inject fresh air into the enclosed volume and/or to increase a clearance rate of the pollutant from the enclosed volume.

10. A control device for a HVAC system, the control device comprising a processor configured to determine a characteristic air quality recovery score of a pollutant in an enclosed volume, for example carbon dioxide, the processor being in data communication with a memory having instructions stored therein, the instructions, when executed by the processor, causes the processor to:
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- obtain pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times; 10
- identify an event comprising a sub-range of datapoints among the plurality of datapoints, the event comprising at least one datapoint which satisfies a predetermined criterion of maxima or minima; 15
- determine that the event is of a decay event type which follows a pollutant decay pattern; 20
- determine a pollutant decay characteristic from the event; and
- determine the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic. 25
11. A method for determining a characteristic air quality recovery score of a pollutant, for example carbon dioxide, in an enclosed volume, comprising providing a processor for:
- 30
- obtaining pollutant data comprising a plurality of datapoints, the plurality of datapoints indicative of a pollutant concentration of the pollutant over different times; 35
- identifying an event comprising a sub-range of datapoints among the plurality of datapoints, the event comprising at least one datapoint which satisfies a predetermined criterion of maxima or minima; 40
- determining that the event is of a decay event type which follows a pollutant decay pattern;
- determining a pollutant decay characteristic from the event; and
- determining the characteristic air quality recovery score of the pollutant based on the pollutant decay characteristic. 45
12. The method of claim 11, wherein determining that the event is of the decay event type which follows the pollutant decay pattern comprises determining a first increase in the pollutant concentration of the pollutant from a current pollutant data. 50
13. The method of claim 12, wherein determining the characteristic air quality recovery score based on the pollutant decay characteristic comprises:
- 55
- calculating a plurality of event air quality recovery scores; and
- determining the characteristic air quality recovery scores based on the plurality of event air quality recovery scores.
14. The method of claim 13, wherein determining the pollutant decay characteristic from the event comprises:
- determining a first point having a first maximum, the first point corresponding to the determined first increase in the pollutant concentration of the pollutant from the current pollutant data; and
- determining a second point having a first minimum, the second point corresponding to a first decrease determined in the pollutant concentration of the pollutant from the first point.
15. The method of claim 14, wherein determining an event air quality recovery score of the pollutant based on the pollutant decay characteristic comprises calculating a first parameter based on the first point having the first maximum and the second point having the first minimum.
16. The method of claim 15, wherein determining the pollutant decay characteristic from the event further comprises:
- determining a third point having a second maximum, the third point corresponding to a second increase determined in the pollutant concentration of the pollutant from the second point; and
- determining a fourth point having a second minimum, the fourth point corresponding to a second decrease determined in the pollutant concentration of the pollutant from the third point, and, optionally,
- wherein determining the event air quality recovery score of the pollutant based on the pollutant decay characteristic further comprises:
- calculating a second parameter based on the third point having the second maximum and the fourth point having the second minimum; and
- calculating a mean of the first parameter and the second parameter.

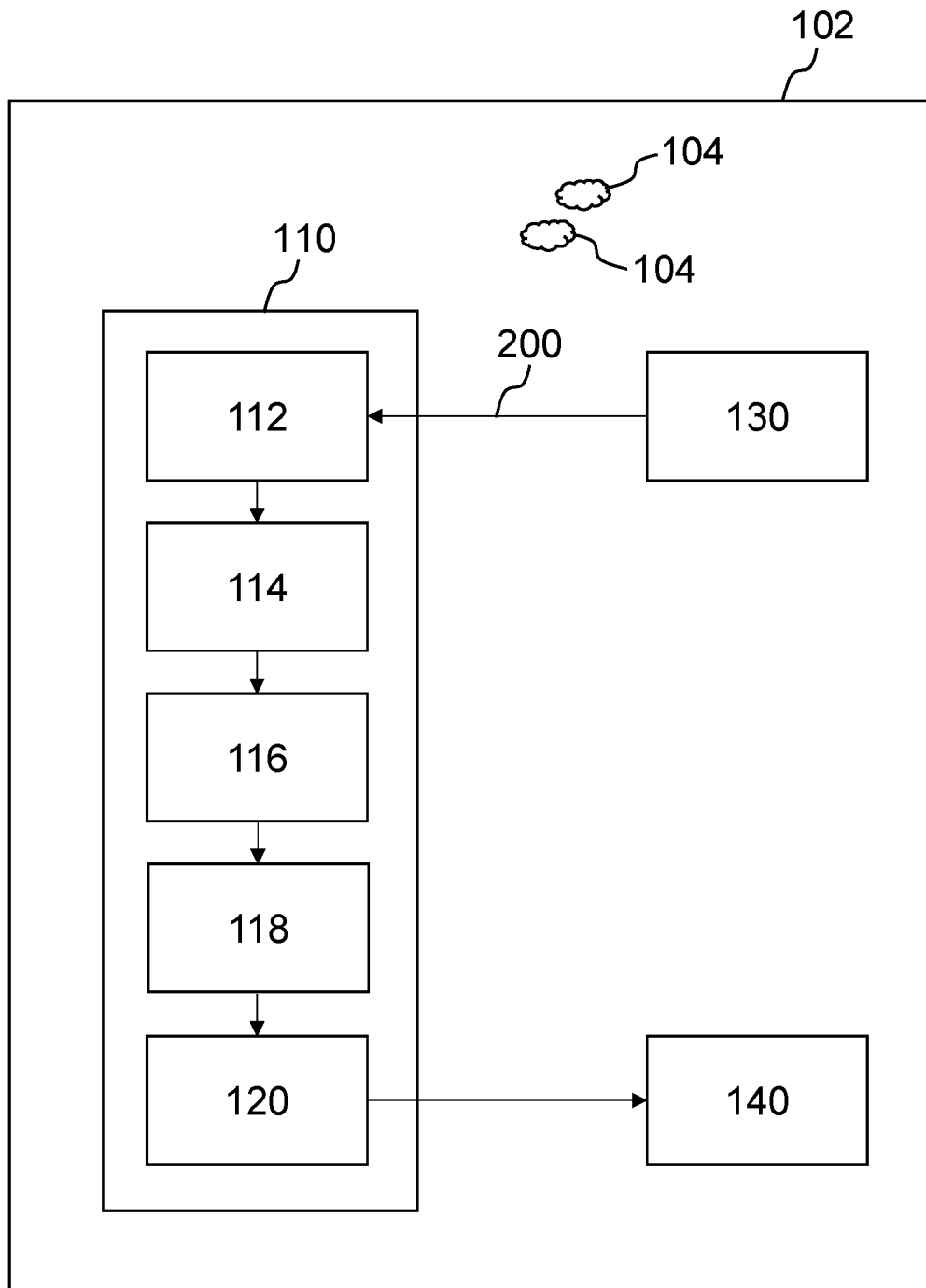
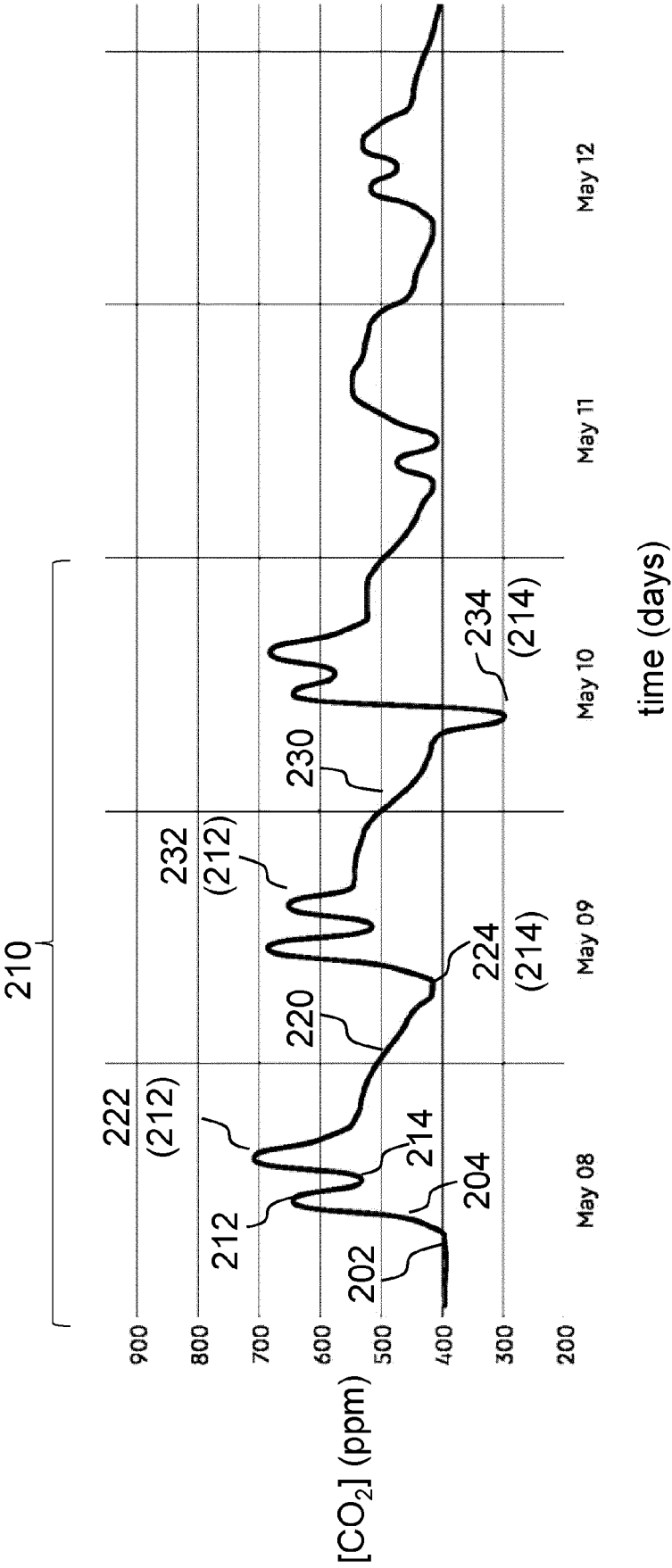
100

FIG. 1

FIG. 2



300

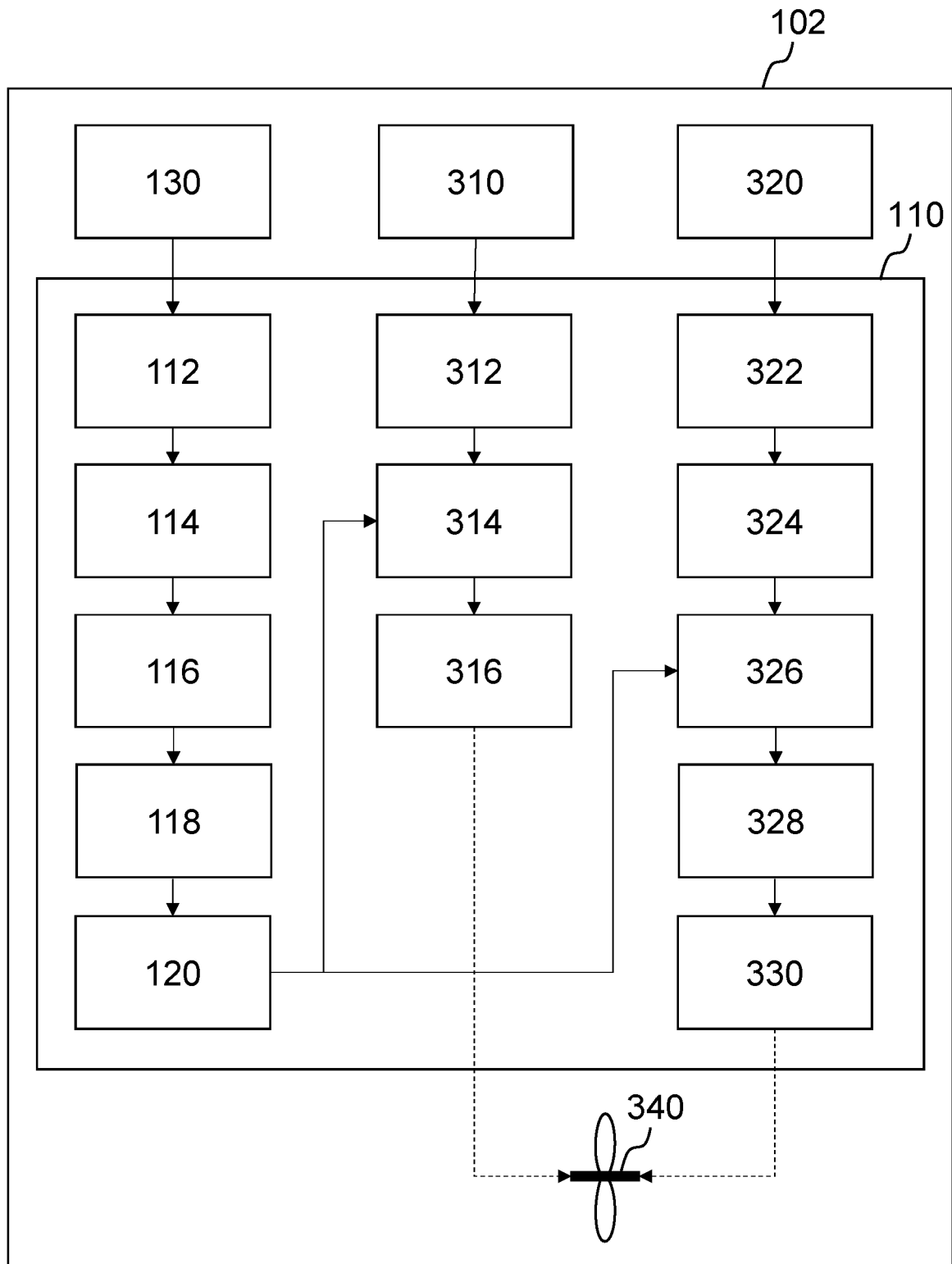


FIG. 3

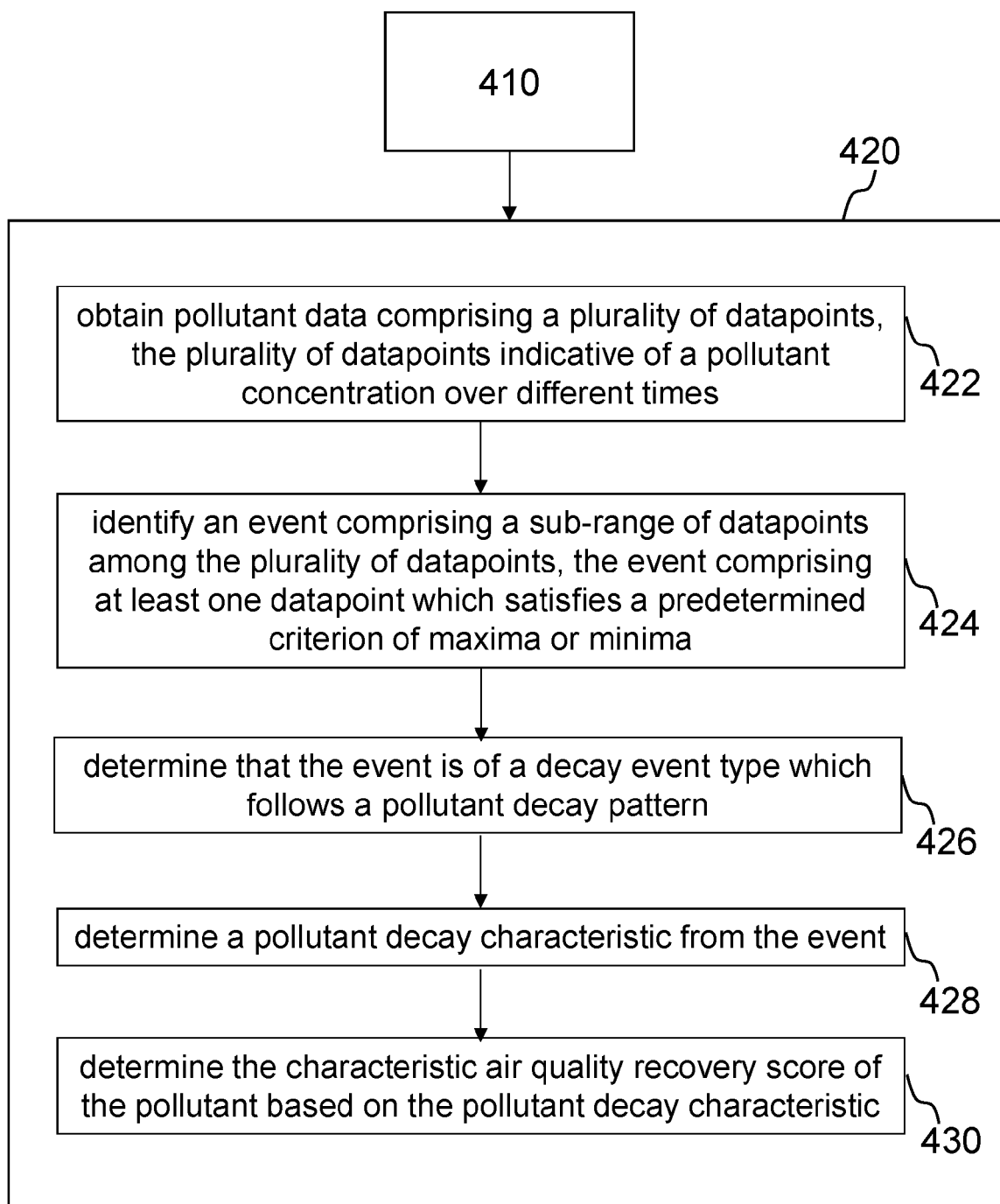
400

FIG. 4

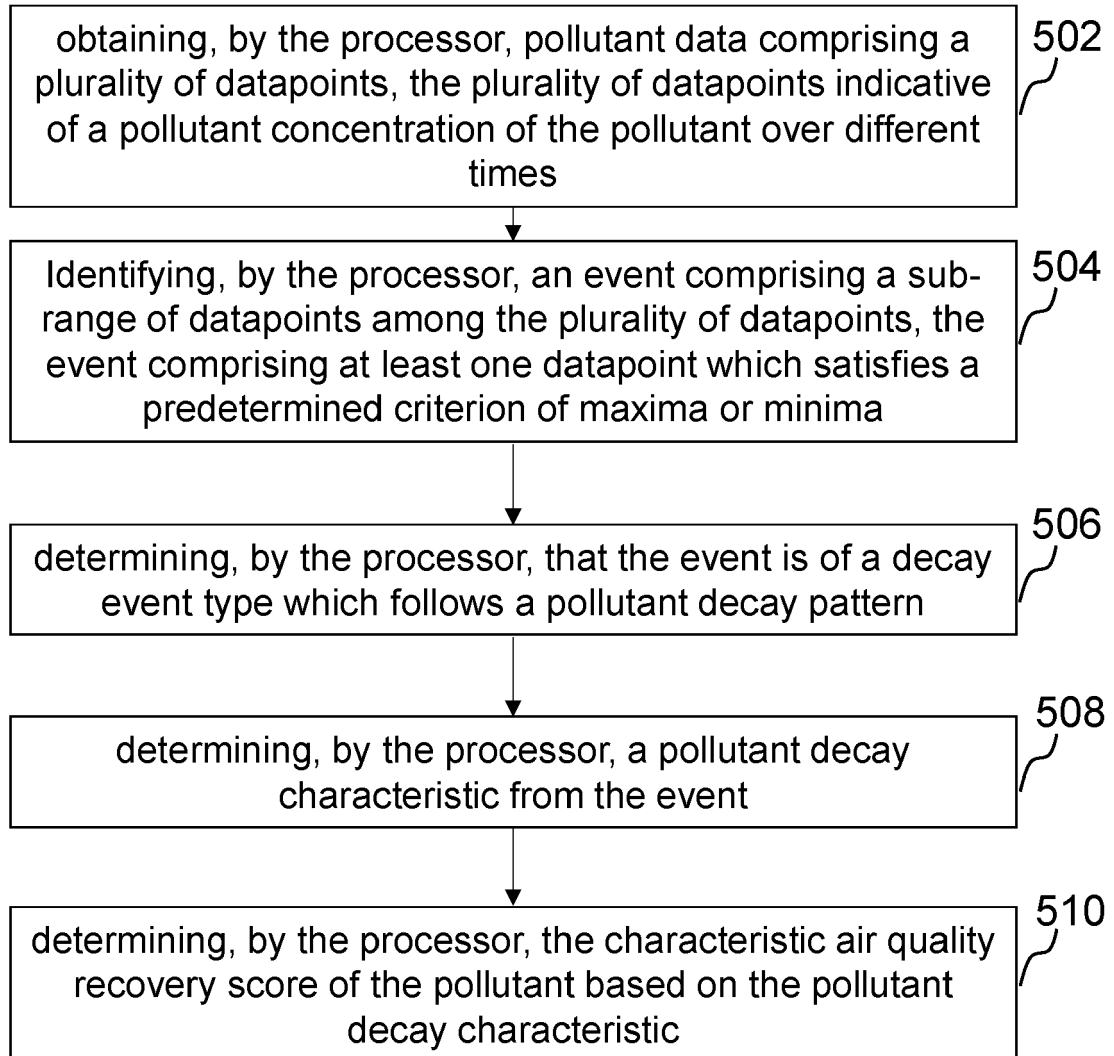
500

FIG. 5

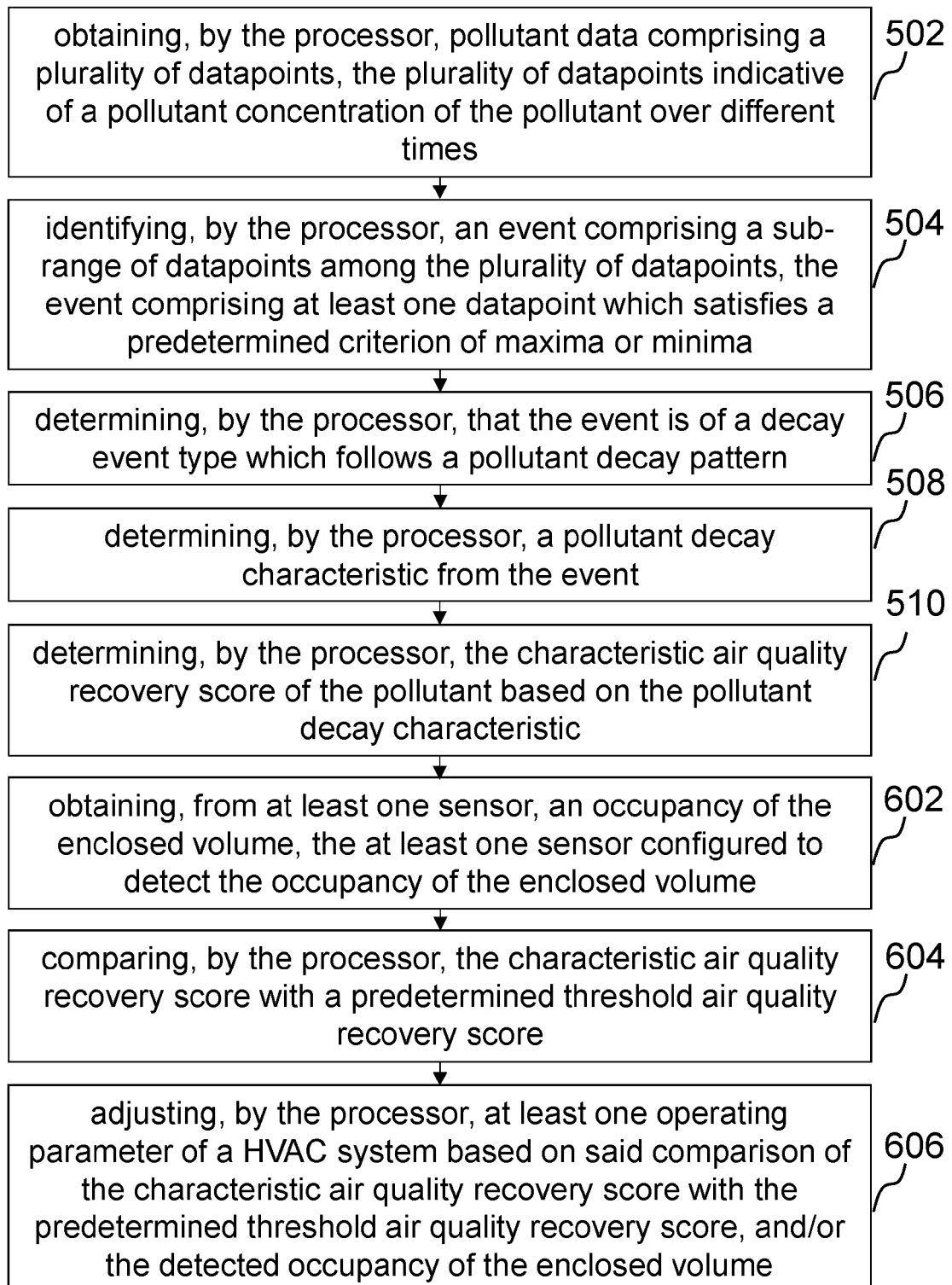
600

FIG. 6

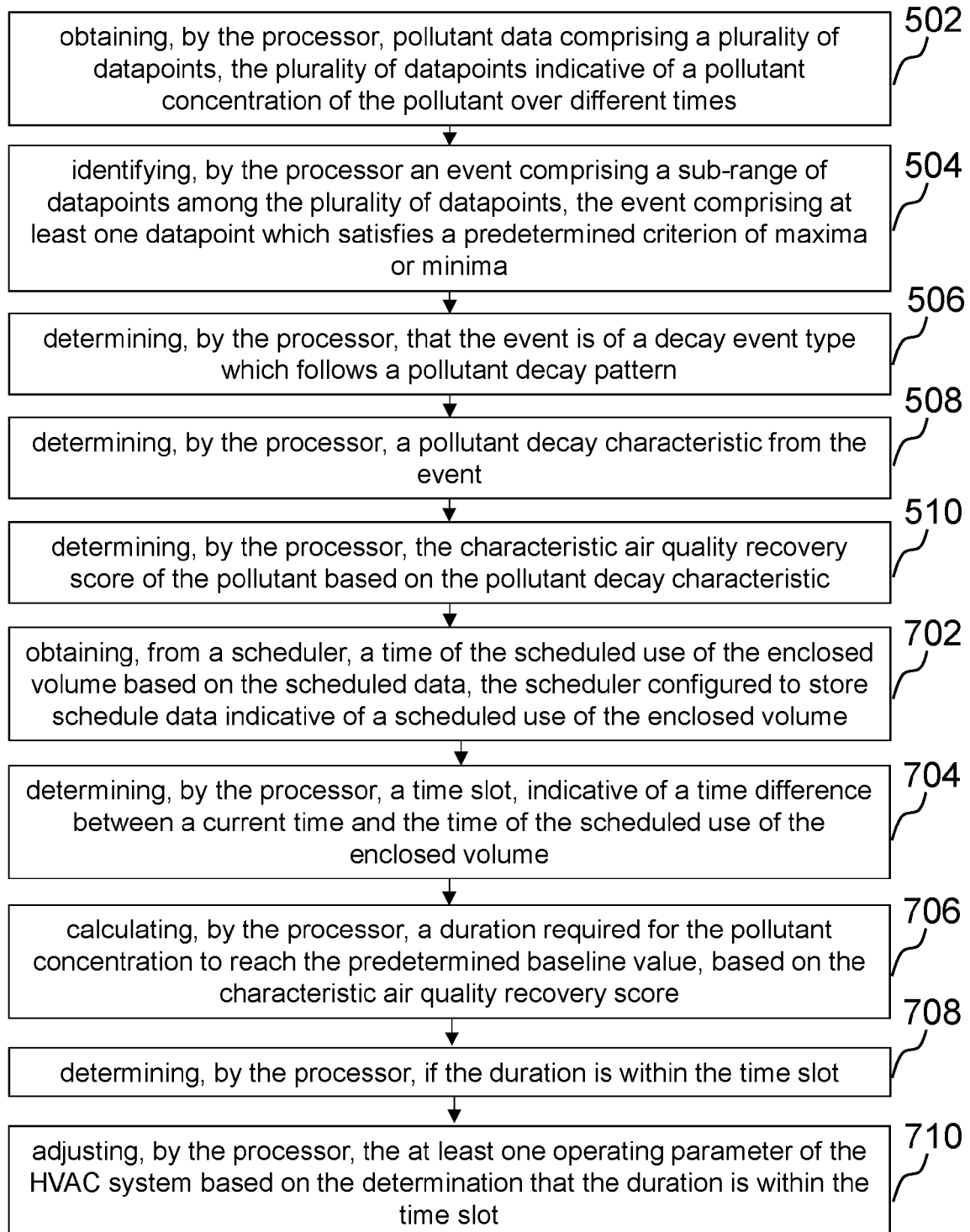
700

FIG. 7



EUROPEAN SEARCH REPORT

Application Number

EP 24 18 3266

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Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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			F24F
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		13 November 2024	Silex, Anna
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