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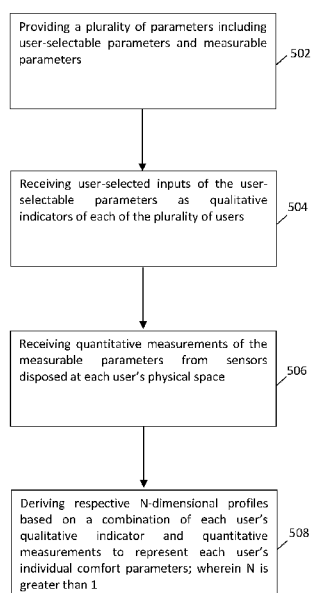


FIG. 7

(57) Abstract: Method and apparatus for deriving and/or controlling individual comfort parameters are disclosed herein. In a described embodiment, the method includes deriving individual comfort parameters for a plurality of user associated 0 with respective physical spaces. The method includes providing a plurality of parameters including user-selectable parameters and measurable parameters at 502; receiving user-selected inputs of the user-selectable parameters as qualitative indicators of each of the plurality of users at 504; receiving quantitative measurements of the measurable parameters from sensors 5 disposed at each user's physical space at 506; and deriving respective N-dimensional profiles based on a combination of each user's qualitative indicator and quantitative measurements to represent each user's individual comfort parameters at 508; wherein N is greater than 1. A method/apparatus for detecting 'true' presence of a user is also disclosed.

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Method and Apparatus for Deriving and/or Controlling Individual Comfort Parameters

TECHNICAL FIELD

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The present disclosure generally relates to method and apparatus for deriving and/or controlling individual comfort parameters. The method may relate to a building indoor environment management, and in particular, a building management system (BMS) for measuring, monitoring and controlling energy, environmental parameters such as temperature, humidity, light, noise, air quality and so on and other parameters in a building at individual level to enhance "comfort" for every individual.

BACKGROUND

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Now-a-days most modern buildings are managed by a building management system (BMS). The building management system is known to locally monitor and centrally control all modern facilities fitted to a building. Typically, a building management system controls heating, cooling, ventilation, lighting, electric power and security systems of the building. It may also be linked with features such as intercom, fire alarm, smoke detection, surveillance (for example Closed Circuit Television widely known as CCTV), access control, elevators, plumbing and other engineering systems. Despite use of such modern facilities, the modern buildings have been found to have poor ambient indoor environments. For example, there are 2-10 times more pollutants indoor than outdoors; 75% of office workers feel uncomfortable due to excess cooling or excess heating; 70% of office workers complain about noise; insufficient lighting and so on. Further, energy consumption of these buildings are also not optimum. For example, buildings consume 40 % of the energy in the world and electric plug loads form about 18-20 % of the total electric load in such buildings.

Measurement of physical conditions in a building is complicated with a large number of variables. Currently, physical ambient conditions in a building such as an office or an enterprise environment is typically measured by a handful of thermostats located in a limited number of locations on a given floor of the building, with no particular attention given to each work station or cubicle. Further, employees have limited or no control to adjust the physical conditions of their own work stations or cubicles to suit their comfort level.

Furthermore, very little information are available on the other equally important parameters such as lighting levels, humidity, noise levels (especially in offices with open cubicles), air quality levels, energy consumption and so on either at a floor level or at an individual level.

The above parameters i.e. lighting levels, humidity, noise levels, air quality levels, energy consumption and so on can be measured using multiple individual devices for each parameters. However, deploying individual devices for each parameter generally becomes expensive and complex to use. The devices are not very user friendly and are typically used for short term measurements.

Further, even if any information is known or available on the above parameters the information relates to entire building, floor or zone and not personalised.

Multiple scientific studies have shown that there is a strong correlation between employee comfort and productivity. Considering that the cost of manpower is typically the largest single item for a company, enhancing employee productivity is critical to profitability and prudent financial practice.

Further, recently there is a push to reduce the amount of energy usage in office buildings thereby not only saving money but also being identified as “green” office, reducing the carbon footprint for a given office building.

It is thus desirable to provide a method and apparatus for deriving and/or controlling individual comfort parameters which address at least one of the shortcomings of the above prior art and/or to provide the public with a useful
5 choice.

SUMMARY

In a first aspect, there is provided a method of deriving individual comfort
10 parameters for a plurality of users associated with respective physical spaces, the method including:

- (i) providing a plurality of parameters including user-selectable parameters and measurable parameters;
- (ii) receiving user-selected inputs of the user-selectable parameters as
15 qualitative indicators of each of the plurality of users;
- (iii) receiving quantitative measurements of the measurable parameters from sensors disposed at each user's physical space; and
- (iv) deriving respective N-dimensional profiles based on a combination of each user's qualitative indicator and quantitative measurements to represent
20 each user's individual comfort parameters; wherein N is greater than 1.

The described embodiment advantageously addresses the issue of individual comfort based on qualitative and quantitative measurements of a range of parameters including some measurable parameters and some user-selectable
25 parameters.

In some embodiments, the plurality of parameters may include attributes relating to thermal, visual, aural, ergonomic and well-being conditions at respective user's physical spaces or environment.

Indeed, it is envisaged that the plurality of parameters may include a combination of at least some of temperature, humidity, noise level, illumination level, hue of light, air quality, breeze, weather condition, clothing of users, posture and ergonomic data (such as height of seat, distance of seat from desk
5 etc.), furniture characteristics, presence of window, presence of plants and feeling of space etc.

In some embodiments, the N-dimensional profile of each user may include a series of personal comfort indexes, with each personal comfort index being
10 associated with corresponding combinations of the qualitative indicators and quantitative measurements.

It is also possible that the method of deriving individual comfort parameters may include performing correlation between the qualitative indicators and the
15 quantitative measurements to arrive at the corresponding personal comfort index.

In second aspect, a method of controlling comfort parameters for a plurality of users having respective physical spaces based on the N-dimensional profile
20 derived from the first aspect is provided. Such a method comprises receiving a change in a setting of at least one of the plurality of parameters; the changed setting being associated with a user's physical space; and controlling a local mitigation system to adjust an environmental condition at the physical space of the user to restore comfort level of the user based on the user's desired
25 personal comfort index corresponding to the N-dimensional profile.

The described embodiment advantageously control environmental conditions to suit individual user's comfort based on an N-dimensional profile of the user with the help of a local mitigation system.

In some embodiments, the method of controlling comfort parameters may include dynamically updating the N-dimensional profile based on user preference for controlling the comfort parameters.

- 5 In a specific implementation, the method of controlling comfort parameters may include:

measuring conditions associated with the plurality of parameters at the corresponding physical space by a sensor module;

- 10 analysing the conditions associated with the plurality of parameters at a physical space and taking control action, by a control module, based on the N-dimensional profile corresponding to the respective user of the corresponding physical space; and

displaying the conditions associated with the plurality of parameters to a display device of the respective user of the corresponding physical space.

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It is envisaged that the plurality of parameters may include energy parameters including at least some of energy consumption, electrical power, reactive power, current, voltage, power factor of a plurality of energy consuming devices disposed at the corresponding physical space.

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- In some embodiments, taking control action by the control module may include turning off automatically one or more energy consuming devices disposed at the corresponding physical space if the respective user is determined to be not present within the corresponding physical space based on a predefined preference established by the user.
- 25

- It is possible that the physical spaces may be associated with a building, and the method may further include requesting automatically a building management system of the building to control the conditions associated with the plurality of parameters on an aggregate level.
- 30

In third aspect, a method of determining physical presence of a user within respective physical space is provided. Such a method comprises:

receiving a first data from a motion sensor disposed at the respective physical space;

5 receiving a second data based on at least one measurable parameters from sensors disposed at respective physical space; and

determining physical presence of the user within respective physical space based on a combination of the first data and the second data.

10 As a result, the described embodiment is able to determine the “true” presence of the user within respective physical space based on two sets of data.

In some embodiments, the measurable parameters may comprise a combination of:

15 environmental parameters including at least some of temperature, humidity, noise level, light and air quality;

energy parameters including energy consumption of one or more energy consuming devices disposed within respective physical space comprising at least some of a computer, a laptop, a printer, a fan, an air purifier, a
20 dehumidifier; and

wireless network signal associated with a mobile device of the user of the respective physical space.

In fourth aspect, a server is provided for deriving individual comfort parameters
25 for a plurality of users associated with respective physical spaces, the server comprising at least a computer processor and a data storage device, the data storage device comprising instructions operative by the processor to:

(i) provide a plurality of parameters including user-selectable parameters and measurable parameters;

30 (ii) receive user-selected inputs of the user-selectable parameters as qualitative indicators of each of the plurality of users;

(iii) receive quantitative measurements of the measurable parameters from sensors disposed at each user's physical space; and

(iv) derive respective N-dimensional profiles based on a combination of each user's qualitative indicator and quantitative measurements to represent
5 each user's individual comfort parameters; wherein N is greater than 1.

The described embodiment advantageously utilizes existing building infrastructure which may include physical and/or digital infrastructure. The physical infrastructure may include movable items such as tables, desks, chairs,
10 or generally furniture, as well as immovable items a shelf and other furniture; and immovable infrastructure such as office carpets, windows, lightings, air-conditioning vents and ducts and so forth. The digital infrastructure may include communication networks be it wired/wireless networks, intranet, servers, computers, electronic systems etc.

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In fifth aspect, an apparatus is provided for controlling a plurality of parameters at respective physical spaces of users, the plurality of parameters including user-selectable parameters and measurable parameters, the apparatus comprising:

20 a plurality of sensor modules, each sensor module arranged to measure conditions associated with the measurable parameters at the corresponding physical space;

a user input device for receiving user selected inputs of the user-selectable parameters; and

25 a local mitigation system for adjusting the conditions at the corresponding physical space of the user to restore comfort level of the user based on the user's desired personal comfort index of an N-dimensional profile derived by a server based on the user-selectable parameters and the measurable parameters.

30

The described embodiment is able to mitigate local environmental conditions of the individual work station for comfort of the respective user without disturbing global environmental condition of entire building.

- 5 In some embodiments, the local mitigation system may include at least some of a desk fan, a USB fan, a ceiling fan, a wall-mounted fan, a table fan, a stand fan, a personal ventilation system, a dehumidifier, an air purifier and an air freshener etc.
- 10 In some embodiments, the user input device may include at least one of an office desktop, a laptop, a tablet, a smartphone, a wearable device and an Internet of Things (IoT) device etc.

A sixth aspect relates to apparatus for controlling a plurality of comfort
15 parameters for a plurality of users having respective physical spaces based on N-dimensional profile derived from features related to the first aspect, the apparatus comprising:

a plurality of sensor modules, each sensor module is arranged to measure conditions associated with the plurality of parameters at the
20 corresponding physical space;

a control module for analysing the conditions associated with the plurality of parameters at the corresponding physical space and controlling the conditions, based on the N-dimensional profile, corresponding to the respective user of the corresponding physical space to generate a control signal;

25 a local mitigation system for adjusting the conditions associated with at least some of the plurality of parameters at the corresponding physical space to restore the comfort level of the user based on the control signal; and

a display device for displaying the conditions associated with the plurality of parameters of the corresponding physical space to the respective user.

The disclosure of the embodiment have been provided to address individual comfort, and minimization of energy usage in a building by measuring, monitoring and controlling environmental parameters and energy parameters at individual level as well as at aggregate level. It is also possible to provide a display of the environmental conditions and energy consumption associated with the respective physical space of the user.

In some embodiments, the control module may be further configured to perform automatic firmware updates of the plurality of the sensor modules.

In some embodiments, the physical spaces may be associated with a building which may include one of an office building, a commercial building, an enterprise building and a residential building; and the physical space may include one of an office cubicle, an office desk, an office workstation and a residential unit.

It is to be understood that both the foregoing general description and the following detailed description are intended to provide an overview or framework for understanding the nature and character of the invention as it is claimed. The accompanying drawings are included to provide a further understanding of the described embodiment and are incorporated into and constitute a part of this specification. The drawings together with the description serve to explain the principles and operation of an embodiment.

BRIEF DESCRIPTION OF THE DRAWINGS

The above mentioned and other features and advantages of the described embodiment, and the manner of attaining them, will become more apparent and better understood by reference to the accompanying drawings, wherein:

FIG. 1 is a schematic block diagram of a building comprising a building management system communicatively coupled to a building sense system according to one embodiment;

FIG. 2 is a schematic block diagram of the building of FIG. 1 comprising the building sense system which measures, monitors and controls indoor environment and energy consumption of the building at individual level to enhance comfort for each individual;

FIG. 3 is a schematic block diagram of the building sense system of FIG. 2 which includes an environmental sensor module;

FIG. 4 is a schematic block diagram of the building of FIG. 1 comprising multiple physical spaces, wherein each physical space includes one environmental sensor module of FIG. 3;

FIG. 5 is a schematic block diagram of the environmental sensor module of FIG. 3;

FIG. 6 is a flowchart illustrating a method of measuring, monitoring and controlling at least some of the parameters relating to indoor environment, energy consumption, and ergonomic data associated with users of the building of FIG. 1 at individual level based on respective N-dimensional profiles representing each user's individual comfort parameters, performed by the building sense system of FIG. 3;

FIG. 7 is a flowchart illustrating a method of deriving the respective N-dimensional profiles of FIG. 6 representing each user's individual comfort parameters;

FIG. 8 shows parameters from the display of the building sense system of FIG. 3;

FIG. 9 shows parameters from the display of the building sense system of FIG. 3 to illustrate alternative parameters to be displayed; and

FIGs. 10a and 10b are schematic diagrams illustrating various ergonomic data which may be used to derive the N-dimensional profiles of FIG. 7.

DETAILED DESCRIPTION

Reference will now be made in detail to the exemplary embodiment(s), examples of which are illustrated in the accompanying drawings. Whenever possible, the same reference numerals will be used throughout the drawings to refer to the same or like parts.

An embodiment will now be described with reference to a building sense system retrofitted to a building for assisting a building management system. Thus, the building management system may be considered to be upgraded to an improved building management system. A building sense system and a corresponding method is provided according to the embodiment for measuring, monitoring and controlling multiple environmental parameters, multiple energy parameters and multiple ergonomic parameters to enhance comfort of every individuals in a building. Comfort can be described in many forms – thermal, visual, aural, ergonomic and also a feeling of well-being. The “comfort” indicators may be a function of some basic parameters such as temperature, humidity, illumination level, hue of light, noise level, air quality, breeze, weather condition, clothing of users, postures and ergonomic parameters, furniture characteristics, presence of window, presence of trees and feeling of space and so forth.

FIG. 1 is a schematic block diagram to illustrate a building 100 having a building management system 101 communicatively coupled to a building sense system 102 according to a first embodiment. The building management system 101 working with the enhancement of the building sense system 102 provides an improved building management system to the building 100.

FIG. 2 is a schematic block diagram of the building 100 including the building sense system 102 for measuring, monitoring and controlling at least a number of parameters including indoor environment parameters, energy parameters

and ergonomic parameters associated with users of the building 100 according to the first embodiment. The building sense system 102 may be deployed in a smart office, enterprise, educational campus, institutional premises, industrial environment, commercial buildings, residential complex and other modern
5 buildings, and need not be located within the building 100. For the sake of explanation the building 100 is considered as an office building comprising multiple physical spaces for respective users and in this embodiment, the physical spaces include individual work stations. However it should be understood that the first embodiment is not limited to only office buildings and
10 may be extended to any other type of buildings including the residential buildings. Each individual work station provides an individual and personal work environment for each user or occupant. Generally, the building sense system 102 is communicatively connected to all building indoor environmental devices 104, all building electrical devices 106, all computer systems 108 provided at
15 individual work stations and a local mitigation system 110 of the building 100 over a wireless network for providing the measurement and control functions. In this embodiment, the building indoor environmental devices 104 include heating, ventilation, and air-conditioning units, and the building electrical devices 106 include lighting, security and surveillance system, access control device,
20 elevator, intercom, fire alarm and smoke detector. The computer systems 108 at each individual work station include Personal Computer (PC), Laptop, Tablet, and Smartphone.

The local mitigation system 110 comprises electrical devices provided
25 specifically to control environmental conditions at a particular work station. In this embodiment, the local mitigation system includes a desk fan, an air purifier and a local dehumidifier, although other examples of the local mitigation system 110 may include a ceiling fan, a table fan, a stand fan, an air freshener, a personal ventilation system and so forth. In this embodiment, although the
30 building sense system 102 uses a wireless network to communicatively connect with the building indoor environmental devices 104, the building electrical

devices 106, the computer systems 108 and the local mitigation system 110, it would be apparent that the connection may be via a wired network of the building 100 too.

5 FIG. 3 is a schematic block diagram of the building sense system 102 of FIG. 2. The building sense system 102 includes multiple environmental sensor modules 202, multiple energy sensor modules 204, multiple ergonomic sensor modules 212, a control module 206, a display module 208 and database 210. In this embodiment, the control module 206, the database 210, and the display module
10 208 are part of a server 214. The environmental sensor modules 202, the energy sensor modules 204 and the ergonomic sensor modules 212 are located at work stations of individual users.

FIG. 4 is a schematic block diagram illustrating the location of the building
15 sense system 102 within the building 100. The building 100 includes multiple work stations 100.1, 100.2 up to 100.n. It should be appreciated that each user's workstation has a computer system 108, a desk fan, an air purifier, and a local dehumidifier as part of the local mitigation system 110. In this embodiment, each user's work station 100.1, 100.2...100.n also includes one environmental
20 sensor module 202, one energy sensor module 204 and one ergonomic sensor module 212. The server 214 is located within the building 100 at a server room in this embodiment. However, it should be understood that the server 214 may be located at external locations to the building 100. The building sense system 102 is configured to measure, monitor, analyse and control indoor
25 environmental conditions, the electric power consumption of the building 100 and the ergonomic parameters both at personal level of each user as well as at aggregate level of the entire building 100 or of a collective space.

Each environmental sensor module 202 located at the user's workstation
30 includes a plurality of sensors for continuous and real time measurement of indoor environmental parameters of the particular work station. FIG. 5 is a

schematic block diagram showing the various components of one of the environmental sensor module 202 which includes a temperature sensor 202a, a light sensor 202b, a humidity sensor 202c, a particle sensor 202d, a noise sensor 202e, a Passive Infra-Red (PIR) sensor 202f, a micro-processor 202g and a wireless communication module 202h according to this embodiment. However, it should be appreciated that the environmental sensor module 202 is not limited to these sensors and may contain other environmental sensors based on user requirements.

10 The temperature sensor 202a is arranged to measure temperature at the immediate vicinity of the user's work station. The light sensor 202b is arranged to measure illumination level of at the immediate vicinity of the user's work station. The relative humidity at the user's work station is measured by the humidity sensor 202c and the particle sensor 202d is arranged to measure air
15 quality at the user's workstation and also includes measuring content of Carbon Dioxide (CO₂), Volatile Organic Compounds (VoC), and Particulate Matter 2.5 (PM2.5). Noise level at the user's work station is measured by the noise sensor 202e. The PIR sensor 202f is arranged to measure physical presence of the user within the user's work station.

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The micro-processor 202g is arranged to facilitate local data analysis and processing. For example, if the measured values of the environmental sensor module 202 contain noise data, the micro-processor 202g is configured to filter out the noise data and record the actual values of the environmental
25 parameters. The recorded values of the environmental parameters are then encrypted and sent to the database 210 by the wireless communication module 202h for further analysis and computation. It should be understood that the micro-processor 202g may provide necessary intelligence to the environmental sensor module 202 to take local action based on the measured values of the
30 environmental parameters for mitigating certain environmental conditions.

In this embodiment, the individual sensors such as the temperature sensor 202a, the light sensor 202b, the humidity sensor 202c, the particle sensor 202d, the noise sensor 202e and the PIR sensor 202f are integrated into one multimodal integrated environmental sensor module 202 for measuring
5 individual environmental parameters and provide overall environmental information corresponding to the user's work station. However, it should be appreciated that the individual sensors may be pluggable units which can be plugged into a sensor bank as the environmental sensor module 202.

10 Coming back to FIG. 3, each energy sensor module 204 disposed at the user's work station is configured to measure and monitor the electrical parameters of energy consuming devices connected at the user's work station. In this embodiment, the energy consuming devices include the computer system 108, a monitor of the computer system 108, the desk fan, the air purifier and the local
15 dehumidifier as the local mitigation system 110 and a printer device. It should be understood that the energy consuming devices may include other electrical devices which is not included in this embodiment. The electrical parameters measured by the energy sensor module 204 include electrical power in Watt, electrical energy in kWh, current in Ampere, voltage in Volt, power factor (PF)
20 and reactive power in VAR.

In this embodiment, the energy sensor module 204 includes a smart plug having multiple sockets for different types of pins and internal sensor circuits connected to the socket wirings for measurement of the various electrical
25 parameters. The smart plug type energy sensor module 204 may be integrated into the multimodal integrated environmental sensor module 202 as a variation.

Each ergonomic sensor module 212 disposed at the user's work station is arranged to measure the ergonomic parameters associated with the user as
30 illustrated in FIGs 10a and 10b. FIG 10a illustrates a person 600 in a standing position relative to a workstation 602 and the relevant ergonomic data are

standing eye height 604, standing elbow height 606 and viewing distance 608. On the other hand, if the user is sitting, another set of ergonomic data may be relevant and this is illustrated in FIG. 10b, and the relevant ergonomic data are sitting eye height 610, seat height 612, sitting elbow height 614, sitting viewing
5 distance 616 and monitor angle 618. In this embodiment, each ergonomic sensor module 212 includes multiple sensors mounted at various locations of the furniture in the work station such as office desk, chair and monitor of the computer system 108 in order to provide measurements relating to the seat height 612, sitting elbow height 614, sitting eye height 610, sitting viewing
10 distance 616 and the monitor angle 618. However it should be understood that the ergonomic parameters may also include other parameters such as table height, knee clearance, knee angle, seat back angle, elbow angle, keyboard height and so forth. The ergonomic sensor module 212 advantageously provides the ergonomic parameters responsible for individual user's comfort.

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According to the present embodiment, the environmental sensor module 202 and the energy sensor module 204 are integrated into the structure of office desk of the user's work station by modular fitting. It should be understood that the environmental sensor module 202 and the energy sensor module 204 may
20 be disposed at the user's work station in many other ways, such as, on the ceiling of the work station, on the workstation desk, on top of cubicle divider walls, attached to a wall of a room, adjacent to the computer system 108, above an entrance of the work station, or on top of side wall of the work station for the successful implementation of the embodiments.

25

As discussed above, the measured data corresponding to the environmental parameters by each environmental sensor module 202, the energy parameters by each energy sensor module 204 and ergonomic parameters by each ergonomic sensor module 212 disposed at each user's work station is sent to
30 the database 210 for further processing. In this embodiment, the measured data is sent to the database 210 in real time and continuously round the clock 24x7

for 365 days a year. The database 210 is part of the server 214 and is located in the server room of the building 100. It should be appreciated that the server 214 (and thus the database 210) may be located in the cloud. In the first embodiment, a wireless WiFi network is used to transfer the measured data
5 from the environmental sensor modules 202, the energy sensor modules 204 and the ergonomic sensor module 212 to the database 210. It is also possible to transfer the measured data by any other conventional wired or wireless protocols. The implementation of the described embodiment advantageously does not require a separate network infrastructure and the data transfer occurs
10 by "piggy-backing" on the existing communication network. However, it should be understood that in the absence of any wireless network, the building sense system 102 may set up its own WiFi or Bluetooth based wireless network. The wireless network may be based on a standard or a proprietary network depending on the circumstances.

15

According to this embodiment, the measured data, in the form of a data packet, is sent by the individual environmental sensor module 202, the individual energy sensor module 204 and the individual ergonomic sensor module 212 at a particular time instance and the data packet contains a unique identifier. The
20 unique identifier of the data packet includes an identification number to identify the originating environmental sensor module 202 or energy sensor module 204 or ergonomic sensor module 212 that sends the data packet and a timestamp identifying the time of data transfer. Since the environmental, energy parameters and ergonomic parameters are measured continuously from each
25 environmental sensor module 202, each energy sensor module 204 and each ergonomic sensor module 212, tagging the unique identifier with the data packets advantageously enables the database 210 in segregating and classifying the measured data from the other environmental sensor module 202, the other energy sensor module 204 and the other ergonomic sensor module
30 212. This minimizes error in data analysis and subsequent control action in relation to individual user's comfort.

The building sense system 102 is arranged to determine the time interval of data transmission from the environmental sensor module 202, the energy sensor module 204 and the ergonomic sensor module 212 to the database 210.

- 5 In this embodiment, the time period is set as 5 seconds, however it should be understood that the time interval may be set as 3 seconds, 10 seconds or any other value based on either historical data or user defined criteria.

- 10 The database 210 includes a series of memory devices, in the present embodiment. After receiving the measured data from the environmental sensor module 202, the energy sensor module 204 and the ergonomic sensor module 212, the database 210 categorizes, classifies and stores the data in a repository for historical report generation and for further processing. Categorization includes separating the measured data corresponding to environmental
15 parameters from the energy parameters and the ergonomic parameters and similarly for separating the energy parameters and the ergonomic parameters. Classification includes segregating the data related to environmental, energy and ergonomic parameters between two environmental sensor modules 202, energy sensor modules 204 and ergonomic sensor modules 212. The
20 repository of the database 210 would be accessible from any location over an internet network.

- The control module 206 is configured to fetch the categorized and classified data from the database 210 for further processing and analysis. The control
25 module 206 includes a micro-processor. However, it should be understood that the control module 206 may contain a plurality of interconnected processors. The control module 206 is configured to perform a series of analysis and processing on the fetched data from the database 210.

- 30 The data analysis performed by the control module 206 on the fetched data includes data fusion technique applied on the measured data from the

environmental sensor module 202, the energy sensor module 204 and ergonomic sensor module 212 to make intelligent decisions on specific control action. In this embodiment, the control module 206 is configured to establish an N-dimensional profile with respect to each user based on their comfort level and preference on the environmental parameters. The control module 206 is also configured to control and mitigate a specific situation within the user's work station based on the N-dimensional profile of the user. The method of deriving the N-dimensional profile is discussed in detail in a later section.

10 The data analysis performed by the control module 206 also includes determining "true" presence of the user within his work station. This requires combining data of environmental parameters received from the particle sensor 202d, the noise sensor 202e, and the energy sensor module 204 with data from the PIR sensor 202f. Further, WiFi signal from a mobile device of the user is also combined with the physical presence data of the PIR sensor 202f, carbon dioxide data of the particle sensor 202d, noise level data of the noise sensor 202e and the energy consumption data of the energy sensor module 204 to determine the "true" presence. If the energy consuming devices are sensed to be in "sleep" mode, the user may not be using the devices and this infers with greater confidence that the user is physically not present within his work station. However, it should be understood that many other environmental and energy parameters may be combined to determine the physical presence of the user within his work station. Accordingly, the control module 206 makes decisions on remotely turning off the energy consuming devices in the user's work station if the user is found not present based on the determination of "true" presence. Further, the number and nature of the energy consuming devices turned off depends on a pre-defined preference set by the user of the work station. However, it should be understood that the control decision to turn off the energy consuming devices may be taken based on other pre-defined criteria or schedule.

Further, the control module 206 may be capable of managing the environmental sensor, the energy sensors and the ergonomic sensors in various situations, such as, automatic configuration, real time firmware update, on-line and off-line monitoring, inaccurate performance of the sensors indicating a problem, sensor
5 in switched off condition, troubleshooting, trouble-ticket issuance, generation of alerts, alarms and reports and so forth.

The control module 206 may also be configured to automatically upgrade necessary software or firmware of the environmental, energy and ergonomic
10 sensor modules 202, 204, 212 connected to the network. Such automatic periodic update may be performed through over the air (OTA) technique.

After data analysis, the processed information is then sent to the display module 208 for transmission to the various users for viewing. Specifically, the display
15 module 208 is arranged to send the analysed environmental parameters, the energy parameters and the ergonomic parameters to the computer system 108 for display at the users of individual work stations. Generally, a user has access to the environmental parameters, the energy parameters and the ergonomic parameters related to his own workstation. Additionally, a user may have
20 access to the environmental and energy parameters of the whole floor. The information on the environmental, energy and ergonomic parameters is sent to a native application installed on the computer system 108. However, it should be appreciated that the information on the environmental, energy and ergonomic parameters may be sent to a responsive web-site on the computer
25 system 108 of individual work space. It should be appreciated that instead of the computer system 108, the processed information may be displayed to the user via other means such as dashboard, data visualisation etc.

The display module 208 also sends the analysed data on environmental, energy
30 and ergonomic parameters to a building administrator. The data is presented based on both individual work station or at aggregate level related to a

department, an office group and entire floor. The data may also be sent on the basis of a physical zone defined by the administrator.

FIG. 6 is a flowchart illustrating a method of measuring, monitoring and
5 controlling indoor environment, energy consumption and/or ergonomic data of the building 100 of FIG. 1 at individual level based on respective N-dimensional profiles representing each user's individual comfort parameters, performed by the building sense system 102. Initially at step 402, the N-dimensional profiles representing each user's individual comfort parameters is derived by the control
10 module 206 and stored at the database 210. Here N represents a whole number which is greater than 1. The detailed method steps for deriving the N-dimensional profiles of the each user are illustrated with reference to a flowchart of FIG. 7. At step 502, initially the control module 206 identifies the parameters responsible for the individual user's comfort. After identification, the control
15 module 206 classifies the parameters into user-selectable parameters and measurable parameters. The user-selectable parameters require inputs from the user and the measurable parameters can be measured by sensors of the environmental sensor module 202, the energy sensor module 204 and ergonomic sensor module 212.

20

Next at step 504, the control module 206 receives user-selected inputs of the user-selectable parameters as qualitative indicators of each users comfort level. The quantitative measurements of the measurable parameters are received by the control module 206 from the sensors disposed at individual user's work
25 station at step 506. Based on combination of each user's qualitative indicator and qualitative measurements, the control module 206, at step 508, derives respective N-dimensional profiles representing each user's individual comfort parameters.

30 Coming back to FIG. 6, at step 404, the environmental parameters, the energy parameters and the ergonomic parameters associated with the respective

user's work station are measured by the environmental sensor module 202, the energy sensor module 204 and ergonomic sensor modules 212 disposed at the particular work station (for the purpose of explanation, work station 100.1 is selected by way of example, which includes the environmental sensor module 202.1, energy sensor module 204.1, ergonomic sensor module 212.1, computer system 108.1 and local mitigation system 110.1). Therefore, the environmental parameters of work station 100.1, the energy parameters of work station 100.1 and the ergonomic parameters of work station 100.1 are measured continuously on 24x7 basis by the environmental sensor module 202.1, the energy sensor module 204.1 and the ergonomic sensor modules 212.1 respectively disposed at work station 100.1.

Next at step 406, the measured data from the environmental sensor module 202.1, the energy sensor module 204.1 and the ergonomic sensor module 212.1 corresponding to the work station 100.1 is transmitted to the database 210. As discussed earlier, the measured data is transmitted in real time at the predefined time interval of 5 seconds. The data packet sent at a particular instant of time, also includes the unique identifier having the sensor identification numbers of the environmental sensor module 202.1 or the energy sensor module 204.1 or the ergonomic sensor modules 212.1 and a timestamp indicating the time of data transfer. The database 210 classifies and stores the measured data for further analysis by the control module 206. The control module 206 is arranged to perform data analysis on the classified data. The data analysis includes generating current reports and historical reports on trends of parameters hourly, daily, weekly, monthly or annual basis.

Further, the data analysis includes a data fusion technique to determine "true" presence of the user within work station 100.1. The true presence of the user at work station 100.1 is determined by combining data from the PIR sensor 202.1f and the data from other the environmental sensors such as the particle sensor 202.1d, the noise sensor 202.1e and the energy sensor module 204.1 disposed

on the work station 100.1. The WiFi signal associated with the mobile device of the user is also considered for determination of “true” presence of the user.

Based on the analysed data, certain control actions are taken by the control
5 module 206 at step 408. The control action includes automatically initiating the local mitigation system 110.1 of work station 100.1 if measured values of one or more environmental parameters fall outside the N-dimensional profile of the respective user of the work station 100.1. For example, if the measured temperature of work station 100.1 is higher than the temperature comfort level
10 corresponding to N-dimensional profile of the respective user (indicating that the user feels too warm), the desk fan (not shown in the Figures) disposed at the work station 100.1 is automatically turned on. Similarly, based on the measured values and N-dimensional profile, if a high humidity level is detected, the local dehumidifier (not shown in the Figures) disposed at the work station 100.1 is
15 automatically turned on so that the combined parameters fall within the N-dimensional profile associated with the user in order for the user to remain at the preferred comfort level. Likewise, if the particle sensor 202.1d detects a change in the air quality such that the combined parameters are outside of the N-dimensional profile of the user, the control module 206 controls the local
20 mitigation system 110.1 and specifically, the air purifier (not shown in the Figures) disposed at the work station 100.1 is automatically switched on to compensate the conditions at the work station 100.1 so that the combined parameters would fall within the N-dimensional profile associated with the user. Further, if illumination level of the work station 100.1 is outside the N-
25 dimensional profile of the user (indicating too bright or too dark), the lighting level (part of building electrical devices 106) of the work station 100.1 is automatically adjusted. Based on high or low illumination level, either number or intensity of light source is reduced or increased to be within the “comfort” range of the individual user. Further, in case the local mitigation system 110.1 is
30 insufficient to control the parameters, the control module 206 may request automatically to the building management system 101 of the building 100 to

control the conditions associated with the parameters on an aggregate level with the help of the building indoor environmental devices 104 and the building electrical devices 106.

5 Furthermore, the control action also includes energy savings measures. For example, if the user is found to be not present at his work station 100.1, the control module 206 automatically switches off certain energy consuming devices disposed on his workstation based on the predefined preference of the user. For example, switching off and switching on the personal computer
10 system 108.1, the monitor, the printer device and the lights disposed at workstation 100.1.

Finally, at step 410, the analysed data corresponding to the environmental parameters, the energy parameters and the ergonomic parameters are sent to
15 the display module 208 for the display of these parameters at display devices of the user. In this embodiment, the display data is sent to the display of the computer system 108.1 disposed at work station 100.1. The computer system 108.1 may include the respective user's personal computer (PC), Laptop, Smartphone, and Tablet. However, it should be understood that the display
20 device may include a wearable device, or an Internet of Things (IoT) device.

The displayed data at the computer system 108.1 includes current values and historical trends (hourly/ daily/ weekly/ monthly/ yearly) of the environmental parameters, energy parameters and ergonomic parameters corresponding to
25 the work station 100.1. The values are displayed in numeric values and in graphical representations for easy visualisation of the user. However it should be understood that the display data may include other information, such as, indicators of comforts based on personalised preference of the combination of the environmental parameters and the ergonomic parameters of the user of
30 work station 100.1 and global comfort indicators of the floor.

FIG. 8 shows parameters from a display 650 of the computer system 108.1. The display 650 includes the name of the user and the sensor identification number of the environmental sensor module 202.1 disposed at the work station 100.1. The display of environmental parameters includes illumination level in Lux, temperature in degrees, relative humidity in percentage, noise level in dB. Further, the display 650 also includes the energy parameters such as power in Watt and energy in kWh. Additionally, the display 650 includes floor level average information of important environmental parameters such as light, temperature, noise and amount of carbon dioxide, amount of VOC represented in numeric and visual format. Also, the display provides the information on floor level power consumption. Furthermore, the display 650 also includes data relating to external weather condition including maximum and minimum temperature, relative humidity, sky condition, wind speed, information on external air quality including PM2.5, PM10 and O3. The display data additionally includes certain tips or "Did You Know?" notes on interesting aspects of the environmental parameters. The information on external weather condition and "Did You Know" notes are typically collected from public sources such as internet by the control module 206. It should be appreciated that the display 650 may contain other environmental parameters such as amount of carbon dioxide in PPM, volatile organic compound (VOC) in PPB, amount of dust in mg/cubic m and so forth.

It is envisaged that the display 650 may take other forms such as that illustrated in FIG. 9, which shows an alternative display 652. The alternative display 652 includes the sensor identification number of the corresponding energy sensor module 204.1. The alternative display 652 includes data relating to active power in Watts, apparent power in VA, power factor, RMS current in Amp, RMS voltage in Volt corresponding to the energy consuming devices disposed at the work station 100.1. Further, the display data contains energy related information with respect to the entire floor such as total energy consumption in kWh, total cost in local currency, daily energy consumption in kWh and daily cost incurred.

Additionally, the display data contains useful tips and “Did You Know?” information on relevant aspects of energy parameters collected by the control module 206 over the internet.

- 5 It should be understood that the display data of environmental parameters and the energy parameters may include variations of FIG. 8 and FIG. 9 and may include some ergonomic parameters associated to the user.

10 It should be understood that the building sense system 102 may not be independent of the building management system 101, and may be integrated within the building management system 101 for measuring, monitoring and controlling environmental, energy and ergonomic parameters of the building 100 ensuring comfort at individual level.

- 15 A method of developing an N-dimensional profile of personalized preference of combination of environmental, energy, ergonomic and other comfort parameters of each employee in the building is explained below. This may be considered as “comfort map” which is the basis of a Personal Comfort Index (PCI) for all individuals in the building.

20

Background

Human comfort is qualitative and therefore subjective in nature. Comfort can be described in many ways such as physical and psychological.

- 25 Physical parameters which are typically discussed in the context of the comfort for an individual may include but not limited to temperature, humidity, noise, air quality, lighting level and so forth. But there may be many other possible factors, for example, hue of light, presence of daylight, the amount of breeze, weather condition, dependence on the type of clothing, ergonomic parameters such as
30 sitting height, sitting elbow height, sitting eye height, screen height, viewing distance, viewing angle, table height, knee clearance, knee angle, seat back

angle, elbow angle, keyboard height, furniture characteristics such as the angle of a chair the individual is sitting on, the firmness of a pillow an individual is resting head on and so forth.

- 5 Psychological parameters may include but not limited to the presence of a window through which the individual can see outside, the presence of a pet or friend, feeling of safety, presence of plants, feeling of space such as space between physical spaces, height of partition between physical spaces, free space within a physical space and so forth.

10

Physical Parameters for Comfort

Physical comfort can be considered to be made up of “N” mutually exclusive parameters (P), where “N” could be a very large number suggesting that list of factors that impact comfort may be very large. Some of these parameters are mentioned above and they include height of chair, distance from height of chair to the desktop, outside weather conditions, breeze, clothing, chair, posture, pillow firmness and so forth. “N” is the superset of parameters which impact physical comfort. “N” is dynamic and grows as new parameters are identified and added to the database and may be represented as:

20

$[N] = [P1, P2, P3, P4, \dots, PN]$, where P is a parameter which impacts physical comfort.

It is recognised that each individual’s comfort levels are unique and are based on “n” parameters which reflect the different variables impacting comfort for that specific individual. “[n]” is a given subset of [N] which applies to a particular individual and if there is a specific parameter, “Q”, (applicable to that individual), which is not included in the current instantiation of [N], then “Q” is added to [n] and also [N]. Therefore, [N] would continue to grow.

30

Therefore, it seems impractical to have a finite limit to the value of “N” and since comfort is highly subjective and personalised. Some parameters would apply to few individuals, while the same parameters may not apply to the rest. For the rest, some other parameters may contribute to their comfort – this leads to a straightforward, yet “dynamic” mapping exercise.

Quantifying Physical Comfort

Comfort level itself may vary from qualitative descriptions such as from unbearable, slightly uncomfortable to comfortable or even very comfortable. Such “descriptive” terms is mapped to a given physical parameter and then assigned a quantitative value using some form of a Likert scale. Such a quantitative value of comfort level could be represented on a scale of 0 – 1 in tiers of 0.25. It should be understood that this quantitative comfort value of 0.0 to 1.0 is just an example and could be pre-defined or established with the help of inputs from that specific individual or even be dynamic in nature – forming part of a ‘learning’ algorithm.

Example of Temperature - all other parameters being constant:

Temperature	Below 16 C Above 30 C	Between 16-18 C Between 28-30 C	Between 18-20 C Between 26-28 C	Between 20-22 C Between 24-26 C	Between 22-24 C
Comfort Level	Unbearable	Highly Uncomfortable	Uncomfortable	Slightly Uncomfortable	Comfortable
Comfort Value	0.00	0.25	0.50	0.75	1.00

Example of Humidity - all other parameters being constant:

Relative Humidity	Below 45% Above 85%	Between 45-50% Between 80-85%	Between 50-55% Between 75-80%	Between 55-60% Between 70-75%	Between 60-70%
Comfort Level	Unbearable	Highly Uncomfortable	Uncomfortable	Slightly Comfortable	Comfortable
Comfort Value	0.00	0.25	0.50	0.75	1.00

Example of Combining Temperature & Humidity:

- In reality both Temperature and Humidity, contribute to comfort levels of an individual. For example, just for simplicity – an individual could be comfortable (say Comfort Index Value of 1.00) at a combined Temperature of 22C and 65 % Relative Humidity. However, that individual could also have the same Comfort Index Value of 1.00 at a temperature of 23 C and 68 % Relative Humidity).

Temperature	Below 16 C Above 30 C	Between 16-18 C Between 28-30 C	Between 18-20 C Between 26-28 C	Between 20-22 C Between 24-26 C	Between 22-24 C
Relative Humidity	Below 45% Above 85%	Between 45-50% Between 80-85%	Between 50-55% Between 75-80%	Between 55-60% Between 70-75%	Between 60-70%
Comfort Level	Unbearable	Uncomfortable	Slightly Uncomfortable	Slightly Comfortable	Comfortable
Comfort Value	0.00	0.25	0.50	0.75	1.00

This indicates that a single Comfort value has possible multiple combinations of input parameters. In the case of Temperature and Humidity, it becomes a 2-Dimensional (i.e. $N=2$) mathematical exercise and if a 3rd and 4th parameter are added such as Light and Noise, it becomes a 4-Dimensional exercise. If extrapolated to the set $[n]$ as discussed earlier, this exercise transforms into an n -dimensional mathematical surface which helps to quantify the comfort levels for a given individual.

- Since 'true' comfort is an aggregate of the individual comfort parameters, some form of weighted average would be more appropriate based on the relative importance of a given parameter, for that particular individual. This exercise is then repeated for every individual in a given building, providing a full suite of customized n -dimensional comfort profiles associated with all individuals across the building. This comfort profile is represented in a mathematical function of the different physical parameters, P_1 through P_n such as:

$$\text{Comfort} = f(P_1, P_2, P_3, P_4 \dots P_n).$$

- The function f , forms an n -dimensional surface representing the complete comfort profile or PCI (Personal Comfort Index) for a given individual. As discussed earlier, " n " is only a subset of " N " and so, this profile is likely to grow, as more and more parameters are added.

Collection of Information

- In view of the foregoing approach, the next section explains a methodology to collect and correlate this information on various physical and comfort parameters which contribute to personal comfort. Out of these physical parameters, some parameters are measurable and for the other parameters user selected values are taken as qualitative indicator.

The holistic envelope of a PCI is realistically based on “n” physical parameters which not only influence comfort but are quantifiable and are quantified in a straightforward manner. A step by step approach is described next based on a specific example. The following is a step by step approach:

- 5 1. Identifying by the control module 206 a list of “n” physical parameters which can be measured and quantified easily.
2. Identifying by the control module 206 which of these parameters can
10 be measured by using sensors and the information can be captured in real time on a continuous basis, and these would be the measurable parameters.
3. Identifying by the control module 206 which parameters need to be
15 “inputted” by the individual and this would be the user-selectable parameters for selection/adjustment by users.
4. Measuring the measurable parameters by the associated real time
20 sensors, such as, temperature sensor 202a, light sensor 202b, humidity sensor 202c, particle sensor 202d, noise sensor 202e. This measurement is carried out every x seconds or every y minutes. The values of x and y are defined by the user or organization on a customized basis.
5. Storing this data related to the measurable parameters in the database
25 210 along with the specific time stamp as to when the data was collected in the database 210 and the sensor identification number identifying the sensor of the corresponding data.
6. At some integral multiple of x and y (multiple could be 1), collecting by
30 the control module 206 the qualitative comfort indicators of the user-selectable parameters from the individuals in the space, room, floor or

building – where the above sensor based measurements are carried out. Also capture the timestamp of such measurements.

- 5 7. Storing the information related to the user-selectable parameters in the database 210.
8. Performing real time cross mapping of the quantitative values the [n] parameters against the qualitative comfort indicators to allow a real time correlation of the conditions by the control module 206.
- 10 9. Developing a robust correlation between personal comfort index (PCI) and the “n” parameters by the control module 206. This correlation is first based on some form of “supervised learning” methodology such that it is based on known data/ inputs. The correlation allows for a
- 15 “convergence” in terms of predictability of the comfort index.
10. Establishing a “predictive” model for the PCI by the control module 206, by continuously cross-checking against new data points such that it is continuously improved and can correctly predict comfort
- 20 levels/ indices.

Example

25 Temperature (T), Humidity (H), Lighting (L) Levels and Noise (N) as a set of 4 parameters (i.e. N=4) are chosen to exemplify the approach.

For example: Sensor Data and Comfort Values

Time Sunday 4 Dec 20XX @ 10.15 AM

Parameter	Value	Comfort Type	Weightage	Qualitative	Quantitative
Temperature	24 C	Thermal	50 %	Comfortable	1.0
Humidity	65 %				
Light Level	605 Lux	Visual	25 %	Too Bright – Slightly Uncomfortable	0.50
Noise Level	65 dB	Acoustic	25 %	Too Noisy - Uncomfortable	0.25
Overall Aggregate			100 %	Slightly Comfortable	0.6875

The values of the measurable parameters are captured concurrently, with a time stamp, with the qualitative comfort indicators of the user-selectable parameters. This data mapping is continuously performed and over time, a full “n-dimensional” surface of comfort would be developed with reference to the specific individual. This means that a functional representation of “Comfort” can be developed for example:

$$\text{Comfort} = f(\text{Temperature, Humidity, Light, Noise}) = f(T, H, L, N).$$

10

An example of this correlation could be:

$$\text{Comfort} = a_0 + b_0T + c_0H + d_0L + e_0N + b_1T^2 + c_1H^2 + d_1L^2 + e_1N^2 + b_2TH + c_2TL + d_2TN + b_3T^3 + c_3H^3 \dots$$

15 The coefficients, a_0 , b_0 etc. are constants

However it should be understood that the above is not necessarily the only form of such a comfort index function. This mathematical function can be any form, for example, a multivariate Taylor Series or any other which adequately

represents the overall dataset. Such a formulation then forms the basis for a “Personal Comfort Index” or N-dimensional profile of comfort with respect to every individual.

5 Psychological Parameters for Comfort

The psychological parameters are qualitative in nature and are difficult to convert into a quantitative fashion. However, in principle the above approach and methodology can be applied on the psychological parameters and combined with the physical parameters to get an overall Comfort Index or PCI.

10

It should be appreciate that with the building sense system 102, this helps to enhance the comfort of every individual user of the building 100 and may minimize the energy usage of the building 100. The building sense system 102 also helps to facilitate monitoring of the building indoor parameters at individual, zone or floor level.

15

It should be apparent that the building sense system 102 is easy to use, inexpensive and may utilize existing building infrastructure and network. The building sense system 102 attempts to mitigate local environmental conditions of the individual work stations for ensuring comfort of the respective user without disturbing global environmental condition of the entire building.

20

It will be apparent to those skilled in the art that various modifications and variations can be made to the described embodiment without departing from the spirit and scope of the invention. For example, although the above description has been made with respect to a single computer system that term is meant to include distributed data storage environment, such as networked computers. Thus it is intended that the present is not to be limited by the specific illustrated embodiment but cover the modifications and variations of this invention provided they come within the scope of the appended claims and their equivalents. Also, if more parameters are used, the more accurate it would be

25

30

to determine the N-dimensional profiles of users. However, it is envisaged that depending on implementation and requirement, it may not be necessary to have environmental parameters, energy parameters and ergonomic parameters, but at least one of these, or combinations of them.

Claims

1. A method of deriving individual comfort parameters for a plurality of users associated with respective physical spaces; the method including:
 - 5 (i) providing a plurality of parameters including user-selectable parameters and measurable parameters;
 - (ii) receiving user-selected inputs of the user-selectable parameters as qualitative indicators of each of the plurality of users;
 - (iii) receiving quantitative measurements of the measurable parameters
 - 10 from sensors disposed at each user's physical space; and
 - (iv) deriving respective N-dimensional profiles based on a combination of each user's qualitative indicator and quantitative measurements to represent each user's individual comfort parameters; wherein N is greater than 1.
- 15 2. The method according to claim 1, wherein the plurality of parameters include attributes relating to thermal, visual, aural, ergonomic and well-being conditions at respective user's physical spaces or environment.
3. The method according to claim 1 or 2, wherein the plurality of parameters
- 20 include a combination of at least some of temperature, humidity, noise level, illumination level, hue of light, air quality, breeze, weather condition, clothing of users, posture and ergonomic parameters, furniture characteristics, presence of window, presence of plants and feeling of space.
- 25 4. The method according to any preceding claim, wherein the N-dimensional profile of each user includes a series of personal comfort indexes, with each personal comfort index being associated with corresponding combinations of the qualitative indicators and quantitative measurements.

5. The method according to claim 4, further including performing correlation between the qualitative indicators and the quantitative measurements to arrive at the corresponding personal comfort index.
- 5 6. A method of controlling comfort parameters for a plurality of users having respective physical spaces based on the N-dimensional profile derived from any preceding claim, the method comprising:
- receiving a change in a setting of at least one of the plurality of parameters; the changed setting being associated with a user's physical space;
- 10 controlling a local mitigation system to adjust an environmental condition at the physical space of the user to restore comfort level of the user based on the user's desired personal comfort index corresponding to the N-dimensional profile.
- 15 7. The method of claim 6, further comprising dynamically updating the N-dimensional profile based on user preference for controlling the comfort parameters.
8. The method of claim 6 or 7, further comprising:
- 20 measuring conditions associated with the plurality of parameters at the corresponding physical space by a sensor module;
- analysing the conditions associated with the plurality of parameters at a physical space and taking control action, by a control module, based on the N-dimensional profile corresponding to the respective user of the corresponding physical space; and
- 25 displaying the conditions associated with the plurality of parameters to a display device of the respective user of the corresponding physical space.
9. The method according to claim 8, wherein the plurality of parameters
- 30 comprises energy parameters including at least some of energy consumption,

electrical power, reactive power, current, voltage, power factor of a plurality of energy consuming devices disposed at the corresponding physical space.

10. The method according to claim 8 or 9, wherein taking control action by
5 the control module includes turning off automatically one or more energy consuming devices disposed at the corresponding physical space if the respective user is determined to be not present within the corresponding physical space based on a predefined preference established by the user.

10 11. The method of any of claims 8 to 10, wherein the physical spaces are associated with a building, and the method further comprises requesting automatically a building management system of the building to control the conditions associated with the plurality of parameters on an aggregate level.

15 12. A method of determining physical presence of a user within respective physical space comprising:

receiving a first data from a motion sensor disposed at the respective physical space;

20 receiving a second data based on at least one measurable parameters from sensors disposed at respective physical space; and

determining physical presence of the user within respective physical space based on a combination of the first data and the second data.

25 13. The method according to claim 12, wherein the measurable parameters comprises a combination of:

environmental parameters including at least some of temperature, humidity, noise level, light and air quality;

30 energy parameters including energy consumption of one or more energy consuming devices disposed within respective physical space comprising at least some of a computer, a laptop, a printer, a fan, an air purifier, a dehumidifier; and

wireless network signal associated with a mobile device of the user of the respective physical space.

14. A server for deriving individual comfort parameters for a plurality of users associated with respective physical spaces, the server comprising at least a computer processor and a data storage device, the data storage device comprising instructions operative by the processor to:

- (i) provide a plurality of parameters including user-selectable parameters and measurable parameters;
- 10 (ii) receive user-selected inputs of the user-selectable parameters as qualitative indicators of each of the plurality of users;
- (iii) receive quantitative measurements of the measurable parameters from sensors disposed at each user's physical space; and
- (iv) derive respective N-dimensional profiles based on a combination of
15 each user's qualitative indicator and quantitative measurements to represent each user's individual comfort parameters; wherein N is greater than 1.

15. Apparatus for controlling a plurality of parameters at respective physical spaces of users, the plurality of parameters including user-selectable parameters and measurable parameters, the apparatus comprising:

- a plurality of sensor modules, each sensor module arranged to measure conditions associated with the measurable parameters at the corresponding physical space;
- a user input device for receiving user selected inputs of the user-selectable parameters; and
25
- a local mitigation system for adjusting conditions at the corresponding physical space of the user to restore comfort level of the user based on the user's desired personal comfort index of an N-dimensional profile derived by a server based on the user-selectable parameters and the measurable
30 parameters.

16. The apparatus according to claim 15, wherein the local mitigation system comprises at least some of a desk fan, a USB fan, a ceiling fan, a wall-mounted fan, a table fan, a stand fan, a personal ventilation system, a dehumidifier, an air purifier and an air freshener.

5

17. The apparatus according to claim 15 or 16, wherein the user input device comprises at least one of an office desktop, a laptop, a tablet, a smartphone, a wearable device and an Internet of Things (IoT) device.

10 18. Apparatus for controlling a plurality of comfort parameters for a plurality of users having respective physical spaces based on N-dimensional profile derived from any one of claims 1 to 5, the apparatus comprising:

15 a plurality of sensor modules, each sensor module is arranged to measure conditions associated with the plurality of parameters at the corresponding physical space;

a control module for analysing the conditions associated with the plurality of parameters at the corresponding physical space and controlling the conditions, based on the N-dimensional profile, corresponding to the respective user of the corresponding physical space to generate a control signal;

20 a local mitigation system for adjusting the conditions associated with at least some of the plurality of parameters at the corresponding physical space to restore the comfort level of the user based on the control signal; and

a display device for displaying the conditions associated with the plurality of parameters of the corresponding physical space to the respective users.

25

19. The system according to claim 18, wherein the control module is further configured to perform automatic firmware updates of the plurality of the sensor modules.

30 20. The system according to claim 18 or 19, wherein the physical spaces are associated with a building which comprises one of an office building, a

commercial building, an enterprise building and a residential building; and the physical space comprises one of an office cubicle, an office desk, an office workstation and a residential unit.

5

10

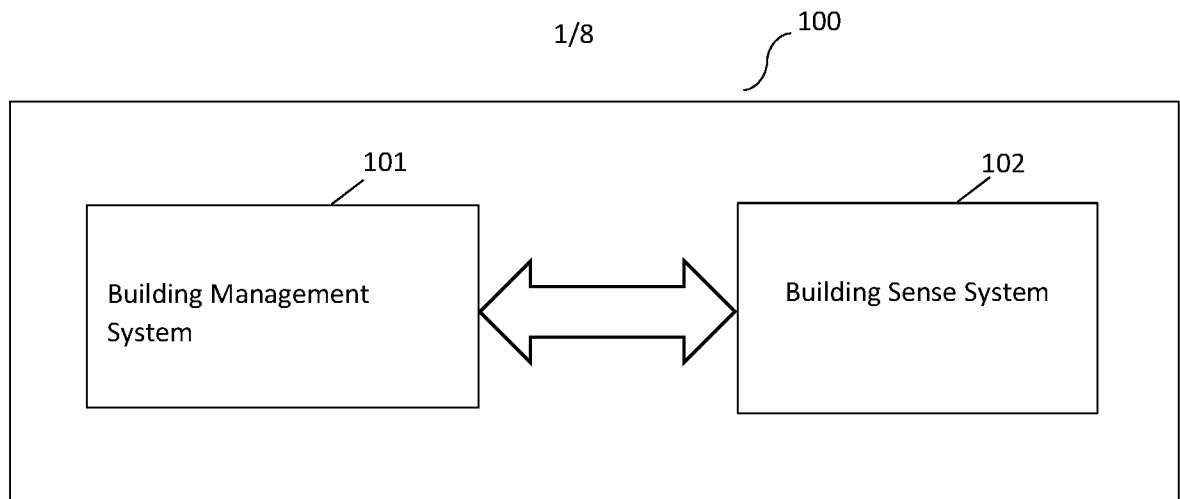


FIG. 1

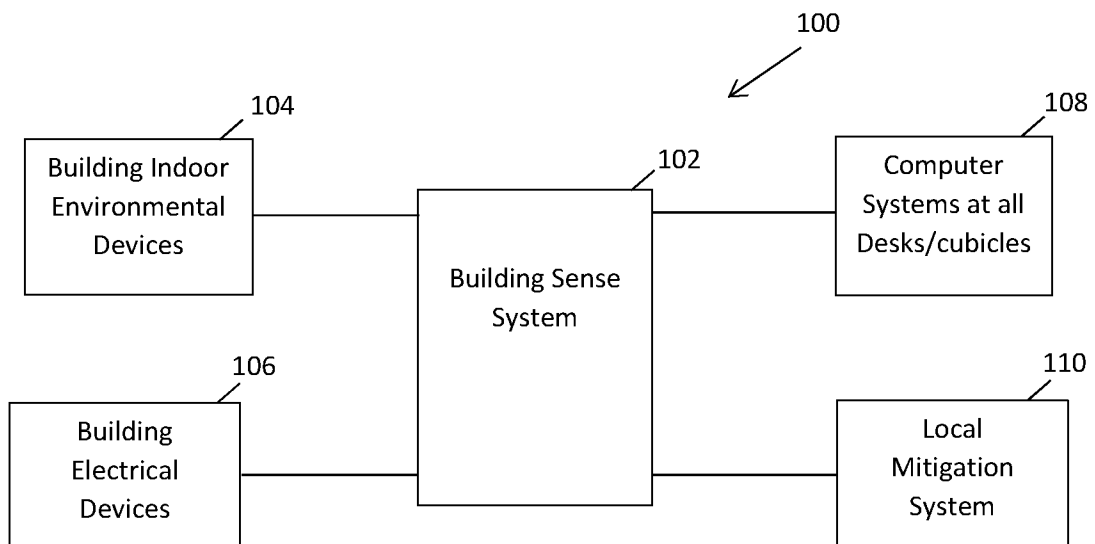


FIG. 2

2/8

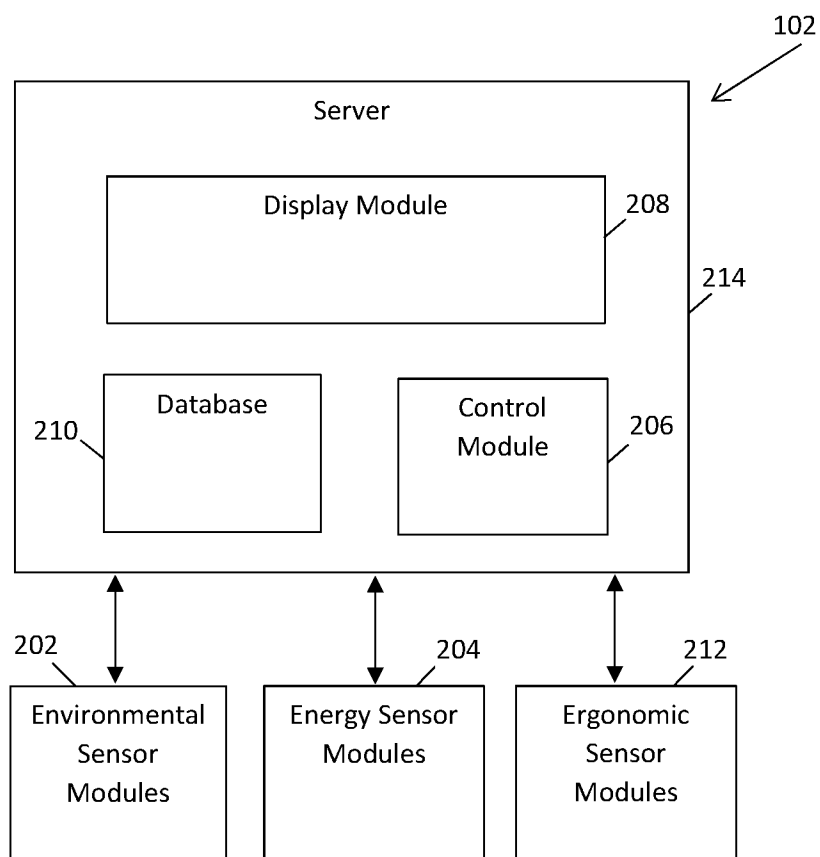


FIG. 3

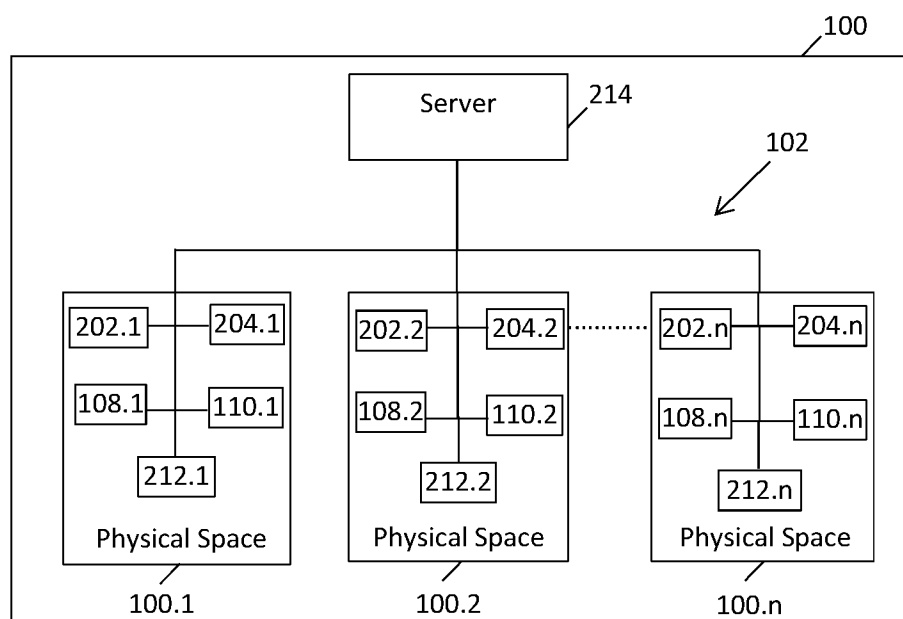


FIG. 4

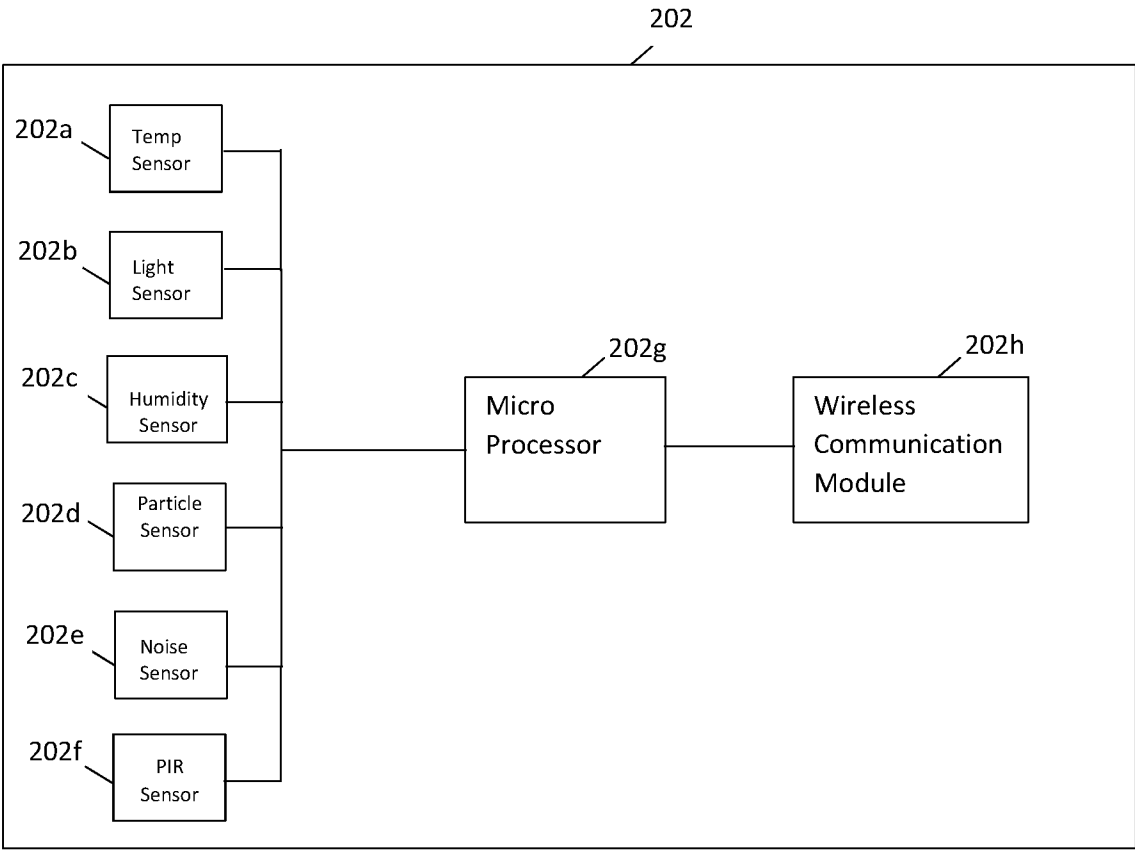


FIG. 5

4/8

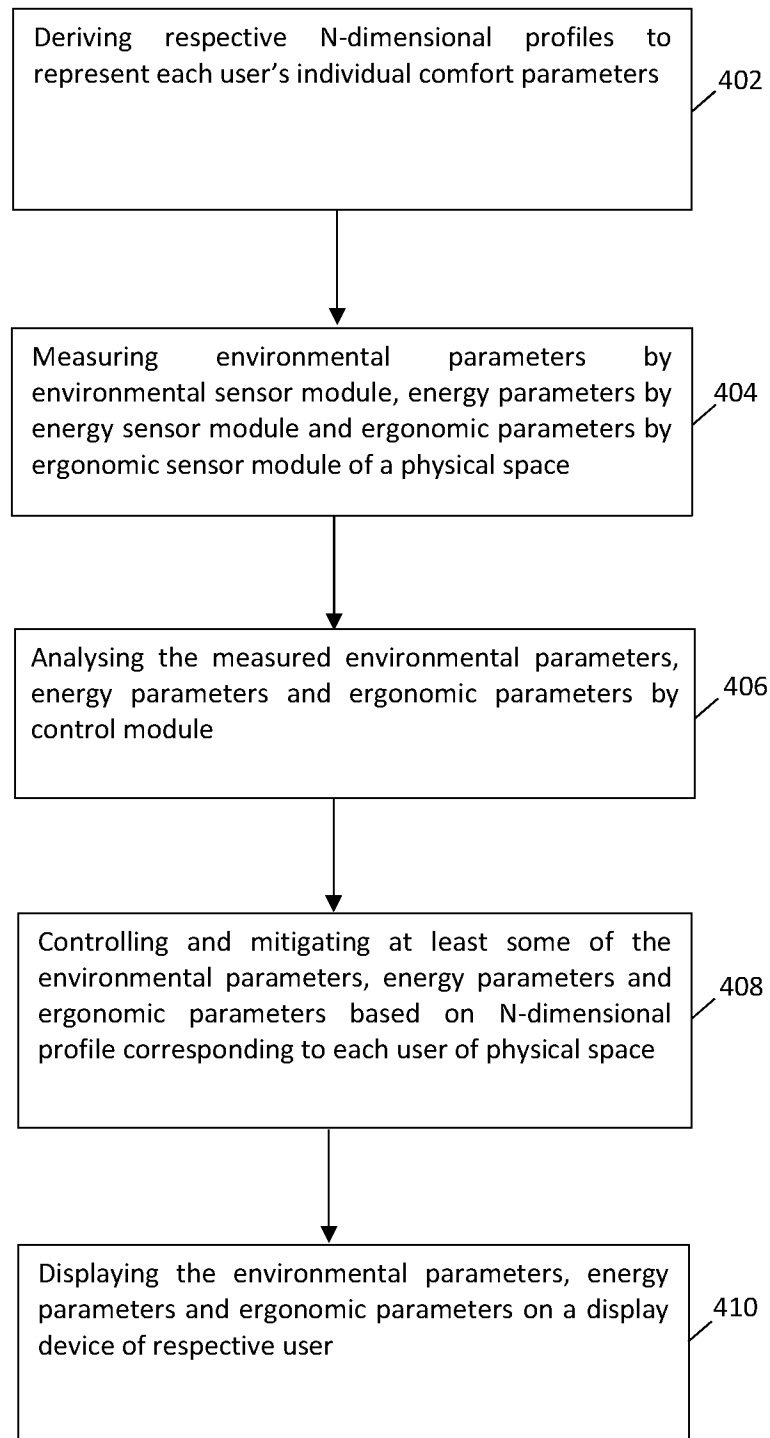
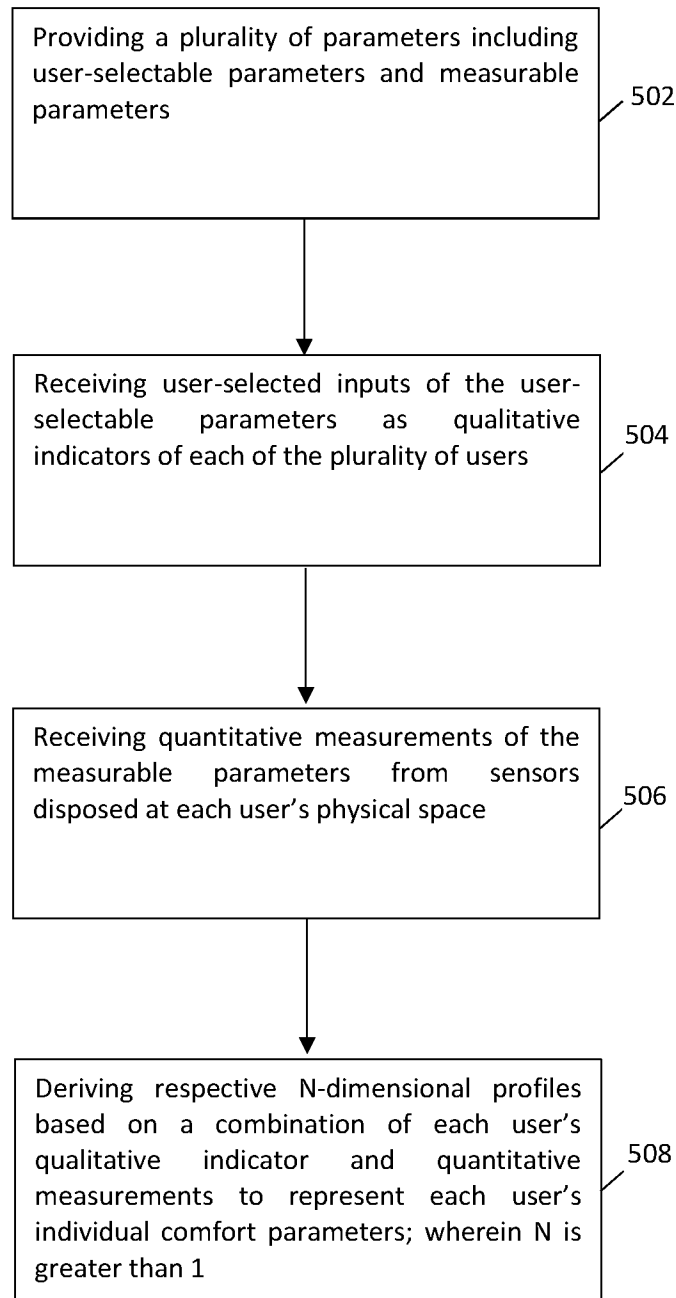


FIG. 6

5/8

**FIG. 7**

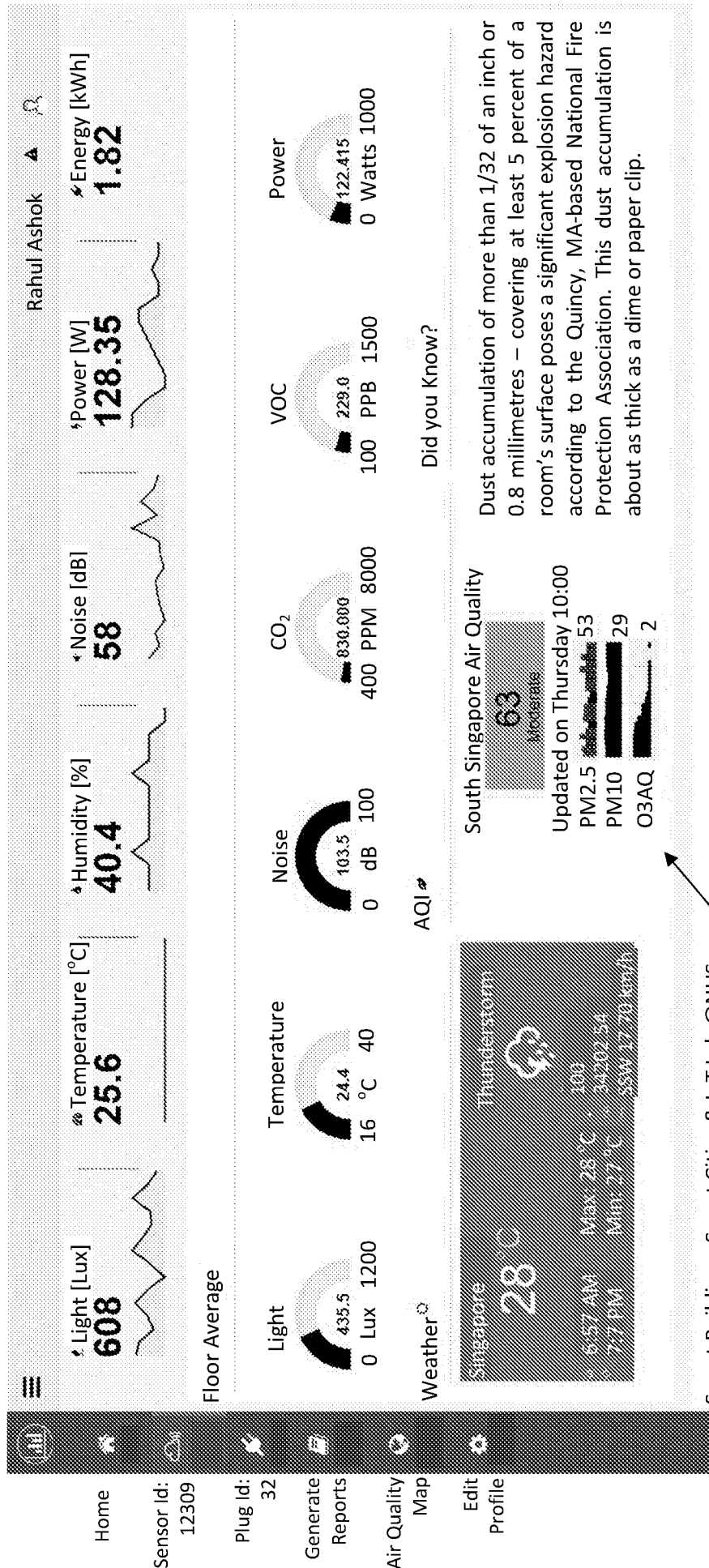


FIG. 8

650

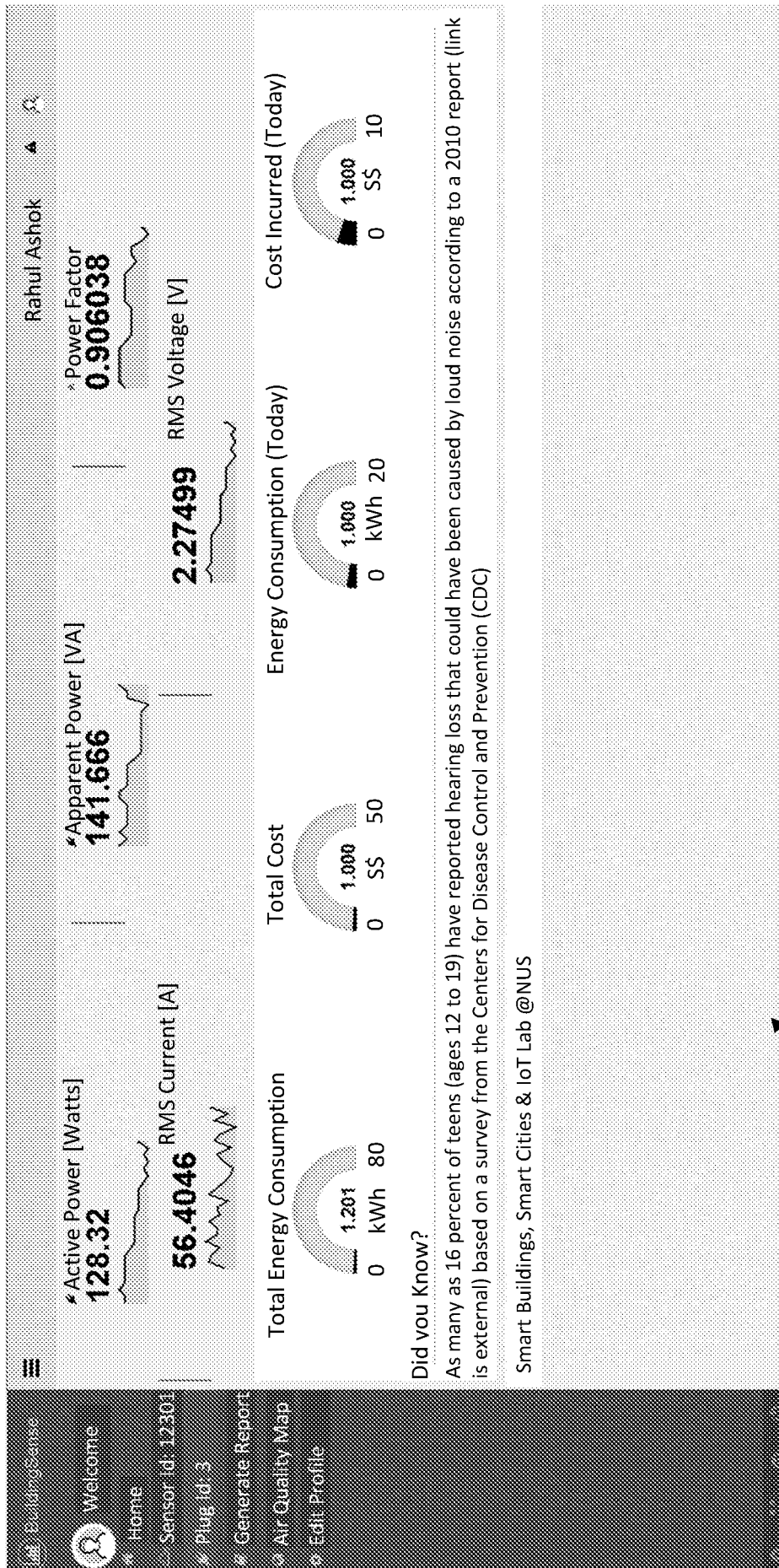


FIG. 9

652

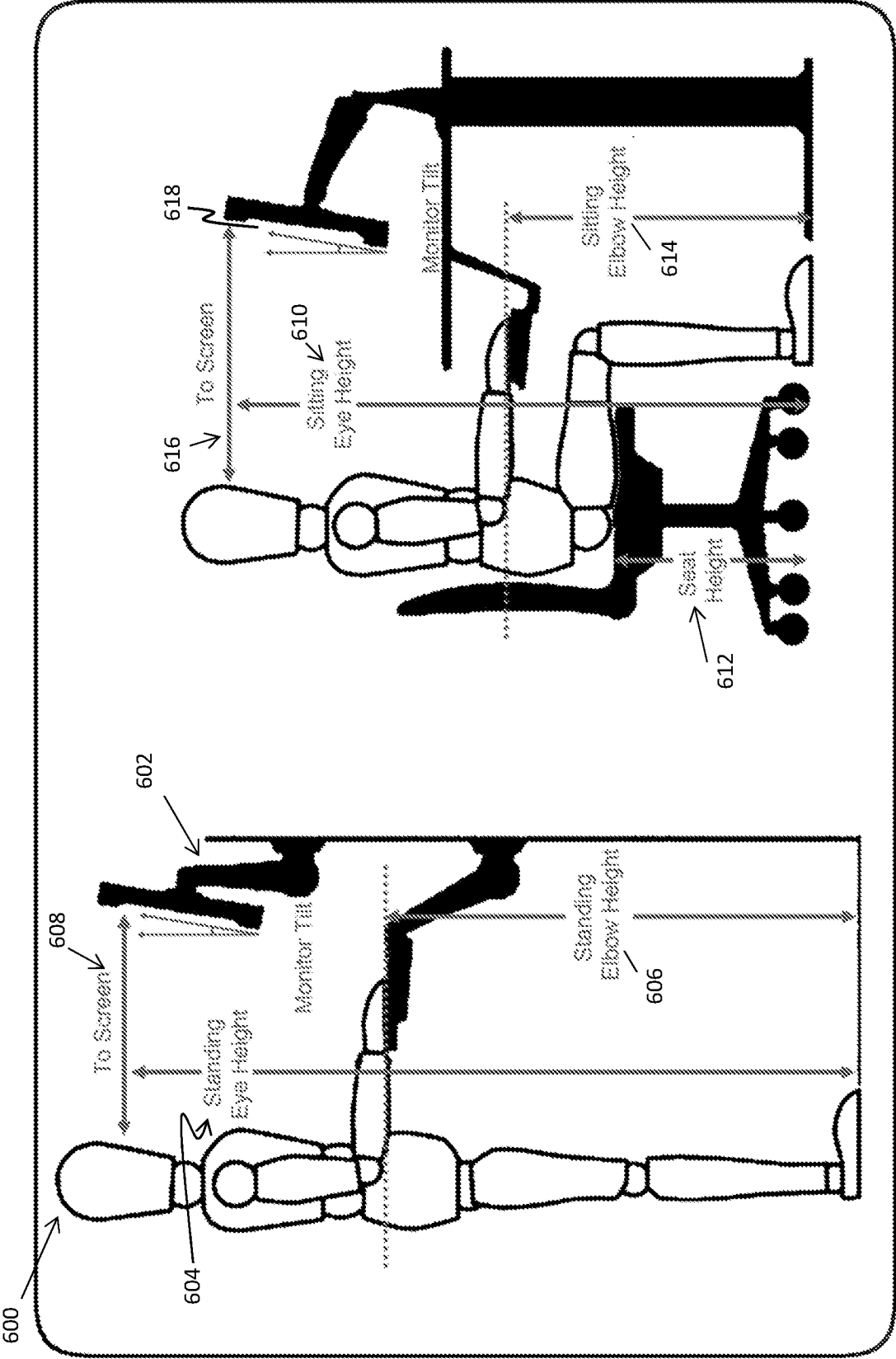


FIG. 10a

FIG. 10b

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2018/050271

A. CLASSIFICATION OF SUBJECT MATTER

G05D 27/00 (2006.01) F24F 11/62 (2018.01)

According to International Patent Classification (IPC)

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G05D, F24F

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)

FAMPAT, IEEE: thermal comfort, ergonomics, feedback, parameters, index, score, weight, consumption, power, energy, 热舒适, 人机, 反馈, 参数, 能源, 参数, 消耗 and other 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	JAZIZADEH, F. ET AL., Human-Building Interaction Framework for Personalized Thermal Comfort-Driven Systems in Office Buildings. <i>JOURNAL OF COMPUTING IN CIVIL ENGINEERING</i> , 18 February 2013, Vol. 28, No. 1, pages 2-16 [Retrieved on 2018-08-17] <DOI: 10.1061/(ASCE)CP.1943-5487.0000300> Introduction and Motivation, HBI-TC Framework for Personalized HVAC Operations, Building Sensor Network, Personalized Comfort Profiling, Learning Comfort Profiles, BMS Controller, Participatory Sensing Using an Intermediary, Figures 1-2	1-11, 14-20
X	LAM, A. H.-Y. ET AL., An Occupant-participatory Approach for Thermal Comfort Enhancement and Energy Conservation in Buildings. <i>e-Energy '14 Proceedings of the 5th international conference on Future energy systems</i> , 13 June 2014, pages 133-143 [Retrieved on 2018-08-17] <DOI: 10.1145/2602044.2602067> Abstract, 3. Occupant-Participatory Thermal Comfort: An Overview, 4. Temperature-Comfort Correlation Model, 4.2 Model Development, 5. The Setpoint Optimization Algorithm, 7. Implementation Details, 7.1 A mobile application for Occupants, Figures 1, 9	1-11, 14-20

☒ Further documents are listed in the continuation of Box C.

☒ See patent family annex.

*Special categories of cited documents:

"A" document defining the general state of the art which is not considered to be of particular relevance

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

"O" document referring to an oral disclosure, use, exhibition or other means

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

"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention

"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone

"Y" document of particular relevance; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art

"&" document member of the same patent family

Date of the actual completion of the international search

20/08/2018

(day/month/year)

Date of mailing of the international search report

12/09/2018

(day/month/year)

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INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2018/050271

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	CN 104833063 A (ANHUI BUILDING UNIVERSITY) 12 August 2015 paras. [0005]-[0012], [0031]-[0032], [0047]-[0054], [0087]-[0105], [0115] of the original non-English language document (a machine translation is enclosed only for your reference)	1-7, 14-16
X	WO 2015/049664 A1 (UNIVERSITÀ POLITECNICA DELLE MARCHE) 9 April 2015 pgs. 5, 8-12, Fig. 2	1-6, 14-17
A	CN 103941656 A (ENERGY SAVING GREEN BUILDING ENERGY SAVING TECHNOLOGY) 23 July 2014 paras. [0014], [0024]-[0025] of the original non-English language document (a machine translation is enclosed only for your reference)	
A	US 2011/0218690 A1 (O' CALLAGHAN, C. ET AL.) 8 September 2011 Whole document especially para. [0132]	

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2018/050271**Box No. II Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)**

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:

because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:

because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:

because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

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

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

Please refer to Supplemental Box (Continuation of Box No. III).

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☐ As all searchable claims could be searched without effort justifying additional fees, this Authority did not invite payment of additional fees.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

1-11, 14-20

Remark on Protest ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.

☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.

☐ No protest accompanied the payment of additional search fees.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SG2018/050271

Supplemental Box **(Continuation of Box No. III)**

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

Invention I: Claims 1-11 and 14-20 are directed towards a method, server and apparatus for deriving and controlling control parameters associated with physical spaces through deriving N dimensional profiles based on received qualitative and quantitative measurements and a local mitigation system for adjusting conditions to restore comfort levels.

Invention II: Claims 12-13 are directed towards a method of determining physical presence of a user within a physical space based on a first data from a motion sensor and a second data from sensors disposed at the physical space.

In the above groups of claims, the identified features may have the potential to make a contribution over the prior art but are not common to all the claimed inventions and therefore cannot provide the required technical relationship. Therefore there is no special technical feature common to all the claimed inventions and the requirements for unity of invention are consequently not satisfied *a priori*.

Please refer to **Box No. IV** of Written Opinion of The International Searching Authority (Form PCT/ISA/237) for detailed explanation.

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No.

PCT/SG2018/050271

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
CN 104833063 A	12/08/2015	NONE	
WO 2015/049664 A1	09/04/2015	IT MO20130279 A1	04/04/2015
CN 103941656 A	23/07/2014	NONE	
US 2011/0218690 A1	08/09/2011	WO 2011/109757 A1 WO 2011/109759 A1 US 2011/0218691 A1	09/09/2011 09/09/2011 08/09/2011