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(54) Title: WEARABLE DEVICE COUPLED TO A FACILITY NETWORK

(57) Abstract: A network system in an enclosure includes one or more building systems such as tintable windows, HVAC components, sensors, computing devices, media display devices, and/or service devices. A physical condition of a user within the enclosure may be determined based on sensor data, and environmental adjustments can be implemented via the building systems based on the user's physical condition and determined location.

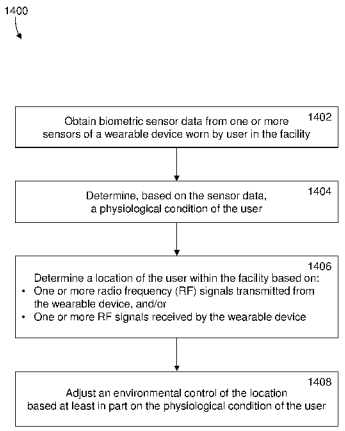


Figure 14

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[Continued on next page]

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WEARABLE DEVICE COUPLED TO A FACILITY NETWORK

RELATED APPLICATIONS

[0001] This application claims the benefit of U.S. Provisional Patent Application Serial No. 63/305,407, filed February 1, 2022, entitled "WEARABLE DEVICE COUPLED TO A FACILITY NETWORK". This application also claims the benefit of, and is a continuation-in-part of, International Patent Application Serial No. PCT/US2021/027418, filed April 15, 2021, entitled "INTERACTION BETWEEN AN ENCLOSURE AND ONE OR MORE OCCUPANTS". This application also claims the benefit of U.S. Provisional Patent Application Serial No. 63/170,245, filed April 2, 2021, entitled "DISPLAY CONSTRUCT FOR MEDIA PROJECTION AND WIRELESS CHARGING". This application also claims the benefit of U.S. Provisional Patent Application Serial No. 63/154,352, filed February 26, 2021, entitled "DISPLAY CONSTRUCT FOR MEDIA PROJECTION AND WIRELESS CHARGING". This application also claims the benefit of, and is a continuation-in-part of, U.S. Patent Application Serial No. 17/249,148, filed February 22, 2021, entitled "CONTROLLING OPTICALLY-SWITCHABLE DEVICES". Each of the above recited patent applications is entirely incorporated herein by reference.

BACKGROUND

[0002] This disclosure relates generally to user interaction (e.g., control) with one or more interactive targets in an enclosure. The interactive targets can comprise an optically switchable device (e.g., tintable window in a building), projected media, environmental appliance, sensor, or any other apparatus that is communicatively coupled to a communication network in an enclosure.

[0003] The ability to control and/or customize environmental conditions or aspects within at least a portion of the enclosure is gaining increased popularity, as well as deployment and manipulation of related apparatuses such as sensors, emitters, devices that affect the environment. Controlling and/or customizing the environment may be with the aim to increase comfort of occupant(s) and/or to reduce power consumption and improving the efficiency of systems controlling the environment of the enclosure (e.g., heater, cooler, vent, lighting, or a combination thereof). A user's control and/or customization of conditions/aspects the environment, however, traditionally entails manual adjustment of devices using physical user interfaces.

SUMMARY

[0004] Various aspects disclosed herein alleviate as least part of the shortcomings and/or aspirations related to controlling one or more aspects of an environment of a facility. Various embodiments herein relate to methods, systems, software and networks for automatic control of one or more environmental aspects. Various embodiments disclosed herein relate to determining a physical condition of a user (e.g., a patient) based on biometric sensor data. Environmental adjustments can be implemented based on the user's physical condition and

determined location.

[0005] In another aspect, a method for sensor-based control of one or more aspects of an environment of a facility, the method comprises: obtaining sensor data from one or more sensors of a wearable device worn by a user in the facility; determining, based on the sensor data, a physiological condition of the user; determining a location of the user within the facility based, at least in part, on: one or more radio frequency (RF) signals transmitted from the wearable device, and/or one or more RF signals received by the wearable device; and adjusting an environmental control of the location based, at least in part, on the physiological condition of the user.

[0006] In some embodiments, the one or more sensors comprise a sensor configured to measure a sugar level of the user, a heart rate of the user, a step count of the user, a blood pressure of the user, a blood oxygen level of the user, a temperature of the user, a pulse of the user, or a combination thereof. In some embodiments, obtaining the sensor data comprises receiving the sensor data from the wearable device and/or from a control device communicatively coupled with the wearable device. In some embodiments, the control device comprises a controller of the facility, a mobile phone, laptop, or tablet. In some embodiments, adjusting the environmental control of the location is further based on a user preference. In some embodiments, the method further comprises: determining an identity of the user based on an association of the user with the wearable device; and determining the user preference based on the identity of the user; wherein adjusting the environmental control of the location is further based on the user preference. In some embodiments, the user preference comprises a temperature setting, a window tint setting, a lighting setting, or a combination thereof. In some embodiments, the lighting setting comprises a brightness and/or color of light. In some embodiments, adjusting the environmental control of the location comprises adjusting air flow to and/or from the location; a temperature of air flowing into the location; an oxygen level of the location; a carbon dioxide (CO_2) level of the location; an amount of lighting at the location; a color of lighting at the location; a window tint at the location; a temperature at the location; or a combination thereof. In some embodiments, adjusting the environmental control of the location comprises: determining a building system associated with the location; and causing the building system to adjust the environmental control. In some embodiments, the building system comprises a system controlling heating, ventilation, and air conditioning (HVAC) of the location; an oxygen level of the location; a carbon dioxide (CO_2) level of the location; an amount of lighting at the location; a color of lighting at the location; a degree of window tint at the location; or a combination thereof. In some embodiments, the building system comprises a device ensemble having a housing that encloses one or more devices that comprise: (i) sensors, (ii) a transceiver, (iii) a sensor and an emitter, or (iv) a combination thereof. In some embodiments, the device ensemble is disposed in a fixture of the facility, or is attached to a fixture of the facility. In some embodiments, the building system comprises a tintable window. In some

embodiments, the tintable window comprises an electrochromic window.

[0007] In another aspect, an apparatus for sensor-based control of one or more aspects of an environment of a facility, the apparatus comprises one or more processors comprising circuitry, wherein the one or more processors are configured to: obtain, or direct obtaining of, sensor data from one or more sensors of a wearable device worn by a user in the facility; determine, or direct determining of, a physiological condition of the user based on the sensor data; determine, or direct determining of, a location of the user within the facility based, at least in part, on: one or more radio frequency (RF) signals transmitted from the wearable device, and/or one or more RF signals received by the wearable device; and adjust, or direct adjusting of, an environmental control of the location based, at least in part, on the physiological condition of the user.

[0008] In some embodiments, the one or more sensors comprise a sensor configured to measure a sugar level of the user, a heart rate of the user, a step count of the user, a blood pressure of the user, a blood oxygen level of the user, a temperature of the user, a pulse of the user, or a combination thereof. In some embodiments, to obtain, or direct obtaining of, sensor data, the one or more processors are configured to receive the sensor data from the wearable device and/or from a control device communicatively coupled with the wearable device. In some embodiments, the control device comprises a controller of the facility, a mobile phone, laptop, or tablet. In some embodiments, the one or more processors are configured to adjust, or direct adjusting of, the environmental control of the location further based on a user preference. In some embodiments, the one or more processors are further configured to: determine, or direct determining of, an identity of the user based on an association of the user with the wearable device; and determine, or direct determining of, the user preference based on the identity of the user; wherein the one or more processors are configured to adjust, or direct adjusting of, the environmental control of the location further based on the user preference. In some embodiments, the user preference comprises a temperature setting, a window tint setting, a lighting setting, or a combination thereof. In some embodiments, the lighting setting comprises a brightness and/or color of light. In some embodiments, to adjust, or direct adjusting of, the environmental control of the location, the one or more processors are configured to adjust air flow to and/or from the location; a temperature of air flowing into the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a window tint at the location; a temperature at the location; or a combination thereof. In some embodiments, to adjust, or direct adjusting of, the environmental control of the location, the one or more processors are configured to: determine, or direct determining of, a building system associated with the location; and cause, or direct causing of, the building system to adjust the environmental control. In some embodiments, the building system comprises a system controlling heating, ventilation, and air conditioning (HVAC) of the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a degree of window tint at the

location; or a combination thereof. In some embodiments, the building system comprises a device ensemble having a housing that encloses one or more devices that comprise: (i) sensors, (ii) a transceiver, (iii) a sensor and an emitter, or (iv) a combination thereof. In some embodiments, the device ensemble is disposed in a fixture of the facility, or is attached to a fixture of the facility. In some embodiments, the building system comprises a tintable window. In some embodiments, the tintable window comprises an electrochromic window. In some embodiments, the apparatus comprises the wearable device; a control device communicatively coupled with the wearable device; or a computer server communicatively coupled with the wearable device, a control device, or both.

[0009] In another aspect, a non-transitory computer program product for sensor-based control of one or more aspects of an environment of a facility, which non-transitory computer program product contains instructions inscribed thereon that, when executed by one or more processors, cause the one or more processors to execute operations comprises: obtaining sensor data from one or more sensors of a wearable device worn by a user in the facility; determining, based on the sensor data, a physiological condition of the user; determining a location of the user within the facility based, at least in part, on: one or more radio frequency (RF) signals transmitted from the wearable device, and/or one or more RF signals received by the wearable device; and adjusting an environmental control of the location based, at least in part, on the physiological condition of the user.

[0010] In some embodiments, the one or more sensors comprise a sensor configured to measure a sugar level of the user, a heart rate of the user, a step count of the user, a blood pressure of the user, a blood oxygen level of the user, a temperature of the user, a pulse of the user, or a combination thereof. In some embodiments, the operations comprising obtaining the sensor data include operations comprising receiving the sensor data from the wearable device and/or from a control device communicatively coupled with the wearable device. In some embodiments, the control device comprises a controller of the facility, a mobile phone, laptop, or tablet. In some embodiments, adjusting the environmental control of the location is further based on a user preference. In some embodiments, the operations further comprises: determining an identity of the user based on an association of the user with the wearable device; and determining the user preference based on the identity of the user; wherein adjusting the environmental control of the location is further based on the user preference. In some embodiments, the user preference comprises a temperature setting, a window tint setting, a lighting setting, or a combination thereof. In some embodiments, the lighting setting comprises a brightness and/or color of light. In some embodiments, the operations comprising adjusting the environmental control of the location include operations comprising adjusting air flow to and/or from the location; a temperature of air flowing into the location; an oxygen level of the location; a carbon dioxide (CO_2) level of the location; an amount of lighting at the location; a color of lighting at the location; a window tint at the location; a temperature at the location; or a

combination thereof. In some embodiments, the operations comprising adjusting the environmental control of the location include operations comprising: determining a building system associated with the location; and causing the building system to adjust the environmental control. In some embodiments, the building system comprises a system controlling heating, ventilation, and air conditioning (HVAC) of the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a degree of window tint at the location; or a combination thereof. In some embodiments, the building system comprises a device ensemble having a housing that encloses one or more devices that comprise: (i) sensors, (ii) a transceiver, (iii) a sensor and an emitter, or (iv) a combination thereof. In some embodiments, the device ensemble is disposed in a fixture of the facility, or is attached to a fixture of the facility. In some embodiments, the building system comprises a tintable window. In some embodiments, the tintable window comprises an electrochromic window.

[0011] In another aspect, an apparatus for controlling a facility, the apparatus comprising at least one controller having circuitry, which at least one controller is configured to: (a) operatively couple to one or more sensors disposed in the facility, and to one or more devices disposed in the facility; (b) identify, or direct identification of, a user; (c) track, or direct tracking of, location of the user in the facility by using the one or more sensors; (d) receive an input related to the user; and (e) automatically control (e.g., alter), or direct automatic control (e.g., alteration) of, one or more devices in the facility by using the input and location information of the user.

[0012] In some embodiments, at least one controller is configured to utilize location of the user that is a present location of the user or a past location of the user. In some embodiments, the at least one controller is configured to identify, or direct identification of, the user at least in part by (I) receiving an identification card reading, or (II) performing image recognition on a captured image of the user in the facility. In some embodiments, the one or more sensors comprise a camera or a geolocation sensor. In some embodiments, the geolocation sensor comprises an ultrawide bandwidth sensor. In some embodiments, the geolocation sensor can locate the user with a resolution of at least twenty (20) centimeters or higher. In some embodiments, the input related to the user comprises a service request made by, on behalf of, or for, the user. In some embodiments, the input related to the user relates to activity of the user in an enclosure of the facility in which the user is located. In some embodiments, the input related to the user comprises an electronic file. In some embodiments, the input related to the user comprises a gesture and/or voice command made by the user. In some embodiments, the input related to the user relates to preference of the user. In some embodiments, the preference of the user is provided by a machine learning module that considers past activities of the user, wherein the at least one controller is operatively coupled to the machine learning module. In some embodiments, the preference of the user is input by the user. In some embodiments, the one or more devices comprises a lighting, a ventilation system, and air conditioning system, a heating

system, a sound system, or a smell conditioning system. In some embodiments, the one or more devices is configured to affect an atmosphere of an enclosure of the facility in which the user is disposed. In some embodiments, the one or more devices comprises a service, office, or factory apparatus, or a combination thereof. In some embodiments, the one or more devices are disposed out of an enclosure of the facility in which the user is located. In some embodiments, the one or more devices are disposed in an enclosure of the facility in which the user is located. In some embodiments, the one or more devices comprise a media projecting device. In some embodiments, the one or more devices comprise a tintable window. In some embodiments, the one or more devices comprise an electrochromic window. A non-transitory computer readable medium for controlling a facility, the non-transitory computer readable medium, when read by one or more processors, is configured to execute operations comprising operations of any of the above one or more controllers.

[0013] In another aspect, the present disclosure provides systems, apparatuses (e.g., controllers), non-transitory computer-readable medium (e.g., software), or a combination thereof, that implement any of the methods disclosed herein.

[0014] In another aspect, the present disclosure provides methods that use any of the systems and/or apparatuses disclosed herein, e.g., for their intended purpose.

[0015] In another aspect, an apparatus comprises at least one controller that is programmed to direct a mechanism used to implement (e.g., effectuate) any of the method disclosed herein, wherein the at least one controller is operatively coupled to the mechanism.

[0016] In another aspect, an apparatus comprises at least one controller that is configured (e.g., programmed) to implement (e.g., effectuate) the method disclosed herein. The at least one controller may implement any of the methods disclosed herein.

[0017] In another aspect, a system comprises at least one controller that is programmed to direct operation of at least one another apparatus (or component thereof), and the apparatus (or component thereof), wherein the at least one controller is operatively coupled to the apparatus (or to the component thereof). The apparatus (or component thereof) may include any apparatus (or component thereof) disclosed herein. The at least one controller may direct any apparatus (or component thereof) disclosed herein.

[0018] In another aspect, a computer software product, comprising a non-transitory computer-readable medium in which program instructions are stored, which instructions, when read by a computer, cause the computer to direct a mechanism disclosed herein to implement (e.g., effectuate) any of the method disclosed herein, wherein the non-transitory computer-readable medium is operatively coupled to the mechanism. The mechanism can comprise any apparatus (or any component thereof) disclosed herein.

[0019] In another aspect, the present disclosure provides a non-transitory computer-readable medium comprising machine-executable code that, upon execution by one or more computer processors, implements any of the methods disclosed herein.

[0020] In another aspect, the present disclosure provides a non-transitory computer-readable medium comprising machine-executable code that, upon execution by one or more computer processors, effectuates directions of the controller(s) (e.g., as disclosed herein).

[0021] In another aspect, the present disclosure provides a computer system comprising one or more computer processors and a non-transitory computer-readable medium coupled thereto. The non-transitory computer-readable medium comprises machine-executable code that, upon execution by the one or more computer processors, implements any of the methods disclosed herein and/or effectuates directions of the controller(s) disclosed herein.

[0022] The content of this summary section is provided as a simplified introduction to the disclosure and is not intended to be used to limit the scope of any invention disclosed herein or the scope of the appended claims.

[0023] Additional aspects and advantages of the present disclosure will become readily apparent to those skilled in this art from the following detailed description, wherein only illustrative embodiments of the present disclosure are shown and described. As will be realized, the present disclosure is capable of other and different embodiments, and its several details are capable of modifications in various obvious respects, all without departing from the disclosure. Accordingly, the drawings and description are to be regarded as illustrative in nature, and not as restrictive.

[0024] These and other features and embodiments will be described in more detail with reference to the drawings.

INCORPORATION BY REFERENCE

[0025] All publications, patents, and patent applications mentioned in this specification are herein incorporated by reference to the same extent as if each individual publication, patent, or patent application was specifically and individually indicated to be incorporated by reference.

BRIEF DESCRIPTION OF THE DRAWINGS

[0026] The novel features of the invention are set forth with particularity in the appended claims. A better understanding of the features and advantages of the present invention will be obtained by reference to the following detailed description that sets forth illustrative embodiments, in which the principles of the invention are utilized, and the accompanying drawings or figures (also “Fig.” and “Figs.” herein), of which:

[0027] Fig. 1 shows a perspective view of an enclosure (e.g., a building) and a control system;

[0028] Fig. 2 schematically depicts a computer system;

[0029] Fig. 3 shows a block diagram of an example master controller (MC);

[0030] Fig. 4 shows a block diagram of an example network controller (NC);

[0031] Fig. 5 illustrates an example NC including a plurality of modules;

[0032] Fig. 6 shows an apparatus including a sensor ensemble and its components and connectivity options;

[0033] Fig. 7 is a diagram illustrating wristbands as example wearable/sensing devices;

[0034] Fig. 8 is a diagram illustrating example electronic components of a sensing device, according to an embodiment;

[0035] Fig. 9 is a block diagram illustrating an example building control system;

[0036] Fig. 10 is a block diagram illustrating another example building control system, with some physical context;

[0037] Fig. 11 is an illustration of example screenshots of a patient interface and a doctor/nurse interface of an application;

[0038] Fig. 12 is an illustration of different types of user groups that an application may accommodate, according to an example;

[0039] Fig. 13 is a flow diagram of an example method of automatically controlling building systems with data from a wearable device, according to an embodiment;

[0040] Fig. 14 shows a flowchart of an example method for sensor-based control of one or more aspects of an environment of a facility, according to an embodiment;

[0041] Fig. 15A shows a user interacting with a wall device, and Fig. 15B shows a configuration of components that may be used to implement certain control methods described herein;

[0042] Figs. 16A-16C show various configurations of components that may be used to implement certain control methods described herein;

[0043] Figs. 17A and 17B show various windows and display constructs;

[0044] Fig. 18 schematically shows a display construct assembly;

[0045] Fig. 19 depicts an enclosure communicatively coupled to its digital twin representation;

[0046] Fig. 20 shows an example of a building with device ensembles;

[0047] Fig. 21 illustrates a flow chart for a control method;

[0048] Fig. 22 shows an example of a schematic cross-section of an electrochromic device;

[0049] Fig. 23 shows an example implementation of an insulated glass unit (IGU); and

[0050] Fig. 24 illustrates a voltage profile as a function of time.

[0051] The figures and components therein may not be drawn to scale. Various components of the figures described herein may not be drawn to scale.

DETAILED DESCRIPTION

[0052] While various embodiments of the invention have been shown, and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. Numerous variations, changes, and substitutions may occur to those skilled in the art without departing from the invention. It should be understood that various alternatives to the embodiments of the invention described herein might be employed.

[0053] Terms such as “a,” “an,” and “the” are not intended to refer to only a singular entity but include the general class of which a specific example may be used for illustration. The terminology herein is used to describe specific embodiments of the invention(s), but their usage does not delimit the invention(s).

[0054] When ranges are mentioned, the ranges are meant to be inclusive, unless otherwise

specified. For example, a range between value 1 and value 2 is meant to be inclusive and include value 1 and value 2. The inclusive range will span any value from about value 1 to about value 2. The term "adjacent" or "adjacent to," as used herein, includes "next to," "adjoining," "in contact with," and "in proximity to."

[0055] The term "operatively coupled" or "operatively connected" refers to a first element (e.g., mechanism) that is coupled (e.g., connected) to a second element, to allow the intended operation of the second and/or first element. The coupling may comprise physical or non-physical coupling. The non-physical coupling may comprise signal-induced coupling (e.g., wireless coupling). Coupled can include physical coupling (e.g., physically connected), or non-physical coupling (e.g., via wireless communication). Additionally, in the following description, the phrases "operable to," "adapted to," "configured to," "designed to," "programmed to," or "capable of" may be used interchangeably where appropriate.

[0056] An element (e.g., mechanism) that is "configured to" perform a function includes a structural feature that causes the element to perform this function. A structural feature may include an electrical feature, such as a circuitry or a circuit element. A structural feature may include a circuitry (e.g., comprising electrical or optical circuitry). Electrical circuitry may comprise one or more wires. Optical circuitry may comprise at least one optical element (e.g., beam splitter, mirror, lens, optical fiber, or a combination thereof). A structural feature may include a mechanical feature. A mechanical feature may comprise a latch, a spring, a closure, a hinge, a chassis, a support, a fastener, or a cantilever, and so forth. Performing the function may comprise utilizing a logical feature. A logical feature may include programming instructions. Programming instructions may be executable by at least one processor. Programming instructions may be stored or encoded on a medium accessible by one or more processors.

[0057] The following detailed description is directed to specific example implementations for purposes of disclosing the subject matter. Although the disclosed implementations are described in sufficient detail to enable those of ordinary skill in the art to practice the disclosed subject matter, this disclosure is not limited to particular features of the specific example implementations described herein. On the contrary, the concepts and teachings disclosed herein can be implemented and applied in a multitude of different forms and ways without departing from their spirit and scope. For example, while the disclosed implementations focus on electrochromic windows (also referred to as smart windows), some of the systems, devices and methods disclosed herein can be made, applied or used without undue experimentation to incorporate, or while incorporating, other types of optically switchable devices that are actively switched/controlled, rather than passive coatings such as thermochromic coatings or photochromic coatings that tint passively in response to the sun's rays. Some other types of actively controlled optically switchable devices include liquid crystal devices, suspended particle devices, and micro-blinds, among others. For example, some or all of such other optically switchable devices can be powered, driven or otherwise controlled or integrated with one or

more of the disclosed implementations of controllers described herein.

[0058] In some embodiments, an enclosure comprises an area defined by at least one structure (e.g., fixture). The at least one structure may comprise at least one wall. An enclosure may comprise and/or enclose one or more sub-enclosures. The at least one wall may comprise metal (e.g., steel), clay, stone, plastic, glass, plaster (e.g., gypsum), polymer (e.g., polyurethane, styrene, or vinyl), asbestos, fiber-glass, concrete (e.g., reinforced concrete), wood, paper, or a ceramic. The at least one wall may comprise wire, bricks, blocks (e.g., cinder blocks), tile, drywall, or frame (e.g., steel frame and/or wooden frame).

[0059] In some embodiments, the enclosure comprises one or more openings. The one or more openings may be reversibly closable. The one or more openings may be permanently open. A fundamental length scale of the one or more openings may be smaller relative to the fundamental length scale of the wall(s) that define the enclosure. A fundamental length scale may comprise a diameter of a bounding circle, a length, a width, or a height. The fundamental length scale may be abbreviated herein as "FLS." A surface of the one or more openings may be smaller relative to the surface the wall(s) that define the enclosure. The opening surface may be a percentage of the total surface of the wall(s). For example, the opening surface can measure about 30%, 20%, 10%, 5%, or 1% of the walls(s). The wall(s) may comprise a floor, a ceiling or a side wall. The closable opening may be closed by at least one window or door. The enclosure may be at least a portion of a facility. The facility may comprise a building. The enclosure may comprise at least a portion of a building. The building may be a private building and/or a commercial building. The building may comprise one or more floors. The building (e.g., floor thereof) may include at least one of: a room, hall, foyer, attic, basement, balcony (e.g., inner or outer balcony), stairwell, corridor, elevator shaft, façade, mezzanine, penthouse, garage, porch (e.g., enclosed porch), terrace (e.g., enclosed terrace), cafeteria, duct, or a combination thereof. In some embodiments, an enclosure may be stationary and/or movable (e.g., a train, a plane, a ship, a vehicle, or a rocket). As used herein, the term "environment" may refer to a volume of space (or area/space/feature associated with a volume of space) in or near a building or facility in which a person may be located. This may include an enclosure or, more broadly, a room, plenum, area, region, space bounded by a wall, floor ceiling, etc. of the building or facility.

[0060] In some embodiments, the enclosure encloses an atmosphere. The atmosphere may comprise one or more gases. The gases may include inert gases (e.g., argon or nitrogen) and/or non-inert gases (e.g., oxygen or carbon dioxide). The enclosure atmosphere may resemble an atmosphere external to the enclosure (e.g., ambient atmosphere) in at least one external atmosphere characteristic that includes: temperature, relative gas content, gas type (e.g., humidity, and/or oxygen level), debris (e.g., dust and/or pollen), gas velocity, or a combination thereof. The enclosure atmosphere may be different from the atmosphere external to the enclosure in at least one external atmosphere characteristic that includes: temperature,

relative gas content, gas type (e.g., humidity, and/or oxygen level), debris (e.g., dust and/or pollen), gas velocity, or a combination thereof. For example, the enclosure atmosphere may be less humid (e.g., drier) than the external (e.g., ambient) atmosphere. For example, the enclosure atmosphere may contain the same (e.g., or a substantially similar) oxygen-to-nitrogen ratio as the atmosphere external to the enclosure. The velocity and/or content of the gas in the enclosure may be (e.g., substantially) similar throughout the enclosure. The velocity and/or content of the gas in the enclosure may be different in different portions of the enclosure (e.g., by flowing gas through to a vent that is coupled with the enclosure). The gas content may comprise relative gas ratio.

[0061] In some embodiments, a network infrastructure is provided in the enclosure (e.g., a facility such as a building). The network infrastructure is available for various purposes such as for providing communication and/or power services. The communication services may comprise high bandwidth (e.g., wireless and/or wired) communications services. The communication services can be to occupants of a facility and/or users outside the facility (e.g., building). The network infrastructure may work in concert with, or as a partial replacement of, the infrastructure of one or more cellular carriers. The network may comprise one or more levels of encryption. The network may be communicatively coupled to the cloud and/or to one or more servers external to the facility. The network may support at least a fourth generation wireless (4G), or a fifth-generation wireless (5G) communication. The network may support cellular signals external and/or internal to the facility. The downlink communication network speeds may have a peak data rate of at least about 5 Gigabits per second (Gb/s), 10 Gb/s, or 20 Gb/s. The uplink communication network speeds may have a peak data rate of at least about 2Gb/s, 5Gb/s, or 10 Gb/s. The network infrastructure can be provided in a facility that includes electrically switchable windows. Examples of components of the network infrastructure include a high speed backhaul. The network infrastructure may include at least one cable, switch, (e.g., physical) antenna, transceivers, sensor, transmitter, receiver, radio, processor and/or controller (that may comprise a processor). The network infrastructure may be operatively coupled to, and/or include, a wireless network. The network infrastructure may comprise wiring (e.g., comprising an optical fiber, twisted cable, or coaxial cable). One or more devices (e.g., sensors and/or emitters) can be deployed (e.g., installed) in an environment, e.g., as part of installing the network infrastructure and/or after installing the network infrastructure. The device(s) may be communicatively coupled to the network. The network may comprise a power and/or communication network. The device can be self-discovered on the network, e.g., once it couples (e.g., on its attempt to couple) to the network. The network structure may comprise peer to peer network structure, or client-server network structure. The network may or may not have a central coordination entity (e.g., server(s) or another stable host).

[0062] In some embodiments, a building management system (BMS) is a computer-based control system. The BMS can be installed in a facility to monitor and otherwise control (e.g.,

regulate, manipulate, restrict, direct, monitor, adjust, modulate, vary, alter, restrain, check, guide, or manage) the facility. For example, the BMS may control one or more devices communicatively coupled to the network. The one or more devices may include mechanical and/or electrical equipment such as ventilation, lighting, power systems, elevators, fire systems, security systems, or a combination thereof. Controllers (e.g., nodes and/or processors) may be suited for integration with a BMS. A BMS may include hardware. The hardware may include interconnections by communication channels to one or more processors (e.g., and associated software), e.g., for maintaining one or more conditions in the facility. The one or more conditions in the facility may be according to preference(s) set by a user (e.g., an occupant, a facility owner, a facility manager, or a combination thereof). For example, a BMS may be implemented using a local area network, such as Ethernet. The software can utilize, e.g., internet protocols and/or open standards. One example is software from Tridium, Inc. (of Richmond, Va.). One communication protocol that can be used with a BMS is BACnet (building automation and control networks). A node can be any addressable circuitry. For example, a node can be a circuitry that has an Internet Protocol (IP) address.

[0063] In some embodiments, a BMS may be implemented in a facility, e.g., a multi-story building. The BMS may function (e.g., also) to control one or more characteristics of an environment of the facility. The one or more characteristics may comprise: temperature, carbon dioxide levels, gas flow, various volatile organic compounds (VOCs), humidity in a building, or a combination thereof. There may be mechanical devices that are controlled by a BMS such as one or more heaters, air conditioners, blowers, vents, or a combination thereof. To control one or more aspects of the facility environment, a BMS may turn these various devices on and/or off under defined conditions. A core function of a BMS may be to maintain a comfortable environment for occupants of the environment, e.g., while minimizing heating and cooling costs and/or demand. A BMS can be used to control one or more of the various systems. A BMS may be used to optimize the synergy between various systems. For example, the BMS may be used to conserve energy and lower building operation costs.

[0064] In some embodiments, the facility comprises a multi-story building. The multi-story building may have at least 2, 8, 10, 25, 50, 80, 100, 120, 140, or 160 floors, e.g., that are controlled by the control system and/or comprise the network infrastructure. The number of floors controlled by the control system and/or comprising the network infrastructure may be any number between the aforementioned numbers (e.g., from 2 to 50, from 25 to 100, or from 80 to 160). The floor may be of an area of at least about 150 m^2, 250 m^2, 500m^2, 1000 m^2, 1500 m^2, or 2000 square meters (m^2). The floor may have an area between any of the aforementioned floor area values (e.g., from about 150 m^2 to about 2000 m^2, from about 150 m^2 to about 500 m^2 from about 250 m^2 to about 1000 m^2, or from about 1000 m^2 to about 2000 m^2).

[0065] In some embodiments, a window controller is integrated with a BMS. For example, the window controller can be configured to control one or more tintable windows (e.g.,

electrochromic windows). In one embodiment, the one or more electrochromic windows include at least one all solid state and inorganic electrochromic device, but may include more than one electrochromic device, e.g. where each lite or pane of an IGU is tintable. In one embodiment, the one or more electrochromic windows include only all solid state and inorganic electrochromic devices. In one embodiment, the electrochromic windows are multistate electrochromic windows. Examples of tintable windows can be found in, in U.S. patent application Ser. No. 12/851,514, filed on August 5, 2010, and titled "Multipane Electrochromic Windows," which is incorporated herein by reference in its entirety.

[0066] In some embodiments, one or more devices such as sensors, emitters, actuators, or a combination thereof, are operatively coupled to at least one controller and/or processor. Sensor readings may be obtained by one or more processors and/or controllers. A controller may comprise a processing unit (e.g., CPU or GPU). A controller may receive an input (e.g., from at least one device or projected media). The controller may comprise circuitry, electrical wiring, optical wiring, socket, outlet, or a combination thereof. A controller may receive an input and/or deliver an output. A controller may comprise multiple (e.g., sub-) controllers. An operation (e.g., as disclosed herein) may be performed by a single controller or by a plurality of controllers. At least two operations may be each preconformed by a different controller. At least two operations may be preconformed by the same controller. A device and/or media may be controlled by a single controller or by a plurality of controllers. At least two devices and/or media may be controlled by a different controller. At least two devices and/or media may be controlled by the same controller. The controller may be a part of a control system. The control system may comprise a master controller (MC), floor (e.g., comprising NC) controller, or a local controller. The local controller may be a target controller. For example, the local controller may be a window controller (e.g., controlling an optically switchable window), enclosure controller, or component controller. The controller may be a part of a hierarchal control system. They hierarchal control system may comprise a main controller that directs one or more controllers, e.g., floor controllers, local controllers (e.g., window controllers), enclosure controllers, component controllers, or a combination thereof. The target may comprise a device or a media. The device may comprise an electrochromic window, a sensor, an emitter, an antenna, a receiver, a transceiver, or an actuator.

[0067] In some embodiments, the network infrastructure is operatively coupled to one or more controllers. In some embodiments, a physical location of the controller type in the hierarchal control system changes. A controller may control one or more devices (e.g., be directly coupled to the devices). A controller may be disposed proximal to the one or more devices it is controlling. For example, a controller may control an optically switchable device (e.g., IGU), an antenna, a sensor, an output device (e.g., a light source, sounds source, smell source, gas source, HVAC outlet, or heater), or a combination thereof. In one embodiment, a floor controller may direct one or more window controllers, one or more enclosure controllers, one or more

component controllers, or any combination thereof. The floor controller may comprise a floor controller. For example, the floor (e.g., comprising network) controller may control a plurality of local (e.g., comprising window) controllers. A plurality of local controllers may be disposed in a portion of a facility (e.g., in a portion of a building). The portion of the facility may be a floor of a facility. For example, a floor controller may be assigned to a floor. In some embodiments, a floor may comprise a plurality of floor controllers, e.g., depending on the floor size and/or the number of local controllers coupled to the floor controller. For example, a floor controller may be assigned to a portion of a floor. For example, a floor controller may be assigned to a portion of the local controllers disposed in the facility. For example, a floor controller may be assigned to a portion of the floors of a facility. An MC may be coupled to one or more floor controllers. The floor controller may be disposed in the facility. The MC may be disposed in the facility, or external to the facility. The MC may be disposed in the cloud. A controller may be a part of, or be operatively coupled to, a building management system. A controller may receive one or more inputs. A controller may generate one or more outputs. The controller may be a single input single output controller (SISO) or a multiple input multiple output controller (MIMO). A controller may interpret an input signal received. A controller may acquire data from the one or more components (e.g., sensors). Acquire may comprise receive or extract. The data may comprise measurement, estimation, determination, generation, or any combination thereof. A controller may comprise feedback control. A controller may comprise feed-forward control. Control may comprise on-off control, proportional control, proportional-integral (PI) control, or proportional-integral-derivative (PID) control. Control may comprise open loop control, or closed loop control. A controller may comprise closed loop control. A controller may comprise open loop control. A controller may comprise a user interface. A user interface may comprise (or operatively coupled to) a keyboard, keypad, mouse, touch screen, microphone, speech recognition package, camera, imaging system, or any combination thereof. Outputs may include a display (e.g., screen), speaker, or printer. In some embodiments, a local controller controls one or more devices and/or media (e.g., media projection). For example, a local controller can control one or more IGUs, one or more sensors, one or more output devices (e.g., one or more emitters), one or more media, or any combination thereof.

[0068] In some embodiments, a BMS includes a multipurpose controller. By incorporating feedback (e.g., of the controller), a BMS can provide, for example, enhanced: 1) environmental control, 2) energy savings, 3) security, 4) flexibility in control options, 5) improved reliability and usable life of other systems (e.g., due to decreased reliance thereon and/or reduced maintenance thereof), 6) information availability and/or diagnostics, 7) higher productivity from personnel in the building (e.g., staff), and various combinations thereof. These enhancements may derive automatically controlling any of the devices. In some embodiments, a BMS may not be present. In some embodiments, a BMS may be present without communicating with a master network controller. In some embodiments, a BMS may communicate with a portion of the levels

in the hierarchy of controllers. For example, the BMS may communicate (e.g., at a high level) with a master network controller. In some embodiments, a BMS may not communicate with a portion of the levels in the hierarchy of controllers of the control system. For example, the BMS may not communicate with the local controller and/or intermediate controller. In certain embodiments, maintenance on the BMS would not interrupt control of the devices communicatively coupled to the control system. In some embodiments, the BMS comprises at least one controller that may or may not be part of the hierarchical control system.

[0069] Fig. 1 shows an example of a control system architecture 100 disposed at least partly in an enclosure (e.g., building) 150. Control system architecture 100 comprises a MC 108 that controls floor controllers 106, that in turn control local controllers 104. In the example shown in Fig. 1, a MC 108 is operatively coupled (e.g., wirelessly and/or wired) to a building management system (BMS) 124 and to a database 120. Arrows in FIG. 1 represents communication pathways. A controller may be operatively coupled (e.g., directly/indirectly and/or wired and/wirelessly) to an external source 110. MC 108 may control floor controllers that include NCs 106, that may in turn control local controllers such as window controllers 104. Floor controllers 106 may also include at least one network controller (NC). In some embodiments, the local controllers (e.g., 106) control one or more targets such as IGUs 102, one or more sensors, one or more output devices (e.g., one or more emitters), media, or any combination thereof. The external source may comprise a network. The external source may comprise one or more sensor or output device. The external source may comprise a cloud-based application and/or database. The communication may be wired and/or wireless. The external source may be disposed external to the facility. For example, the external source may comprise one or more sensors and/or antennas disposed, e.g., on a wall or on a ceiling of the facility. The communication may be monodirectional or bidirectional. In the example shown in Fig. 1, the communication all communication arrows are meant to be bidirectional (e.g., 118, 122, 114, and 112).

[0070] The methods, systems and/or the apparatus described herein may comprise a control system. The control system can be in communication with any of the apparatuses (e.g., sensors) described herein. The sensors may be of the same type or of different types, e.g., as described herein. For example, the control system may be in communication with the first sensor and/or with the second sensor. A plurality of devices (e.g., sensors and/or emitters) may be disposed in a container and may constitute an ensemble (e.g., a digital architectural element). The ensemble may comprise at least two devices of the same type. The ensemble may comprise at least two devices of a different type. The devices in the ensemble may be operatively coupled to the same electrical board. The electrical board may comprise circuitry. The electrical board may comprise, or be operatively coupled to a controller (e.g., a local controller). The control system may control the one or more devices (e.g., sensors). The control system may control one or more components of a building management system (e.g.,

lightening, security, air conditioning system, or a combination thereof). The controller may regulate at least one (e.g., environmental) characteristic (or aspect) of the enclosure. The control system may regulate the enclosure environment using any component of the building management system. For example, the control system may regulate the energy supplied by a heating element and/or by a cooling element. For example, the control system may regulate velocity of an air flowing through a vent to and/or from the enclosure. The control system may comprise a processor. The processor may be a processing unit. The controller may comprise a processing unit. The processing unit may be central. The processing unit may comprise a central processing unit (CPU). The processing unit may be a graphic processing unit (GPU). The controller(s) or control mechanisms (e.g., comprising a computer system) may be programmed to implement one or more methods of the disclosure. The processor may be programmed to implement methods of the disclosure. The controller may control at least one component of the forming systems and/or apparatuses disclosed herein. Examples of a digital architectural element can be found in PCT patent application serial number PCT/US20/70123 that is incorporated herein by reference in its entirety.

[0071] Fig. 2 shows a schematic example of a computer system 200 that is programmed or otherwise configured to one or more operations of any of the methods provided herein. The computer system can control (e.g., direct, monitor, regulate, or a combination thereof) various features of the methods, apparatuses and systems of the present disclosure, such as, for example, control heating, cooling, lightening, venting of an enclosure, or any combination thereof. The computer system can be part of, or be in communication with, any sensor or sensor ensemble disclosed herein. The computer may be coupled to one or more mechanisms disclosed herein, and/or any parts thereof. For example, the computer may be coupled to one or more sensors, valves, switches, lights, windows (e.g., IGUs), motors, pumps, optical components, or any combination thereof.

[0072] The computer system can include a processing unit (e.g., 206) (also “processor,” “computer” and “computer processor” used herein). The computer system may include memory or memory location (e.g., 202) (e.g., random-access memory, read-only memory, flash memory), electronic storage unit (e.g., 204) (e.g., hard disk), communication interface (e.g., 203) (e.g., network adapter) for communicating with one or more other systems, and peripheral devices (e.g., 205), such as cache, other memory, data storage, electronic display adapters, or a combination thereof. In the example shown in Fig. 2, the memory 202, storage unit 204, interface 203, and peripheral devices 205 are in communication with the processing unit 206 through a communication bus (solid lines), such as a motherboard. The storage unit can be a data storage unit (or data repository) for storing data. The computer system can be operatively coupled to a computer network (“network”) (e.g., 201) with the aid of the communication interface. The network can be the Internet, an internet extranet, or a combination thereof, or an intranet and/or extranet that is in communication with the Internet. In some cases, the network is

a telecommunication and/or data network. The network can include one or more computer servers, which can enable distributed computing, such as cloud computing. The network, in some cases with the aid of the computer system, can implement a peer-to-peer network, which may enable devices coupled to the computer system to behave as a client or a server.

[0073] The processing unit can execute a sequence of machine-readable instructions, which can be embodied in a program or software. The instructions may be stored in a memory location, such as the memory 202. The instructions can be directed to the processing unit, which can subsequently program or otherwise configure the processing unit to implement methods of the present disclosure. Examples of operations performed by the processing unit can include fetch, decode, execute, and write back. The processing unit may interpret and/or execute instructions. The processor may include a microprocessor, a data processor, a central processing unit (CPU), a graphical processing unit (GPU), a system-on-chip (SOC), a co-processor, a network processor, an application specific integrated circuit (ASIC), an application specific instruction-set processor (ASIPs), a controller, a programmable logic device (PLD), a chipset, a field programmable gate array (FPGA), or any combination thereof. The processing unit can be part of a circuit, such as an integrated circuit. One or more other components of the system 200 can be included in the circuit.

[0074] The storage unit can store files, such as drivers, libraries and saved programs. The storage unit can store user data (e.g., user preferences and user programs). In some cases, the computer system can include one or more additional data storage units that are external to the computer system, such as located on a remote server that is in communication with the computer system through an intranet or the Internet.

[0075] The computer system can communicate with one or more remote computer systems through a network. For instance, the computer system can communicate with a remote computer system of a user (e.g., operator). Examples of remote computer systems include personal computers (e.g., portable PC), slate or tablet PC's (e.g., Apple® iPad, Samsung® Galaxy Tab), telephones, Smart phones (e.g., Apple® iPhone, Android-enabled device, Blackberry®), or personal digital assistants. A user (e.g., via a client application) can access the computer system via the network.

[0076] Methods as described herein can be implemented by way of machine (e.g., computer processor) executable code stored on an electronic storage location of the computer system, such as, for example, on the memory 202 or electronic storage unit 204. The machine executable or machine-readable code can be provided in the form of software. During use, the processing unit 206 can execute the code. In some cases, the code can be retrieved from the storage unit and stored on the memory for ready access by the processor. In some situations, the electronic storage unit can be precluded, and machine-executable instructions are stored on memory.

[0077] The code can be pre-compiled and configured for use with a machine have a processer

adapted to execute the code or can be compiled during runtime. The code can be supplied in a programming language that can be selected to enable the code to execute in a pre-compiled or as-compiled fashion. In some embodiments, the processor comprises a code. The code can be program instructions. The program instructions may cause the at least one processor (e.g., computer) to direct a feed forward and/or feedback control loop. In some embodiments, the program instructions cause the at least one processor to direct a closed loop and/or open loop control scheme. The control may be based at least in part on one or more sensor readings (e.g., sensor data). One controller may direct a plurality of operations. At least two operations may be directed by different controllers. In some embodiments, a different controller may direct at least two of operations (a), (b) and (c). In some embodiments, different controllers may direct at least two of operations (a), (b) and (c). In some embodiments, a non-transitory computer-readable medium cause each a different computer to direct at least two of operations (a), (b) and (c). In some embodiments, different non-transitory computer-readable mediums cause each a different computer to direct at least two of operations (a), (b) and (c). The controller and/or computer readable media may direct any of the apparatuses or components thereof disclosed herein. The controller and/or computer readable media may direct any operations of the methods disclosed herein. The controller may be operatively (communicatively) coupled to control logic (e.g., code embedded in a software) in which its operation(s) are embodied.

[0078] In some embodiments, optically switchable windows forms or occupies substantial portions of a building envelope. For example, the optically switchable windows can form substantial portions of the walls, facades and even roofs of a corporate office building, other commercial building or a residential building. A distributed network of controllers can be used to control the optically switchable windows. For example, a network system may be operable to control a plurality of IGUs. One primary function of the network system is controlling the optical states of electrochromic devices (ECDs) (or other optically switchable devices) within the IGUs. In some implementations, one or more windows can be multi-zoned windows, for example, where each window includes two or more independently controllable ECDs or zones. In some embodiments, the network system (e.g., MC 300 of Fig. 3) is operable to control the electrical characteristics of the power signals provided to the IGUs. For example, the network system can generate and communicate tinting instructions (also referred to herein as “tint commands”) which control voltages applied to the ECDs within the IGUs.

[0079] In some embodiments, another function of the network system is to acquire status information from the IGUs (hereinafter “information” is used interchangeably with “data”). For example, the status information for a given IGU can include an identification of, or information about, a current tint state of the ECD(s) within the IGU. The network system also can be operable to acquire data from various sensors, such as temperature sensors, photosensors (also referred to herein as light sensors), humidity sensors, air flow sensors, or occupancy sensors, whether integrated on or within the IGUs or located at various other positions in, on or

around the building.

[0080] The network system can include any suitable number of distributed controllers having various capabilities or functions. In some implementations, the functions and arrangements of the various controllers are defined hierarchically. For example, the network system can include a plurality of distributed window controllers (WCs), a plurality of NCs, and an MC. The NCs may be included in the floor controllers. In some implementations, the MC can communicate with and control tens or hundreds of NCs. In various implementations, the MC issues high level instructions to the NCs over one or more wired and/or wireless links. The instructions can include, for example, tint commands for causing transitions in the optical states of the IGUs controlled by the respective NCs. Each NC can, in turn, communicate with and control a number of WCs over one or more wired and/or wireless links. For example, each NC can control tens or hundreds of the WCs. Each WC can, in turn, communicate with, drive or otherwise control one or more respective IGUs over one or more wired and/or wireless links.

[0081] In some embodiments, the MC issues communications including tint commands, status request commands, data (for example, sensor data) request commands or other instructions. The MC may issue such communications periodically, at certain predefined times of day (which may change based at least in part on the day of week or year), or based at least in part on the detection of particular events, conditions or combinations of events or conditions (for example, as determined by acquired sensor data or based at least in part on the receipt of a request initiated by a user or by an application or a combination of such sensor data and such a request). In some embodiments, when the MC determines to cause a tint state change in a set of one or more IGUs, the MC generates or selects a tint value corresponding to the desired tint state. In some embodiments, the set of IGUs is associated with a first protocol identifier (ID) (for example, a BACnet ID). The MC then generates and transmits a communication—referred to herein as a “primary tint command”— including the tint value and the first protocol ID over the link via a first communication protocol (for example, a BACnet compatible protocol). The MC may address the primary tint command to the particular NC that controls the particular one or more WCs that, in turn, control the set of IGUs to be transitioned.

[0082] In some embodiments, the NC receives the primary tint command including the tint value and the first protocol ID and maps the first protocol ID to one or more second protocol IDs. Each of the second protocol IDs may identify a corresponding one of the WCs. The NC may subsequently transmit a secondary tint command including the tint value to each of the identified WCs over the link via a second communication protocol. For example, each of the WCs that receives the secondary tint command can then select a voltage or current profile from an internal memory based at least in part on the tint value to drive its respectively connected IGUs to a tint state consistent with the tint value. Each of the WCs may then generate and provide voltage or current signals over the link to its respectively connected IGUs to apply the voltage or current profile, for example.

[0083] In some embodiments, the various targets (e.g., IGUs) are (e.g., advantageously) grouped into zones of targets (e.g., of EC windows). At least one zone (e.g., each of which zones) can include a subset of the targets (e.g., IGUs). For example, at least one (e.g., each) zone of targets (e.g., IGUs) may be controlled by one or more respective floor controllers (e.g., NCs) and one or more respective local controllers (e.g., WCs) controlled by these floor controllers (e.g., NCs). In some examples, at least one (e.g., each) zone can be controlled by a single floor controller (e.g., NC) and two or more local controllers (e.g., WCs) controlled by the single floor controller (e.g., NC). For example, a zone can represent a logical grouping of the targets (e.g., IGUs). Each zone may correspond to a set of targets (e.g., IGUs) in a specific location or area of the building that are driven together based at least in part on their location. For example, a building may have four faces or sides (a North face, a South face, an East Face and a West Face) and ten floors. In such a didactic example, each zone may correspond to the set of electrochromic windows on a particular floor and on a particular one of the four faces. At least one (e.g., each) zone may correspond to a set of targets (e.g., IGUs) that share one or more physical characteristics (for example, device parameters such as size or age). In some embodiments, a zone of targets (e.g., IGUs) is grouped based at least in part on one or more non-physical characteristics such as, for example, a security designation or a business hierarchy (for example, IGUs bounding managers' offices can be grouped in one or more zones while IGUs bounding non-managers' offices can be grouped in one or more different zones).

[0084] In some embodiments, at least one (e.g., each) floor controller (e.g., NC) is able to address all of the targets (e.g., IGUs) in at least one (e.g., each) of one or more respective zones. For example, the MC can issue a primary tint command to the floor controller (e.g., NC) that controls a target zone. The primary tint command can include an (e.g., abstract) identification of the target zone (hereinafter also referred to as a "zone ID"). For example, the zone ID can be a first protocol ID such as that just described in the example above. In such cases, the floor controller (e.g., NC) receives the primary tint command including the tint value and the zone ID and maps the zone ID to the second protocol IDs associated with the local controllers (e.g., WCs) within the zone. In some embodiments, the zone ID is a higher level abstraction than the first protocol IDs. In such cases, the floor controller (e.g., NC) can first map the zone ID to one or more first protocol IDs, and subsequently map the first protocol IDs to the second protocol IDs.

[0085] In some embodiments, the MC is coupled to one or more outward-facing networks via one or more wired and/or wireless links. For example, the MC can communicate acquired status information or sensor data to remote computers, mobile devices, servers, databases in or accessible by the outward-facing network. In some embodiments, various applications, including third party applications or cloud-based applications, executing within such remote devices are able to access data from or provide data to the MC. In some embodiments, authorized users or applications communicate requests to modify the tint states of various IGUs to the MC via the

network. For example, the MC can first determine whether to grant the request (for example, based at least in part on power considerations or based at least in part on whether the user has the appropriate authorization) prior to issuing a tint command. The MC may then calculate, determine, select or otherwise generate a tint value and transmit the tint value in a primary tint command to cause the tint state transitions in the associated IGUs.

[0086] In some embodiments, a user submits such a request from a computing device, such as a desktop computer, laptop computer, tablet computer or mobile device (for example, a smartphone). The user's computing device may execute a client-side application that is capable of communicating with the MC, and in some examples, with a master controller application executing within the MC. In some embodiments, the client-side application may communicate with a separate application, in the same or a different physical device or system as the MC, which then communicates with the master controller application to affect the desired tint state modifications. For example, the master controller application or other separate application can be used to authenticate the user to authorize requests submitted by the user. The user may select a target to be manipulated (e.g., the IGUs to be tinted), and directly or indirectly inform the MC of the selections, e.g., by entering an enclosure ID (e.g., room number) via the client-side application.

[0087] In some embodiments, a mobile circuitry of a user (e.g., mobile electronic device or other computing device) can communicate, e.g., wirelessly with various local controllers (e.g., WCs). For example, a client-side application executing within a mobile circuitry of a user (e.g., mobile device) can transmit wireless communications including control signals related to a target to the local controller to control the target, which target is communicatively coupled to the local controller (e.g., via the network). For example, a user may initiate directing a tint state control signals to a WC to control the tint states of the respective IGUs connected to the WC. For example, the user can use the client-side application to control (e.g., maintain or modify) the tint states of the IGUs adjoining a room occupied by the user (or to be occupied by the user or others at a future time). For example, a user may initiate directing a sensor frequency change control signals to a local controller to control the data sampling rate of a sensor communicatively coupled to the local controller. For example, the user can use the client-side application to control (e.g., maintain or modify) the data sampling rate of the sensor adjoining a room occupied by the user (or to be occupied by the user or others at a future time). For example, a user may initiate directing a light intensity change control signals to a local controller to control the light of a lamp communicatively coupled to the local controller. For example, the user can use the client-side application to control (e.g., maintain or modify) the light intensity of the light adjoining a room occupied by the user (or to be occupied by the user or others at a future time). For example, a user may initiate directing a media projection change control signals to a local controller to control the media projected by a projector communicatively coupled to the local controller. For example, the user can use the client-side application to control (e.g., maintain or

modify) the media projected by a projector in a room occupied by the user (or to be occupied by the user or others at a future time). The wireless communications can be generated, formatted, transmitted, or a combination thereof, using various wireless network topologies and protocols, for example.

[0088] In some embodiments, the control signals sent to the local controller (e.g., WC) from a mobile circuitry (e.g., device) of a user (or other computing device) override a previously sent signal (e.g., a tint value previously received by the WC from the respective NC). The previously sent signal may be automatically generated, e.g., by the control system. In other words, the local controller (e.g., WC) may provide the applied voltages to the target (e.g., IGUs) based at least in part on the control signals from the mobile circuitry of the user (e.g., user's computing device), e.g., rather than based at least in part on the predetermined signal (e.g., the tint value). For example, a control algorithm or rule set stored in and executed by the local controller (e.g., WC) may dictate that one or more control signals from a mobile device of a user (e.g., an authorized user's computing device) that will take precedence over a respective signal received from the control system (e.g., a tint value received from the NC). In some embodiments, such as in high demand cases, control signals (such as a tint value from the NC) take precedence over any control signals received by the local controller (e.g., WC) from a mobile circuitry of a user (e.g., a user's computing device). A control algorithm or rule set may dictate that control signal (e.g., relating to tint) overrides from only certain users (or groups or classes of users) may take precedence based at least in part on permissions granted to such users. In some instances, other factors including time of day or the location of the target (e.g., IGUs) may influence the permission to override a predetermined signal of the control system.

[0089] In some embodiments, based at least in part on the receipt of a control signal from a mobile circuity of a user (e.g., an authorized user's computing device), the MC uses information about a combination of known parameters to calculate, determine, select and/or otherwise generate a command signal (e.g., relating to a tint value) that provides (e.g., lighting) conditions requested by a (e.g., typical) user, e.g., while in some instances also using power efficiently. For example, the MC may determine a state of a target based at least in part on preset preferences defined by or for the particular user that requested the target status change via the mobile circuitry (e.g., via the computing device). For example, the MC may determine the tint value based at least in part on preset preferences defined by or for the particular user that requested the tint state change via the computing device. For example, the user may be required to enter a password or otherwise login or obtain authorization to request a change in a state of a target (e.g., tint state change). The MC may determine the identity of the user based at least in part on a password, a security token, an identifier of the particular mobile circuitry (e.g., mobile device or other computing device), or a combination thereof. After determining the identity of the user, the MC may then retrieve preset preferences for the user, and use the preset preferences alone or in combination with other parameters (such as power considerations and/or information from

various sensors) to generate and transmit a status change of the target (e.g., tint value for use in tinting the respective IGUs).

[0090] In some embodiments, the network system includes wall switches, dimmers, or other (e.g., tint-state) controlling devices. A wall switch generally refers to an electromechanical interface connected to a local controller (e.g., WC). The wall switch can convey a target status change (e.g., tint) command to the local controller (e.g., WC), which can then convey the target status change (e.g., tint) command to an upper level controller such as a local controller (e.g., NC). Such control devices can be collectively referred to as "wall devices," although such devices need not be limited to wall-mounted implementations (for example, such devices also can be located on a ceiling or floor or integrated on or within a desk or a conference table). For example, some or all of the offices, conference rooms, or other rooms of the building can include such a wall device for use in controlling the state of a target (e.g., tint states of the adjoining IGUs, or light state of a light bulb). For example, the IGUs adjoining a particular room can be grouped into a zone. Each of the wall devices can be operated by an end user (for example, an occupant of the respective room) to control the state of grouped targets (e.g., to control tint state or other functions or parameters of the IGUs that adjoin the room). For example, at certain times of the day, the adjoining IGUs may be tinted to a dark state to reduce the amount of light energy entering the room from the outside (for example, to reduce AC cooling requirements). For example, at certain times of the day, the adjoining heaters may be turned on to a warmer temperature to facilitate occupant comfort. In some embodiments, when a user requests to use a room then the user can operate the wall device to communicate one or more control signals to cause a (e.g., tint state) transition from one state of a target to another state (e.g., from the dark state to a lighter tint state of an IGU).

[0091] In some embodiments, each wall device includes one or more switches, buttons, dimmers, dials, or other physical user interface controls enabling the user to select a particular tint state or to increase or decrease a current tinting level of the IGUs adjoining the room. The wall device may include a display having a touchscreen interface enabling the user to select a particular tint state (for example, by selecting a virtual button, selecting from a dropdown menu or by entering a tint level or tinting percentage) or to modify the tint state (for example, by selecting a "darken" virtual button, a "lighten" virtual button, or by turning a virtual dial or sliding a virtual bar). In some embodiments, the wall device includes a docking interface enabling a user to physically and communicatively dock a mobile circuitry (e.g., portable device such as a smartphone, multimedia device, remote controller, virtual reality device, tablet computer, or other portable computing device (for example, an IPHONE, IPOD or IPAD produced by Apple, Inc. of Cupertino, CA)). The mobile circuitry may be embedded in a vehicle (e.g., car, motorcycle, drone, airplane). The mobile circuitry may be embedded in a robot. A circuitry may be embedded in (e.g., be part of) a virtual assistant AI technology, speaker, (e.g., smart speaker such as Google Nest, or Amazon Echo Dot). Coupling of the mobile circuitry to the network may

be initiated by a user's presence in the enclosure, or by a user's coupling (e.g., weather remote or local) to the network. Coupling of the user to the network may be security (e.g., having one or more security layers, and/or require one or more security tokens (e.g., keys)). The presence of the user in the enclosure may be sensed (e.g., automatically) by using the sensor(s) that are coupled to the network. The minimum distance from the sensor at which the user is coupled to the network may be predetermined and/or adjusted. A user may override its coupling to the network. The user may be a manager, executive, owner, lessor, administrator of the network and/or facility. The user may be the user of the mobile circuitry. The ability to couple the mobile circuitry to the network may or may not be overridden by the user. The ability to alter the minimum coupling distance between the mobile circuitry and the network may or may not be overridden by the user. There may be a hierarchy of overriding permissions. The hierarchy may depend on the type of user and/or type of mobile circuitry. For example, a factory employee user may not be allowed to alter coupling of a production machinery to the network. For example, an employee may be allowed to alter the coupling distance of his/her company laptop computer to the network. For example, an employee may be permitted to allow or prevent coupling of her/his personal cellular phone and/or car to the network. For example, a visitor may be prevented from having the visitor's mobile circuitry connected to the network. The coupling to the network may be automatic and seamless (e.g., after the initial preference have been set). Seamless coupling may be without requiring input from the user.

[0092] In such an example, the user can control the tinting levels via input to the mobile circuitry (e.g., portable device), which is then received by the wall device through the docking interface and subsequently communicated to the control system (e.g., to the MC, NC, or WC). The mobile circuitry (e.g., portable device) may include an application for communicating with an API presented by the wall device.

[0093] In some embodiments, the wall device can transmit a request for a status change of a target (e.g., a tint state change) to the control system (e.g., to the MC). The control system (e.g., MC) might first determine whether to grant the request (for example, based at least in part on power considerations and/or based at least in part on whether the user has the appropriate authorizations or permissions). The control system (e.g., MC) could calculate, determine, select, and/or otherwise generate a status change (e.g., tint) value and transmit the status change (e.g., tint) value in a primary status change (e.g., tint) command to cause the target to change (e.g., cause the tint state transitions in the adjoining IGUs). For example, each wall device may be connected with the control system (e.g., the MC therein) via one or more wired links (for example, over communication lines such as CAN or Ethernet compliant lines and/or over power lines using power line communication techniques). For example, each wall device could be connected with the control system (e.g., the MC therein) via one or more wireless links. The wall device may be connected (via one or more wired and/or wireless connections) with an outward-facing network, which may communicate with the control system (e.g., the MC therein) via the

link.

[0094] In some embodiments, the control system identifies the target (e.g., target device) associated with the wall device based at least in part on previously programmed or discovered information associating the wall device with the target. For example, the MC identifies the IGUs associated with the wall device based at least in part on previously programmed or discovered information associating the wall device with the IGUs. A control algorithm or rule set can be stored in and executed by the control system (e.g., the MC therein) to dictate that one or more control signals from a wall device take precedence over a tint value previously generated by the control system (e.g., the MC therein), for example. In times of high demand (for example, high power demand), a control algorithm or rule set stored in and executed by the control system (e.g., the MC therein) may be used to dictate that the tint value previously generated by the control system (e.g., the MC therein) takes precedence over any control signals received from a wall device.

[0095] In some embodiments, based at least in part on the receipt of a request or control signal to change to a state of a target (e.g., tint-state-change request or control signal) from a wall device, the control system (e.g., the MC therein) uses information about a combination of known parameters to generate a state change (e.g., tint) value that provides lighting conditions desirable for a typical user. Accordingly, the control system (e.g., the MC therein) may use power more efficiently. In some embodiments, the control system (e.g., the MC therein) can generate the state change (e.g., tint) value based at least in part on preset preferences defined by or for the particular user that requested the (e.g., tint) state change of the target via the wall device. For example, the user may be required to enter a password into the wall device or to use a security token or security fob such as the IBUTTON or other 1-Wire device to gain access to the wall device. The control system (e.g., the MC therein) may then determine the identity of the user, based at least in part on the password, security token, security fob, or a combination thereof. The control system (e.g., the MC therein) may retrieve preset preferences for the user. The control system (e.g., the MC therein) may use the preset preferences alone or in combination with other parameters (such as power considerations or information from various sensors, historical data, user preference, or a combination thereof) to calculate, determine, select and/or otherwise generate a tint value for the respective IGUs.

[0096] In some embodiments, the wall device transmits a tint state change request to the appropriate control system (e.g., to the NC therein). A lower level of the control system (e.g., to the NC therein) may communicate the request, or a communication based at least in part on the request, to a higher level of the control system (e.g., to the MC). For example, each wall device can be connected with a corresponding NC via one or more wired links. In some embodiments, the wall device transmits a request to the appropriate NC, which then itself determines whether to override a primary tint command previously received from the MC or a primary or secondary tint command previously generated by the NC. As described below, the NC may generate tint

commands without first receiving a tint command from an MC. In some embodiments, the wall device communicates requests or control signals directly to the WC that controls the adjoining IGUs. For example, each wall device can be connected with a corresponding WC via one or more wired links such as those just described for the MC or via a wireless link.

[0097] In some embodiments, the NC or the MC determines whether the control signals from the wall device should take priority over a tint value previously generated by the NC or the MC. As described above, the wall device is able to communicate directly with the NC. However, in some examples, the wall device can communicate requests directly to the MC or directly to a WC, which then communicates the request to the NC. In some embodiments, the wall device is able to communicate requests to a customer-facing network (such as a network managed by the owners or operators of the building), which then passes the requests (or requests based therefrom) to the NC either directly or indirectly by way of the MC. For example, a control algorithm or rule set stored in and executed by the NC or the MC can dictate that one or more control signals from a wall device take precedence over a tint value previously generated by the NC or the MC. In some embodiments (e.g., such as in times of high demand), a control algorithm or rule set stored in and executed by the NC or the MC dictates that the tint value previously generated by the NC or the MC takes precedence over any control signals received from a wall device.

[0098] In some embodiments, based at least in part on the receipt of a tint-state-change request or control signal from a wall device, the NC can use information about a combination of known parameters to generate a tint value that provides lighting conditions desirable for a typical user. In some embodiments, the NC or the MC generates the tint value based at least in part on preset preferences defined by or for the particular user that requested the tint state change via the wall device. For example, the user may be required to enter a password into the wall device or to use a security token or security fob such as the IBUTTON or other 1-Wire device to gain access to the wall device. In this example, the NC can communicate with the MC to determine the identity of the user, or the MC can alone determine the identity of the user, based at least in part on the password, security token or security fob. The MC may then retrieve preset preferences for the user, and use the preset preferences alone or in combination with other parameters (such as power considerations or information from various sensors) to calculate, determine, select, or otherwise generate a tint value for the respective IGUs.

[0099] In some embodiments, the control system (e.g., the MC therein) is coupled to an external database (or “data store” or “data warehouse”). The database can be a local database coupled with the control system (e.g., the MC therein) via a wired hardware link, for example. In some embodiments, the database is a remote database or a cloud-based database accessible by the control system (e.g., the MC therein) via an internal private network or over the outward-facing network. Other computing devices, systems, or servers also can have access to read the data stored in the database, for example, over the outward-facing network. One or more control

applications or third party applications could also have access to read the data stored in the database via the outward-facing network. In some embodiments, the control system (e.g., the MC therein) stores in the database a record of all tint commands including the corresponding tint values issued by the control system (e.g., the MC therein). The control system (e.g., the MC therein) may also collect status and sensor data and store it in the database (which may constitute historical data). The local controllers (e.g., WCs) may collect the sensor data and/or status data from the enclosure and/or from other devices (e.g., IGUs) or media disposed in the enclosure, and communicate the sensor data and/or status data to the respective higher level controller (e.g., NCs) over the communication link. The data may move up the control chain, e.g., to the MC. For example, the controllers (e.g., NCs or the MC) may themselves be communicatively coupled (e.g., connected) to various sensors (such as light, temperature, or occupancy sensors) within the building, as well as (e.g., light and/or temperature) sensors positioned on, around, or otherwise external to the building (for example, on a roof of the building). In some embodiments, the control system (e.g., the NCs or the WCs) may also transmit status and/or sensor data (e.g., directly) to the database for storage.

[0100] In some embodiments, the network system is suited for integration with a smart thermostat service, alert service (for example, fire detection), security service, other appliance automation service, or a combination thereof. On example of a home automation service is NEST®, made by Nest Labs of Palo Alto, California, (NEST® is a registered trademark of Google, Inc. of Mountain View, California). As used herein, references to a BMS can in some implementations also encompass, or be replaced with, such other automation services.

[0101] In some embodiments, the e control system (e.g., the MC therein) and a separate automation service, such as a BMS, can communicate via an application programming interface (API). For example, the API can execute in conjunction with a (e.g., master) controller application (or platform) within the controller (e.g., MC), and/or in conjunction with a building management application (or platform) within the BMS. The controller (e.g., MC) and the BMS can communicate over one or more wired links and/or via the outward-facing network. For example, the BMS may communicate instructions for controlling the IGUs to the controller (e.g., MC), which then generate and transmit primary status (e.g., tint) commands of the target to the appropriate lower level controller(s) (e.g., to the NCs). The lower hierarchical level controllers (e.g., the NCs or the WCs) could communicate directly with the BMS (e.g., through a wired/hardware link and/or wirelessly through a wireless data link). In some embodiments, the BMS also receives data, such as sensor data, status data, and associated timestamp data, collected by one or more of the controllers in the control system (e.g., by the MC, the NCs, the WCs, or a combination thereof). For example, the controller (e.g., MC) can publish such data over the network. In some embodiments in which such data is stored in a database, the BMS can have access to some or all of the data stored in the database.

[0102] In some embodiments, the controller (e.g., “the MC”) collectively refers to any suitable

combination of hardware, firmware and software for implementing the functions, operations, processes, or capabilities described. For example, the MC can refer to a computer that implements a master controller application (also referred to herein as a “program” or a “task”). For example, the controller (e.g., MC) may include one or more processors. The processor(s) can be or can include a central processing unit (CPU), such as a single core or a multi-core processor. The processor can additionally include a digital signal processor (DSP) or a network processor in some examples. The processor could also include one or more application-specific integrated circuits (ASICs). The processor is coupled with a primary memory, a secondary memory, an inward-facing network interface, and an outward-facing network interface. The primary memory can include one or more high-speed memory devices such as, for example, one or more random-access memory (RAM) devices including dynamic-RAM (DRAM) devices. Such DRAM devices can include, for example, synchronous DRAM (SDRAM) devices and double data rate SDRAM (DDR SDRAM) devices (including DDR2 SDRAM, DDR3 SDRAM, and DDR4 SDRAM), thyristor RAM (T-RAM), and zero-capacitor (Z-RAM®), among other suitable memory devices.

[0103] In some embodiments, the secondary memory can include one or more hard disk drives (HDDs) or one or more solid-state drives (SSDs). In some embodiments, the memory can store processor-executable code (or “programming instructions”) for implementing a multi-tasking operating system such as, for example, an operating system based at least in part on a Linux® kernel. The operating system can be a UNIX®- or Unix-like-based operating system, a Microsoft Windows®-based operating system, or another suitable operating system. The memory may also store code executable by the processor to implement the master controller application described above, as well as code for implementing other applications or programs. The memory may also store status information, sensor data, or other data collected from NCs, window controllers and various sensors.

[0104] In some embodiments, the controller (e.g., MC) is a “headless” system; that is, a computer that does not include a display monitor or other user input device. For example, an administrator or other authorized user can log in to or otherwise access the controller (e.g., MC) from a remote computer or mobile computing device over a network to access and retrieve information stored in the controller (e.g., MC), to write or otherwise store data in the controller (e.g., MC), and/or to control various: functions, operations, processes parameters, or a combination thereof, implemented or used by the controller (e.g., MC). The controller (e.g., MC) can include a display monitor and a direct user input device (for example, a mouse, a keyboard, a touchscreen, or a combination thereof).

[0105] In some embodiments, the inward-facing network interface enables one controller (e.g., MC) of the control system to communicate with various distributed controllers and/or various targets (e.g., sensors). The inward-facing network interface can collectively refer to one or more wired network interfaces and/or one or more wireless network interfaces (including one or more

radio transceivers). For example, the inward-facing network interface can enable communication with downstream controllers (e.g., NCs) over the link. Downstream may refer to a lower level of control in the control hierarchy.

[0106] In some embodiments, the outward-facing network interface enables the controller (e.g., MC) to communicate with various computers, mobile circuitry (e.g., mobile devices), servers, databases, cloud-based database systems, or a combination thereof, over one or more networks. The outward-facing network interface can collectively refer to one or more wired network interfaces and/or one or more wireless network interfaces (including one or more radio transceivers). In some embodiments, the various applications, including third party applications and/or cloud-based applications, executing within such remote devices can access data from or provide data to the controller (e.g., MC) or to the database via the controller (e.g., MC). For example, the controller (e.g., MC) may include one or more application programming interfaces (APIs) for facilitating communication between the controller (e.g., MC) and various third party applications. Some examples of APIs that controller(s) (e.g., MC) can enable can be found in PCT Patent Application No. PCT/US15/64555 (Attorney Docket No. VIEWP073WO) filed December 8, 2015, and titled MULTIPLE INTERACTING SYSTEMS AT A SITE, which is incorporated herein by reference in its entirety. For example, third-party applications can include various monitoring services including thermostat services, alert services (e.g., fire detection), security services, other appliance automation services, or a combination thereof. Additional examples of monitoring services and systems can be found in PCT Patent Application No. PCT/US2015/019031 (Attorney Docket No. VIEWP061WO) filed March 5, 2015 and titled MONITORING SITES CONTAINING SWITCHABLE OPTICAL DEVICES AND CONTROLLERS, which is incorporated herein by reference in its entirety.

[0107] In some embodiments, one or both of the inward-facing network interface and the outward-facing network interface can include a Building Automation and Control network (BACnet) compatible interface. BACnet is a communications protocol typically used in building automation and control networks and defined by the ASHRAE/ANSI 135 and ISO 16484-5 standards. The BACnet protocol broadly provides mechanisms for computerized building automation systems and devices to exchange information, e.g., regardless of the particular services they perform. For example, BACnet can be used to enable communication among (i) heating, ventilating, and air-conditioning control (HVAC) systems, (ii) lighting control systems, (iii) access and/or security control systems, (iv) fire detection systems, or (v) any combination thereof, as well as their associated equipment. In some examples, one or both of the inward-facing network interface and the outward-facing network interface can include an oBIX (Open Building Information Exchange) compatible interface or another RESTful Web Services-based interface.

[0108] In some embodiments, the controller (e.g., MC) can calculate, determine, select and/or otherwise generate a preferred state for the target (e.g., a tint value for one or more IGUs)

based at least in part on a combination of parameters. For example, the combination of parameters can include time and/or calendar information such as the time of day, day of year or time of season. The combination of parameters may include solar calendar information such as, for example, the direction of the sun relative to the facility and/or target (e.g., IGUs). The direction of the sun relative to the facility and/or target (e.g., IGUs) may be determined by the controller (e.g., MC) based at least in part on time and/or calendar information, e.g., together with information known about the geographical location of the facility (e.g., building) on Earth and the direction that the target (e.g., IGUs) faces (e.g., in a North-East-Down coordinate system). The combination of parameters also can include exterior and/or interior environmental conditions. For example, the outside temperature (external to the building), the inside temperature (within a room adjoining the target IGUs), or the temperature within the interior volume of the IGUs. The combination of parameters may include information about the weather (for example, whether it is clear, sunny, overcast, cloudy, raining or snowing). Parameters such as the time of day, day of year, direction of the sun, or a combination thereof can be programmed into and tracked by the control system (e.g., the MC therein). Parameters (such as the outside temperature, inside temperature, IGU temperature, or a combination thereof) can be obtained from sensors in, on or around the building or sensors integrated with the target (e.g., on or within the IGUs). At times the target can comprise a sensor. Examples of algorithms, routines, modules, or other means for generating IGU tint values are described in U.S. Patent Application No. 13/772,969, filed February 21, 2013 and titled CONTROL METHOD FOR TINTABLE WINDOWS, and in PCT Patent Application No. PCT/US15/029675, filed May 7, 2015 and titled CONTROL METHOD FOR TINTABLE WINDOWS, each of which is hereby incorporated by reference in its entirety.

[0109] In some embodiments, at least one (e.g., each) device (e.g., ECD) within each IGU is capable of being tinted, e.g., responsive to a suitable driving voltage applied across the EC stack. The tint may be to (e.g., virtually) any tint state within a continuous tint spectrum defined by the material properties of the EC stack. However, the control system (e.g., the MC therein) may be programmed to select a tint value from a finite number of discrete tint values (e.g., tint values specified as integer values). In some such implementations, the number of available discrete tint values can be at least 2, 4, 8, 16, 32, 64, 128 or 256, or more. For example, a 2-bit binary number can be used to specify any one of four possible integer tint values, a 3-bit binary number can be used to specify any one of eight possible integer tint values, a 4-bit binary number can be used to specify any one of sixteen possible integer tint values, a 5-bit binary number can be used to specify any one of thirty-two possible integer tint values, and so on. At least one (e.g., each) tint value can be associated with a target tint level (e.g., expressed as a percentage of maximum tint, maximum safe tint, maximum desired or available tint, or a combination thereof). For didactic purposes, consider an example in which the MC selects from among four available tint values: 0, 5, 10 and 15 (using a 4-bit or higher binary number). The tint

values 0, 5, 10 and 15 can be respectively associated with target tint levels of 60%, 40%, 20% and 4%, or 60%, 30%, 10% and 1%, or another desired, advantageous, or suitable set of target tint levels.

[0110] Fig. 3 shows a block diagram of an example MC 300. The MC 300 can be implemented in or as one or more computers, computing devices or computer systems (herein used interchangeably where appropriate unless otherwise indicated). For example, the MC 300 includes one or more processors 302 (also collectively referred to hereinafter as "the processor 302"). Processor 302 can be or can include a central processing unit (CPU), such as a single core or a multi-core processor. The processor 302 can additionally include a digital signal processor (DSP) or a network processor in some examples. The processor 302 could also include one or more application-specific integrated circuits (ASICs). The processor 302 is coupled with a primary memory 304, a secondary memory 306, an inward-facing network interface 308 and an outward-facing network interface 310. The primary memory 304 can include one or more high-speed memory devices such as, for example, one or more random-access memory (RAM) devices including dynamic-RAM (DRAM) devices. Such DRAM devices can include, for example, synchronous DRAM (SDRAM) devices and double data rate SDRAM (DDR SDRAM) devices (including DDR2 SDRAM, DDR3 SDRAM, and DDR4 SDRAM), thyristor RAM (T-RAM), and zero-capacitor (Z-RAM®), among other suitable memory devices.

[0111] In some embodiments, in some implementations the MC and the NC are implemented as a master controller application and a network controller application, respectively, executing within respective physical computers or other hardware devices. For example, each of the master controller application and the network controller application can be implemented within the same physical hardware. Each of the master controller application and the network controller application can be implemented as a separate task executing within a single computer device that includes a multi-tasking operating system such as, for example, an operating system based at least in part on a Linux® kernel or another suitable operating system.

[0112] In some embodiments, the master controller application and the network controller application can communicate via an application programming interface (API). In some embodiments, the master controller and network controller applications communicate over a loopback interface. By way of reference, a loopback interface is a virtual network interface, implemented through an operating system, which enables communication between applications executing within the same device. A loopback interface is typically identified by an IP address (often in the 127.0.0.0/8 address block in IPv4, or the 0:0:0:0:0:0:0:1 address (also expressed as: 1) in IPv6). For example, the master controller application and the network controller application can each be programmed to send communications targeted to one another to the IP address of the loopback interface. In this way, when the master controller application sends a communication to the network controller application, or vice versa, the communication does not need to leave the computer.

[0113] In some embodiments wherein the MC and the NC are implemented as master controller and network controller applications, respectively, there are generally no restrictions limiting the available protocols suitable for use in communication between the two applications. This generally holds true regardless of whether the master controller application and the network controller application are executing as tasks within the same or different physical computers. For example, there is no need to use a broadcast communication protocol, such as BACnet, which limits communication to one network segment as defined by a switch or router boundary. For example, the oBIX communication protocol can be used in some implementations for communication between the MC and the NCs.

[0114] In some embodiments, each of the NCs is implemented as an instance of a network controller application executing as a task within a respective physical computer. In some embodiments, at least one of the computers executing an instance of the network controller application also executes an instance of a master controller application to implement the MC. For example, while only one instance of the master controller application may be actively executing in the network system at any given time, two or more of the computers that execute instances of network controller application can have an instance of the master controller application installed. In this way, redundancy is added such that the computer currently executing the master controller application is no longer a single point of failure of the entire system. For example, if the computer executing the master controller application fails or if that particular instance of the master controller application otherwise stops functioning, another one of the computers having an instance of the master network application installed can begin executing the master controller application to take over for the other failed instance. In some embodiments, more than one instance of the master controller application may execute concurrently. For example, the functions, processes, or operations of the master controller application can be distributed to two (or more) instances of the master controller application.

[0115] Fig. 4 shows a block diagram of an example NC 400, which can be implemented in or as one or more network components, networking devices, computers, computing devices, or computer systems (herein used interchangeably where appropriate unless otherwise indicated). Reference to “the NC 400” collectively refers to any suitable combination of hardware, firmware, and software for implementing the functions, operations, processes or capabilities described. For example, the NC 400 can refer to a computer that implements a network controller application (also referred to herein as a “program” or a “task”). NC 400 includes one or more processors 402 (also collectively referred to hereinafter as “the processor 402”). In some embodiments, the processor 402 is implemented as a microcontroller or as one or more logic devices including one or more application-specific integrated circuits (ASICs) or programmable logic devices (PLDs), such as field-programmable gate arrays (FPGAs) or complex programmable logic devices (CPLDs). When implemented in a PLD, the processor can be programmed into the PLD as an intellectual property (IP) block or permanently formed in the

PLD as an embedded processor core. The processor 402 may be or may include a central processing unit (CPU), such as a single core or a multi-core processor. The processor 402 is coupled with a primary memory 404, a secondary memory 406, a downstream network interface 408, and an upstream network interface 410. In some embodiments, the primary memory 404 can be integrated with the processor 402, for example, as a system-on-chip (SOC) package, or in an embedded memory within a PLD itself. The NC 400 may include one or more high-speed memory devices such as, for example, one or more RAM devices. In some embodiments, the secondary memory 406 can include one or more solid-state drives (SSDs) storing one or more lookup tables or arrays of values. The secondary memory 406 may store a lookup table that maps first protocol IDs (for example, BACnet IDs) received from the MC to second protocol IDs (for example, CAN IDs) each identifying a respective one of the WCs, and vice versa. In some embodiments, the secondary memory 406 stores one or more arrays or tables. The downstream network interface 408 enables the NC 400 to communicate with distributed WCs and/or various sensors. The upstream network interface 410 enables the NC 400 to communicate with the MC and/or various other computers, servers, or databases.

[0116] In some embodiments, when the MC determines to tint one or more IGUs, the MC writes a specific tint value to the AV in the NC associated with the one or more respective WCs that control the target IGUs. For example, the MC may generate a primary tint command communication including a BACnet ID associated with the WCs that control the target IGUs. The primary tint command also can include a tint value for the target IGUs. The MC may direct the transmission of the primary tint command to the NC using a network address such as, for example, an IP address or a MAC address. Responsive to receiving such a primary tint command from the MC through the upstream interface, the NC may unpackage the communication, map the BACnet ID (or other first protocol ID) in the primary tint command to one or more CAN IDs (or other second protocol IDs), and write the tint value from the primary tint command to a first one of the respective AVs associated with each of the CAN IDs.

[0117] In some embodiments, the NC then generates a secondary tint command for each of the WCs identified by the CAN IDs. Each secondary tint command may be addressed to a respective one of the WCs by way of the respective CAN ID. For example, each secondary tint command also can include the tint value extracted from the primary tint command. The NC may transmit the secondary tint commands to the target WCs through the downstream interface via a second communication protocol (for example, via the CANOpen protocol). In some embodiments, when a WC receives such a secondary tint command, the WC transmits a status value back to the NC indicating a status of the WC. For example, the tint status value can represent a “tinting status” or “transition status” indicating that the WC is in the process of tinting the target IGUs, an “active” or “completed” status indicating that the target IGUs are at the target tint state or that the transition has been finished, or an “error status” indicating an error. After the status value has been stored in the NC, the NC may publish the status information or otherwise

make the status information accessible to the MC or to various other authorized computers or applications. In some embodiments, the MC requests status information for a particular WC from the NC based at least in part on intelligence, a scheduling policy, or a user override. For example, the intelligence can be within the MC or within a BMS. A scheduling policy can be stored in the MC, another storage location within the network system, or within a cloud-based system.

[0118] In some embodiments, the NC handles some of the functions, processes, or operations that are described above as being responsibilities of the MC. In some embodiments, the NC can include additional functionalities or capabilities not described with reference to the MC. For example, the NC may also include a data logging module (or "data logger") for recording data associated with the IGUs controlled by the NC. In some embodiments, the data logger records the status information included in each of some or all of the responses to the status requests. For example, the status information that the WC communicates to the NC responsive to each status request can include a tint status value (S) for the IGUs, a value indicating a particular stage in a tinting transition (for example, a particular stage of a voltage control profile), a value indicating whether the WC is in a sleep mode, a tint value (C), a set point voltage set by the WC based at least in part on the tint value (for example, the value of the effective applied voltage V_{Eff}), an actual voltage level V_{Act} measured, detected or otherwise determined across the ECDs within the IGUs, an actual current level I_{Act} measured, detected or otherwise determined through the ECDs within the IGUs, and various sensor data, for example, collected from photosensors or temperature sensors integrated on or within the IGUs. The NC may collect and queue status information in a messaging queue like RabbitMC, ActiveMQ or Kafka and stream the status information to the MC for subsequent processing such as data reduction/compression, event detection, etc., as further described herein.

[0119] In some embodiments, the data logger within the NC collects and stores the various information received from the WCs in the form of a log file such as a comma-separated values (CSV) file or via another table-structured file format. For example, each row of the CSV file can be associated with a respective status request, and can include the values of C, S, V_{Eff}, V_{Act} and I_{Act} as well as sensor data (or other data) received in response to the status request. In some implementations, each row is identified by a timestamp corresponding to the respective status request (for example, when the status request was sent by the NC, when the data was collected by the WC, when the response including the data was transmitted by the WC, or when the response was received by the NC). In some embodiments, each row also includes the CAN ID or other ID associated with the respective WC.

[0120] In some embodiments, each row of the CSV file includes the requested data for all of the WCs controlled by the NC. The NC may sequentially loop through all of the WCs it controls during each round of status requests. In some embodiments, each row of the CSV file is identified by a timestamp (for example, in a first column), but the timestamp can be associated

with a start of each round of status requests, rather than each individual request. In one specific example, columns 2–6 can respectively include the values C, S, V_{Eff}, V_{Act} and I_{Act} for a first one of the WCs controlled by the NC, columns 7–11 can respectively include the values C, S, V_{Eff}, V_{Act} and I_{Act} for a second one of the WCs, columns 12–16 can respectively include the values C, S, V_{Eff}, V_{Act} and I_{Act} for a third one of the WCs, and so on and so forth through all of the WCs controlled by the NC. The subsequent row in the CSV file may include the respective values for the next round of status requests. In some embodiments, each row also includes sensor data obtained from photosensors, temperature sensors, or other sensors integrated with the respective IGUs controlled by each WC. For example, such sensor data values can be entered into respective columns between the values of C, S, V_{Eff}, V_{Act} and I_{Act} for a first one of the WCs but before the values of C, S, V_{Eff}, V_{Act} and I_{Act} for the next one of the WCs in the row. Each row can include sensor data values from one or more external sensors, for example, positioned on one or more facades or on a rooftop of the building. The NC may send a status request to the external sensors at the end of each round of status requests.

[0121] In some embodiments, the NC translates between various upstream and downstream protocols, for example, to enable the distribution of information between WCs and the MC or between the WCs and the outward-facing network. For example, the NC may include a protocol conversion module responsible for such translation or conversion services. The protocol conversion module may be programmed to perform translation between any of a number of upstream protocols and any of a number of downstream protocols. For example, such upstream protocols can include UDP protocols such as BACnet, TCP protocols such as oBix, other protocols built over these protocols as well as various wireless protocols. Downstream protocols can include, for example, CANopen, other CAN-compatible protocol, and various wireless protocols including, for example, protocols based at least in part on the IEEE 802.11 standard (for example, WiFi), protocols based at least in part on the IEEE 802.15.4 standard (for example, ZigBee, 6LoWPAN, ISA100.11a, WirelessHART or MiWi), protocols based at least in part on the Bluetooth standard (including the Classic Bluetooth, Bluetooth high speed and Bluetooth low energy protocols and including the Bluetooth v4.0, v4.1 and v4.2 versions), or protocols based at least in part on the EnOcean standard (ISO/IEC 14543-3-10).

[0122] In some embodiments, the NC uploads the information logged by the data logger (for example, as a CSV file) to the MC on a periodic basis, for example, every 24 hours. For example, the NC can transmit a CSV file to the MC via the File Transfer Protocol (FTP) or another suitable protocol over an Ethernet data link 316. The status information may be stored in a database or made accessible to applications over the outward-facing network.

[0123] In some embodiments, the NC includes functionality to analyze the information logged by the data logger. For example, an analytics module can be provided in the NC to receive and/or analyze the raw information logged by the data logger (e.g., in real time). In real time may include within at most 15seconds (sec.), 30sec., 45sec., 1minute (min), 2min., 3min. 4min.,

5min, 10min., 15min. or 30min from receipt of the logged information by the data logger, and/or from initiation of the operation (e.g., from receipt and/or from start of analysis). In some embodiments, the analytics module is programmed to make decisions based at least in part on the raw information from the data logger. In some embodiments, the analytics module communicates with the database to analyze the status information logged by the data logger after it is stored in the database. For example, the analytics module can compare raw values of electrical characteristics such as V_{Eff}, V_{Act} and I_{Act} with expected values or expected ranges of values and flag special conditions based at least in part on the comparison. For example, such flagged conditions can include power spikes indicating a failure such as a short, an error, or damage to an ECD. The analytics module may communicate such data to a tint determination module or to a power management module in the NC.

[0124] In some embodiments, the analytics module filters the raw data received from the data logger to more intelligently or efficiently store information in the database. For example, the analytics module can be programmed to pass only “interesting” information to a database manager for storage in the database. For example, interesting information can include anomalous values, values that otherwise deviate from expected values (such as based at least in part on empirical or historical values), or for specific periods when transitions are happening. Examples of data manipulation (e.g., filtering, parsing, temporarily storing, and efficiently storing long term in a database) can be found in PCT Patent Application No. PCT/US15/029675 (Attorney Docket No. VIEWP049X1WO) filed May 7, 2015 and titled CONTROL METHOD FOR TINTABLE WINDOWS that is hereby incorporated by reference in its entirety.

[0125] In some embodiments, a database manager module (or “database manager”) in the control system (e.g., in the NC) is configured to store information logged by the data logger to a database on a periodic basis, for example, at least every hour, every few hours, or every 24 hours. The database can be an external database such as the database described above. In some embodiments, the database can be internal to the controller (e.g., the NC). For example, the database can be implemented as a time-series database such as a Graphite database within the secondary memory of the controller (e.g., of the NC) or within another long term memory within the controller (e.g., the NC). For example, the database manager can be implemented as a Graphite Daemon executing as a background process, task, sub-task or application within a multi-tasking operating system of the controller (e.g., the NC). A time-series database can be advantageous over a relational database such as SQL because a time-series database is more efficient for data analyzed over time.

[0126] In some embodiments, the database can collectively refer to two or more databases, each of which can store some or all of the information obtained by some or all of the NCs in the network system. For example, it can be desirable to store copies of the information in multiple databases for redundancy purposes. The database can collectively refer to a multitude of databases, each of which is internal to a respective controller (e.g., NC), e.g., such as a

Graphite or other times-series database. It can be beneficial to store copies of the information in multiple databases such that requests for information from applications including third party applications can be distributed among the databases and handled more efficiently. For example, the databases can be periodically or otherwise synchronized, e.g., to maintain consistency.

[0127] In some embodiments, the database manager filters data received from the analytics module to more intelligently and/or efficiently store information, e.g., in an internal and/or external database. For example, the database manager can be programmed to store (e.g., only) "interesting" information to a database. Interesting information can include anomalous values, values that otherwise deviate from expected values (such as based at least in part on empirical or historical values), for specific periods when transitions are happening, or a combination thereof. More detailed examples of how data manipulation (e.g., how raw data can be filtered, parsed, temporarily stored, and efficiently stored long term in a database) can be found in PCT Patent Application No. PCT/US15/029675 (Attorney Docket No. VIEWP049X1WO) filed May 7, 2015 and titled CONTROL METHOD FOR TINTABLE WINDOWS that is hereby incorporated by reference herein in its entirety.

[0128] In some embodiments, a status determination module of a target is included in the controller (e.g., the NC, the MC, or the WC), e.g., for calculating, determining, selecting, or otherwise generating status values for the target. For example, a tint determination module can be included in the controller (e.g., the NC, the MC, or the WC) for calculating, determining, selecting, or otherwise generating tint values for the IGUs. For example, the status (e.g., tint) determination module can execute various algorithms, tasks, or subtasks to generate tint values based at least in part on a combination of parameters. The combination of parameters can include, for example, the status information collected and stored by the data logger. The combination of parameters also can include time or calendar information such as the time of day, day of year or time of season. The combination of parameters can include solar calendar information such as, for example, the direction of the sun relative to the target (e.g., IGUs). The combination of parameters can include one or more characteristics of the enclosure environment that comprise gaseous concentration (e.g., VOC, humidity, carbon dioxide, or oxygen), debris, gas type, gas flow velocity, gas flow direction, gas (e.g., atmosphere) temperature, noise level, or light level (e.g., brightness). The combination of parameters can include the outside parameters (e.g., temperature) external to the enclosure (e.g., building), the inside parameter (e.g., temperature) within the enclosure (e.g., a room adjoining the target IGUs), the temperature within the interior volume of the IGUs, or a combination thereof. The combination of parameters can include information about the weather (for example, whether it is clear, sunny, overcast, cloudy, raining or snowing). Parameters such as the time of day, day of year, direction of the sun, or a combination thereof, can be programmed into and tracked by the control system (e.g., that includes the NC). Parameters such as the outside temperature, inside temperature, IGU temperature, or a combination thereof, can be obtained from sensors in, on or

around the building or sensors integrated on or within the IGUs, for example. In some embodiments, various parameters are provided by, or determined based at least in part on, information provided by various applications including third party applications that can communicate with the controller(s) (e.g., NC) via an API. For example, the network controller application, or the operating system in which it runs, can be programmed to provide the API.

[0129] In some embodiments, the target status (e.g., tint) determination module determines status (e.g., tint) value(s) of the target based at least in part on user overrides, e.g., received via various mobile circuitry (e.g., device) applications, wall devices, other devices, or a combination thereof. In some embodiments, the status (e.g., tint) determination module determines status (e.g., tint) values based at least in part on command(s) or instruction(s) received by various applications, e.g., including third party applications and/or cloud-based applications. For example, such third party applications can include various monitoring services including thermostat services, alert services (e.g., fire detection), security services, other appliance automation services, or a combination thereof. Additional examples of monitoring services and systems can be found in PCT/US2015/019031 (Attorney Docket No. VIEWP061WO) filed 5 March 2015 and titled MONITORING SITES CONTAINING SWITCHABLE OPTICAL DEVICES AND CONTROLLERS that is incorporated herein by reference in its entirety. Such applications can communicate with the status (e.g., tint) determination module and/or other modules within the controller(s) (e.g., NC) via one or more APIs. Some examples of APIs that the controller(s) (e.g., NC) can enable are described in PCT Patent Application No. PCT/US15/64555 (Attorney Docket No. VIEWP073WO) filed December 8, 2015 and titled MULTIPLE INTERFACING SYSTEMS AT A SITE, that is incorporated herein by reference in its entirety.

[0130] In some embodiments, the analytics module compares values of V_{Eff}, V_{Act} and I_{Act} as well as sensor data obtained in real time and/or previously stored within the database with expected values or expected ranges of values and flag special conditions based at least in part on the comparison. For example, the analytics module can pass such flagged data, flagged conditions or related information to a power management module. For example, such flagged conditions can include power spikes indicating a short, an error, or damage to a smart window (e.g., an ECD). In some embodiments, the power management module modifies operations based at least in part on the flagged data or conditions. For example, the power management module can delay status (e.g., tint) commands of a target until power demand has dropped, stop commands to troubled controller(s) (e.g., local controller such as WC) (and put them in idle state), start staggering commands to controllers (e.g., lower hierarchy controllers such as WCs), manage peak power, signal for help, or a combination thereof.

[0131] Fig. 5 shows an example NC 500 including a plurality of modules. NC 500 is coupled to an MC 502 and a database 504 by an interface 510, and to a WC 506 by an interface 508. In the example, internal modules of NC 500 include data logger 512, protocol conversion module 514, analytics module 516, database manager 518, tint determination module 520, power

management module 522, and commissioning module 524.

[0132] In some embodiments, a controller (e.g., WC) or other network device includes a sensor or sensor ensemble. For example, a plurality of sensors or a sensor ensemble may be organized into a sensor module. A sensor ensemble may comprise a circuit board, such as a printed circuit board, e.g., in which a number of sensors are adhered or affixed to the circuit board. Sensor(s) can be removed from a sensor module. For example, a sensor may be plugged into and/or unplugged out of, the circuit board. Sensor(s) may be individually activated and/or deactivated (e.g., using a switch). The circuit board may comprise a polymer. The circuit board may be transparent or non-transparent. The circuit board may comprise metal (e.g., elemental metal and/or metal alloy). The circuit board may comprise a conductor. The circuit board may comprise an insulator. The circuit board may comprise any geometric shape (e.g., rectangle or ellipse). The circuit board may be configured (e.g., may be of a shape) to allow the ensemble to be disposed in frame portion such as a mullion (e.g., of a window). The circuit board may be configured (e.g., may be of a shape) to allow the ensemble to be disposed in a frame (e.g., door frame and/or window frame). The frame may comprise one or more holes, e.g., to allow the sensor(s) to obtain (e.g., accurate) readings. The circuit board may be enclosed in a wrapping. The wrapping may comprise flexible or rigid portions. The wrapping may be flexible. The wrapping may be rigid (e.g., be composed of a hardened polymer, from glass, or from a metal (e.g., comprising elemental metal or metal alloy). The wrapping may comprise a composite material. The wrapping may comprise carbon fibers, glass fibers, polymeric fibers, or a combination thereof. The wrapping may have one or more holes, e.g., to allow the sensor(s) to obtain (e.g., accurate) readings. The circuit board may include an electrical connectivity port (e.g., socket). The circuit board may be connected to a power source (e.g., to electricity). The power source may comprise renewable and/or non-renewable power source.

[0133] Fig. 6 shows diagram 600 having an example ensemble of sensors organized into a sensor module. Sensors 610A, 610B, 610C, and 610D are shown as included in sensor ensemble 605. An ensemble of sensors organized into a sensor module may include at least 1, 2, 4, 5, 8, 10, 20, 50, or 500 sensors. The sensor module may include a number of sensors in a range between any of the aforementioned values (e.g., from about 1 to about 1000, from about 1 to about 500, or from about 500 to about 1000). Sensors of a sensor module may comprise sensors configured and/or designed for sensing a parameter comprising: temperature, humidity, carbon dioxide, particulate matter (e.g., between 2.5 μm and 10 μm), total volatile organic compounds (e.g., via a change in a voltage potential brought about by surface adsorption of volatile organic compound), ambient visible light, infrared, ultraviolet light, one or more images, audio noise level, pressure (e.g. gas, and/or liquid), acceleration, time, radar, lidar, radio signals (e.g., ultra-wideband radio signals), passive infrared, glass breakage, movement detectors, or a combination thereof. The sensor ensemble (e.g., 605) may comprise non-sensor devices, such

as buzzers and light emitting diodes. Examples of sensor ensembles and their uses can be found in U.S. Patent Application Serial Number 16/447169 filed June 20, 2019, titled "SENSING AND COMMUNICATIONS UNIT FOR OPTICALLY SWITCHABLE WINDOW SYSTEMS" that is incorporated herein by reference in its entirety.

[0134] In some embodiments, an increase in the number and/or types of sensors may be used to increase a probability that one or more measured property is accurate and/or that a particular event measured by one or more sensor has occurred. In some embodiments, sensors of sensor ensemble may cooperate with one another. In an example, a radar sensor of sensor ensemble may determine presence of a number of individuals in an enclosure. A processor (e.g., processor 615) may determine that detection of presence of a number of individuals in an enclosure is positively correlated with an increase in carbon dioxide concentration. In an example, the processor-accessible memory may determine that an increase in detected infrared energy is positively correlated with an increase in temperature as detected by a temperature sensor. In some embodiments, network interface (e.g., 650) may communicate with other sensor ensembles similar to sensor ensemble. The network interface may additionally communicate with a controller.

[0135] Individual sensors (e.g., sensor 610A, sensor 610D, etc.) of a sensor ensemble may comprise and/or utilize at least one dedicated processor. A sensor ensemble may utilize a separate sensing device (e.g., sensing device 654) utilizing a wireless and/or wired communications link. A sensor ensemble may utilize at least one processor (e.g., processor 652), which may represent a cloud-based processor coupled to a sensor ensemble via the cloud (e.g., 650). Processor (e.g., 652) and or sensing device (e.g., 654) may be located in the same building, in a different building, in a building owned by the same or different entity, a facility owned by the manufacturer of the window/controller/sensor ensemble, or at any other location. In various embodiments, as indicated by the dotted lines of Fig. 6, sensor ensemble 605 is not required to comprise a separate processor, sensing device, network interface, or a combination thereof. These entities may be separate entities and may be operatively coupled to ensemble 605. The dotted lines in Fig. 6 designate optional features. In some embodiments, onboard processing and/or memory of one or more ensemble of sensors may be used to support other functions (e.g., via allocation of ensembles(s) memory and/or processing power to the network infrastructure of a building).

[0136] Individual sensors (e.g., sensor 610A, sensor 610D, etc.) may comprise an imaging system capable of capturing one or more images of visible light, infrared (IR), ultraviolet (UV), radar reflections, or a combination thereof. In some embodiments, an imaging system may comprise an IR camera used to capture identifying gesture and/or gait recognition data of a user while preserving the user's privacy. The field of view (FOV) of the camera may be wide-angle (e.g., 30°, 45°, 60°, 90°, 120°, 145°, or 180°) or telephoto (12°, 8°, 6°, or 3°). The image resolution format of the camera may be, for example, 160 x 120, 240 x 180, 480p, 720p, 1080p,

1440p, 1.0 megapixel (MP), 1.3 MP, 2 MP, 3 MP, 5 MP, 8 MP, 12 MP, 16 MP, 20 MP, 33 MP, 2K, 4K, or 8K. An IR camera may perform thermal imaging between a low-temperature threshold (e.g., -50°C, -40°C, -30°C, -20°C, 0°C, 10°C, 20°C, 30°C, or 40°C) and a high-temperature threshold (e.g., 100°C, 120°C, 150°C, 200°C, 300°C, 400°C, 500°C, or 600°C). The spectral range of the IR camera may vary (e.g., 3 μm to 5 μm, or 8 μm to 14 μm), and the frame rate (e.g., frames per second (FPS)) may also vary (e.g., 15 FPS, 24 FPS, 30 FPS, 32 FPS, 48 FPS, 50 FPS, or 60 FPS). In some embodiments, an imaging system may comprise a radar imaging system to capture identifying gesture and/or gait recognition data of a user while preserving the user's privacy. A radar imaging system may scan a volume of space using, for example, one or more antenna arrays (e.g., a transmitter and receiver antenna arrays), and process the radar data from the scan to form a 2D image (e.g., from azimuth and elevation) or 3D image (e.g., from azimuth, elevation, and range). User motion may be determined using Doppler information from a single image (e.g., often called a "4D image") and/or detected movement between images. Similar to a visible-light or IR camera, the FOV of the radar imaging system may be relatively wide (e.g., 30°, 45°, 60°, 90°, 120°, 145°, 180°, 270°, or 360°) or narrow (e.g., 12°, 8°, 6°, or 3°) in either or both azimuth and elevation. Range, too, may vary (e.g., a maximum depth of 10 m, 15 m, 25 m, 50 m, 100 m, or 300 m), as well as Doppler (e.g., ± 1 m/s, 5 m/s, 10 m/s, 25 m/s, 50 m/s, 75 m/s, 100 m/s, 130 m/s, 150 m/s, 175 m/s, or 200 m/s). Resolution of the radar imaging system may vary in either or both azimuth and elevation (e.g., 0.5°, 0.75°, 1°, 1.5°, 2°, 3°, 5°, or 10°), range (which may be dependent on range: e.g., 10 cm @ 10 m versus 50 cm @ 300 m), and Doppler (e.g., 0.01 m/s, 0.05 m/s, 0.1 m/s, 0.5 m/s, 1 m/s, 1.5 m/s, 2 m/s, 3 m/s, 5 m/s, or 10 m/s). The imaging system may use any of a variety of frequencies or frequency ranges, including those used for cellular communication (e.g., 800 MHz, 1900 MHz, 2.1 GHz, 2.3 GHz, 2.6 GHz, 3.5 GHz, 4.8 GHz, 6 GHz, 26 GHz, 28 GHz, 40 GHz, 66 GHz, or 71 GHz), Wi-Fi (1000 MHz, 2.4 GHz, 3.6 GHz, 4.9 GHz, 5 GHz, 5.9 GHz, 6 GHz and 60 GHz), imaging radar-specific frequencies (e.g., 4 GHz, 8 GHz, 77 GHz, 94 GHz, 160 GHz, 300 GHz, 580 GHz, or 600 GHz), or other wireless technologies, including those described hereafter.

[0137] In some embodiments, sensor data is exchanged among various network devices and controllers. The sensor data may also be accessible to remote users (e.g., inside or outside the same building) for retrieval using personal electronic devices, for example. Applications executing on remote devices to access sensor data may also provide commands for controllable functions such as tint commands for a window controller. An example window controller(s) is described in PCT Patent Application No. PCT/US16/58872, titled CONTROLLERS FOR OPTICALLY-SWITCHABLE DEVICES, filed October 26, 2016, and in US Patent Application No. 15/334,832, titled CONTROLLERS FOR OPTICALLY-SWITCHABLE DEVICES, filed October 26, 2016, each of which is herein incorporate by reference in its entirety.

[0138] In some embodiments, sensor data may be obtained from one or more sensing devices. As illustrated in FIG. 4, a sensing device 654 may be communicatively coupled with a sensor ensemble 605. In alternative embodiments, the sensing device 654 may be communicatively coupled with a wireless network, cloud 651, processes of 652 (e.g., with or without direct wireless can indication with the sensor ensemble 605), or a combination thereof. The sensing device 654 may comprise a processor and one or more sensors 656. The sensor(s) 656 of the sensing device 654 may comprise one or more sensors of the sensor types described previously with regard to sensors 610A-610D. A sensing device 654 may be used to control one or more building systems (e.g., to control lighting, temperature, window tint, etc.), and therefore the sensor(s) 656 may comprise a microphone and/or an inertial measurement unit (IMU) (or equivalent accelerometers, gyroscopes, etc.) to detect speech and/or gestures. This may allow a user of the sensing device 654 to adjust one or more aspects of an environment within a building and/or interact with the target using voice control and/or motion (e.g., gesture) control. Such control methods may be more convenient compared to more conventional control methods, e.g., that may require a user to touch or otherwise physically interact with a particular component (e.g., switch, knob, keypad, touchscreen, etc.). Voice control may be beneficial for users, e.g., with certain disabilities.

[0139] In some embodiments, external behavior recognition (e.g., gesture recognition) and/or voice control is used to implement any type of manipulation of a target (e.g., any type of command on an optically switchable device). For example, external behavior recognition and/or voice control may be used to implement tinting commands for a target, or for a group or zone of targets. For example, the command may be for a single optically switchable device (e.g., “change window 1 to tint 4” or “make window 1 darker”), or for a group or zone of optically switchable devices (e.g., “change the windows in zone 1 to tint 4” or “make the windows in zone 1 darker” or “make the windows in zone 1 much darker,” etc.). The commands may relate to discrete optical states to which the relevant optically switchable device(s) should change (e.g., discrete tint levels, or other discrete optical states) or relative changes in the optical states of the optically switchable device(s) (e.g., darker, lighter, more reflective, less reflective, e.g., or “my office is too dark, please lighten it up” or “I want to run the projector,” (letting the system know to darken the room) or “it’s hot in here” (letting the system know to darken the windows and block heat gain) etc.). Where relative changes are used, the control system may be designed and/or configured to implement incremental (e.g., step) changes (e.g., 10% darker or lighter) in the optical state of the optically switchable device to carry out the command. The degree of each incremental (e.g., step) change may be pre-defined. In some embodiments, the control system is designed and/or configured to implement incremental (e.g., step) changes of a size and/or degree specified by the user. Such command(s) may be modified by any relative words used in the command (e.g., “very” or “a little bit,” or “lighter” or “darker” etc.).

[0140] In some embodiments, voice control is also be used to set a schedule for the target

(e.g., optically switchable device). For example, a user may direct the optically switchable device(s) to tint at particular times/days (e.g., “make the windows in zone 1 go to tint 4 at 2 pm Monday through Friday” or “the morning sun makes it hot in here” (letting the system know to tint the windows during the morning hours when the sun impinges on that side of the building) or “I can’t see the mountains well in the afternoon” (letting the system know that the windows are tinted too much in the afternoon and to lighten them during the afternoon)). Similarly, voice control can be used to implement tinting rules for the optically switchable device (e.g., “tint the windows in zone 1 to tint 4 when it’s sunny outside” or “tint the windows in this room if the temperature inside this room is above 70°F”). In some embodiments, any rules that can be implemented on a network of optically switchable devices (including any other networked components such as thermostat, BMS, electronic device, etc.) can be initiated via voice control.

[0141] In some embodiments, voice control is implemented on various components of control architecture for the target (e.g., smart window system), e.g., onboard window controllers or other window controllers, NCs, MCs, wall switches (e.g., interfaces with control components) and/or a separate device that interfaces with any or all of the aforementioned devices and/or components.

[0142] In some embodiments, gesture control is used to control the target. The gesture control may or may not use a limited command set (e.g., at times due to a lesser number of movements that would need to be recognized compared to the more expansive dictionary of words that can be recognized when using voice control). For example, gesture control can be used to implement many types of commands. For example, gesture control can be used to indicate that a particular target (e.g., window) or group of targets (e.g., windows) should change their state (e.g., change to a lighter or darker state (or other optical states if non-electrochromic optically switchable devices are used)). The user may indicate the target(s) (e.g., window(s)) to be changed, e.g., by standing in front of the relevant target(s) (e.g., window(s)) and/or pointing to the relevant target(s) (e.g., window(s)). Indication of the target may trigger coupling of the gesture with the target. The user may indicate the desired change by raising or lowering their hands or arms, or by opening or closing their palms, for instance. A dictionary of recognized gestures may be created to define the types of commands that can be accomplished via gesture control. More expansive gesture dictionaries may enable finer, more complex control of the optically switchable devices. There may be some degree of tradeoff in terms of ease of use, with smaller gesture dictionaries being potentially easier for users to master.

[0143] In some embodiments, a sensing device (e.g. sensing device 654) comprising a wearable device may be used to control the target. A sensor of the sensing device (e.g. sensor(s) 656) may comprise a wireless transceiver used to determine a location of a user. Further, a unique identifier (e.g., serial number, MAC address, etc.) of the sensing device may be associated with a user, thereby enabling some embodiments to identify and track a user’s location within a building. This functionality may then give the user access to a command set for

controlling an object using voice and/or gesture control, based on the user's identity and proximity to the object (e.g., in the same room as the object, within a threshold distance of the object, etc.). Using location tracking (e.g., using wireless location determination techniques described hereafter) of the sensing device, for example, a user may be identified upon walking into a room or other area related to a facility. Based on the user's identification, a library of commands (e.g., voice and/or gesture) may be accessible to the user, based on the user's identity, preferences, security/access level, etc. for controlling a target device related to the room or other area. Preferences can include preferences regarding window tint level, temperature (e.g., heating and/or cooling preferences), lighting (e.g., brightness and/or color), humidity, carbon dioxide (CO2) levels, etc. of a room, preferences regarding one or more devices in a room and/or any other preset preference described herein. In some embodiments, user preferences may be stored by database local to a sensor ensemble (e.g., sensor ensemble 605), in a separate computer of the facility (e.g., processor 654), or in one or more computers separate from the facility (e.g., cloud 651). Once the user's identity is known, preferences corresponding to the user can then be accessed from the database. In some embodiments, once a user's preferences are known, they may be used in multiple facilities communicatively coupled with the one or more for facilities from which the user's preferences were obtained. For example, for embodiments in which user preferences are stored in the cloud (e.g., cloud 651) and/or a computer (e.g., processor 652) connected to the cloud, user identification information and preferences may be propagated to other cloud-connected facilities and/or sensor ensembles enabling a cloud-connected sensor ensemble (e.g., sensor ensemble 605) in a facility, separate from and original facility in which user preferences were initially obtained, to identify a user, give the user access to the user's command set for controlling one or more targets, implement the user's preferences, or a combination thereof. Any changes that the user may make to the user's preferences may further be saved to the cloud and propagated to all other facilities/cloud-connected devices. In this manner, user preferences may be modified and/or updated over time using one or more facilities.

[0144] In some embodiments, the external behavior of the user (e.g., gait and/or gestures) may be detected using at least one sensor. The sensor may be communicatively coupled to the network. The sensor may be an imaging system (e.g., an imaging radar system and/or a camera such as a video camera or IR camera). The sensor(s) (e.g., camera and/or radar) may be provided on any available device, and in some examples is provided as part of a wall unit, as part of a device that interfaces with a wall unit (e.g., a smartphone, tablet, or other electronic device), as part of a hand-held device (e.g., smartphone, tablet, or other electronic device), on an electrochromic window or frame, or as part of any other device that is configured to control an electrochromic or other optically switchable window. For example, a user may walk and/or gesture while holding, wearing, or otherwise moving a sensing device (e.g., sensing device 654) that is configured to sense movement, and/or acceleration, etc. The readings on the sensing

device may be used to help determine the gait of the user and/or what gesture a user has made. The movement sensing device may include one or more accelerometers (e.g., 3-axis accelerometer), gyroscopes, magnetometers, imaging system, or the like (and may be included in a virtual reality (VR) interface, such as the Oculus Quest or Oculus Rift available from Facebook Technologies, LLC, of Menlo Park, California. The mobile circuitry may be, or be included in, a user controller, a character controller, a player controller, or a combination thereof.

[0145] In some embodiments, the sensing device (e.g., sensing device 654) is a fitness device (e.g., any of various wearable devices from Fitbit Inc. or Jawbone, each in San Francisco, CA), watch (e.g., from Apple Inc. of Cupertino, CA or Pebble Technology Corporation in Palo Alto, CA), or similar wearable device. In some embodiments, relative positioning, velocity, acceleration, Doppler effect, or a combination thereof, is used to determine the gait of a user and/or changes in gesture as commands to change the status of the target. In some embodiments, image recognition software is used to identify a human user for gait recognition and/or determine changes in gesture as commands to change the status of the target. In some embodiments, facial recognition software is used to determine changes in facial expressions as commands to change the tint level of windows. The gesture may comprise facial or bodily gesture (e.g.., of limbs or part of limbs). The gesture may comprise kinesthetic movement. The gesture may comprise a physical movement of a body part. The gesture may comprise a corporal and/or anatomic movement. The movement may comprise a muscular movement. The movement may comprise a movement of one or more bones (e.g., by moving their adjoining muscle(s).

[0146] In some embodiments, a type of command that may be initiated via voice control is to turn off “listening mode.” The sound sensor (e.g., listening device) may be operatively (e.g., communicatively) coupled to the network. When listening mode is on, the device that listens for commands is able to pick up oral commands. When listening mode is off, the device that listens for commands is not able to pick up, hear, and/or record such commands. For example, the device that listens for commands may be part of a (e.g., window) controller, IGU, wall device, another electronic device (e.g., phone, tablet, etc.), or a combination thereof. A user may request to turn listening mode off for increased privacy, and/or energy savings, etc. In some cases, the user may request that listening mode turn off for a specified time period (e.g., the duration of a meeting), for example. In order to turn listening mode back on, the user may press a button/touchscreen (e.g., on the device that listens for commands, on the window controller, IGU, wall device, or other electronic device) or otherwise indicate that listening mode should turn back on. Devices may indicate when listening mode is on and/or off. In one example, one or more lights (e.g., LEDs) may indicate whether listening mode is on or off. The light may be turned on to indicate that listening mode is on, and off to indicate that listening mode is off (or vice versa). In another example, a first light or light color may indicate that listening mode is on,

and a second light or light color may indicate that listening mode is off. In another example, devices can use an audio cue, e.g., may emit a tone, e.g., periodically, as a reminder to the user that listening mode is inactive (or active). In certain implementations, listening mode may be deactivated for a period of time (e.g., for at least about 1 minute, 10 minutes, 30 minutes, 1 hour, 2 hour, 3 hours, 1 day, etc.), after which listening mode may automatically be reactivated. The period of time over which listening mode remains deactivated may be chosen by the user, or may be preset, for example. In some embodiments, listening mode is activated by default. Listening mode may be on unless it is turned off (e.g., permanently turned off, or turned off for a period of time, as mentioned herein). In some embodiments, the default setting is that listening mode is off (e.g., listening mode does not activate unless a command is received to turn listening mode on).

[0147] In some embodiments, where gesture command is used, the user can control whether a relevant device that interprets gesture commands is in a "watching mode." Like the listening mode, the watching mode can be turned on and off. When a device is in watching mode, it is able to sense and interpret gesture commands, for example. When the watching mode is off, the device is not able to sense, record, and/or process gesture commands. Details provided herein related to listening mode may similarly apply to watching mode. The device that interprets the gesture may or may not be part of the control system. The gesture interpreting device may comprise a circuitry (e.g., may comprise a processor). The gesture interpreting device may be communicatively coupled to the network and/or to the control system. The gestures may be interpreted with respect to a virtual image of the enclosure in which the controllable target (e.g., an IGU, a sensor, a light, or a media) is disposed in. The gestures may be interpreted with respect to a target it is coupled to (e.g., pointed at).

[0148] In some embodiments, one or more voice commands are used to ask a question to the system controlling the target (e.g., optically switchable device (or some component on the network on which the optically switchable device is installed)). The questions may relate directly to the target (e.g., actuator, or optically switchable device), or more generally, to any target (e.g., optically switchable device) or group of targets (e.g., devices) communicatively coupled to (e.g., on) the network, for example. For instance, a user may ask what the current optical state is for a particular optically switchable device (e.g., "what's the tint level of window 1?"). Similarly, a user may ask what the upcoming behavior will be for a particular optically switchable device (e.g., "when is the next time the windows in my office will begin to get darker?"). The questions may also relate to any other information to which the network has access. For instance, a user may ask about weather data (e.g., temperature data, cloud data, precipitation data, forecast data, etc.), location data (e.g., "where am I?" or "how do I get from here to the nearest printer/exit/bathroom/etc."), access data (e.g., "am I allowed to control the tint level of the windows in this room?"), etc. A user may ask about any environmental characteristic of the enclosure (e.g., as delineated herein). A user may ask for an explanation of why the target (e.g.,

optically switchable device) is performing in a certain way. In one example, a user might ask, "why is window 1 tinting?" and the system may explain in response to the query, "clouds expected to clear in 20 minutes, tinting in anticipation of bright sun." This feature may be particularly useful in cases where the optically switchable device is programmed to execute rules that might not be immediately observable and/or understandable to a user. The answer may be provided visually (e.g., on a screen), as a printed material, or aurally (e.g., through a speaker).

[0149] In some embodiments, a voice command is used to control the degree of privacy in the enclosure (e.g., room), e.g., with respect to (e.g., wireless) communications. In some embodiments, optically switchable windows are patterned to include one or more antenna that may be used to block or allow particular wavelengths to pass through the windows. When activated, these patterned antennae can provide increased security/privacy by blocking cell phone communications, Wi-Fi communications, etc. Examples of patterned antennae and related privacy considerations can be found in PCT Application No. PCT/US15/62387, filed November 24, 2015, and titled WINDOW ANTENNAS that is incorporated herein by reference in its entirety.

[0150] In some embodiments where voice and/or gesture control are used, one or more dictionaries are defined. For voice control, the dictionaries may define a set of words and/or phrases that the system is configured to interpret/understand. Similarly, for gesture control, the dictionaries may define a set of gestures that the system is configured to interpret/understand. Dictionaries may be tiered, e.g., given a command in a first level dictionary, a new dictionary at a second level may be initiated for receiving commands, and once received, yet another level dictionary may be actuated. In this way, individual dictionaries need not be overly complex, and the end user can quickly get to the command structure they desire. In some embodiments, (e.g., when the target is a media) the gestures are interpreted as cursor movement on a media projection.

[0151] Examples of words or phrases that may be defined include names/identifications for each optically switchable device or group of devices (e.g., "window 1," "group 1," "zone 1," etc.). Such names/identifications may also be based at least in part on the location of the optically switchable devices. In this respect, the dictionaries may be defined to include words that identify optically switchable devices based at least in part on location (e.g., "first floor," or "break room," or "east-facing"), and/or words that provide a relation between the user (or some other person) and the optically switchable device being identified (e.g., "my office," "the left window," or "Deepa's room").

[0152] In some embodiments, the dictionaries also define words related to the desired commands that can be instructed. For example, the dictionaries may include words like "tint," "clear," "clearest," "darker," "darkest," "lighter," "lightest," "more," "less," "very," "a little," "tint level," "tint1," "tint2," etc. Any words likely to be used by a person when instructing the optically

switchable device when using verbal commands may be included in the dictionary. In cases where the system is configured to allow a user to set a schedule or rules for the behavior of the optically switchable device, the dictionary or dictionaries can include any words needed to understand such commands (e.g., “Monday,” “Tuesday through Friday,” “morning,” “afternoon,” “bedtime,” “sunrise,” “if,” “then,” “when,” “don’t,” “cloudy,” “sunny,” “degrees,” “someone,” “no one,” “movement,” “only,” etc.). Similarly, in cases where the system is configured to allow a user to ask a question, the dictionary or dictionaries can include any words needed to understand the types of questions the system is designed to answer.

[0153] In some embodiments, there is a tradeoff between larger dictionaries, which may enable finer control, more natural and/or flexible commands, and more complex functions (e.g., answering any question where the answer is available on the internet), compared to smaller dictionaries, which may be easier for people to master, and which may enable faster and/or more local processing. Smaller dictionaries may be used in a tiered format, where access to successive dictionaries is afforded by a user providing the proper voice or gesture command in one dictionary in order to be allowed access to the next dictionary.

[0154] In some embodiments, a single dictionary may be used. In other embodiments, two or more dictionaries may be used, and the dictionary that is used at a particular time depends on what type of command, or what portion of a command a user is trying to convey. For example, a first dictionary may be used when a user is identifying which optically switchable device they wish to control, and a second dictionary may be used when the user is identifying what they want the optically switchable device to do. The first dictionary could include any words needed to identify the relevant optically switchable device, while the second dictionary could include any words needed to interpret what the user wants the optically switchable device to do. Such contextual dictionaries can provide a limited sub-set of words that the system is configured to understand and/or interpret whenever the particular dictionary is being used. This may make it easier to interpret a user’s commands.

[0155] In some embodiments, one or more dictionaries may be tailored to particular users. The dictionaries for defining and/or determining which electrochromic window(s) a user desires to switch may be limited based at least in part on which windows the user is authorized to switch, for instance. In one example, user A is allowed to switch windows 1-5, while user B is allowed to switch windows 6-10. The dictionary or dictionaries used to transcribe and/or interpret commands from user A may be limited to identifying windows 1-5, while the dictionary or dictionaries used to transcribe and/or interpret commands from user B may be limited to identifying windows 6-10.

[0156] In some embodiments, each dictionary includes certain keywords that allow the user to navigate through the system more easily. Such keywords may include phrases such as “help,” “back,” “go back,” “previous,” “undo,” “skip,” “restart,” “start over,” “stop,” “abort,” etc. When a user requests help, the system may be configured to communicate to the user (e.g., visually

and/or aurally) the words, phrases, commands, windows, etc. that the system is currently configured to accept/understand based at least in part on the dictionary that is being used at a given time. For instance, if a user requests help while the system is accessing a dictionary that defines the different windows available for switching, the system may communicate that the available inputs at that time are, e.g., “window 1,” “window 2, “window 3,” “group 1,” etc.

[0157] In some embodiments, the system acts to ensure that a user is authorized to make a particular command before the command is executed. This can prevent unauthorized users from making changes to the optically switchable devices. One setting in which this is particularly valuable is conference rooms, where there may be many people present at once. In such cases, it may be desirable to ensure that people who do not have authority to change the optical state of the optically switchable devices are prevented from doing so. This can reduce the risk that the optically switchable devices will change based at least in part on overheard (typically non-relevant) comments made by those in the room. Another setting in which this feature may be valuable is a commercial office space, where it may be desired that individual people can each control a limited number of optically switchable devices near their workspaces, for instance. In one example, a (e.g., each) person may be authorized to control the target (e.g., optically switchable window(s)) in their particular office, or on their particular floor, etc. For example, it may be beneficial to ensure that the (e.g., only) people who are able to initiate a change in the target (e.g., optical transitions) via voice or gesture command are authorized to do so.

[0158] In some embodiments, authorization is done by having a user “log in” to the system to identify himself or herself. This may be done by logging into an application on an electronic device (e.g., smartphone, tablet, etc.), by keying in a code, electronically recognizing a code, by fingerprinting, eye pattern identification, facial identification, or voicing a passcode, etc. In another example, voice recognition may be used to confirm the identity of a user. In a further example, facial recognition, fingerprint scanning, retinal scanning, or other biometric-based methods may be used to confirm the identity of a user. In another example, gait recognition can be used to identify a user. In some embodiments, gait recognition may be used in conjunction with one or more additional authentication techniques. Different authorization procedures may be best suited for different applications and/or contexts. In a particular example, a user may be automatically authorized. Gait recognition may provide such automatic authorization where a sensor comprising an imaging system used for gait recognition may be situated at a location (e.g., in a building) enabling the imaging system to capture a sufficient amount of video or number of successive images for gait recognition. This may be at or adjacent to a location in a building at which authorization is used. For example, a gait recognition imaging system may be set up to capture video in a hallway leading up to a door, enabling a user to be authorized via gait recognition to provide access at the door (e.g., unlocking the door or activating an additional sensor at or near the door for additional authentication). According to some embodiments, automatic authorization may be based at least in part on a physical authorization token (e.g., an

RFID badge, a BLE beacon, UWF beacon, etc. having appropriate identification information), and the proximity of the physical authorization token to a sensor that reads the token. The sensor may be provided on an optically switchable device or adjacent thereto (e.g., in a frame portion of the IGU such as in a mullion), on a controller in communication with the optically switchable device, on a wall unit in communication with the optically switchable device, etc. The verification may occur locally (e.g., on the sensor that reads the token, on an optically switchable device, on a controller, on a wall unit, etc.), in the cloud, or a combination thereof.

[0159] In some embodiments, authorization occurs whenever it is needed, and authorization may expire after a set amount of time has passed, or after the user has been idle for a set amount of time (e.g., after 24 hours, or after 1 hour, or after 10 minutes). The time period used for auto-logging out may depend on the setting in which the target (e.g., windows) are installed or projected. For example, whether the target(s) (e.g., windows) are in a public area or a private area). In some cases, authorization may not expire until a user logs out (e.g., using any available method including, but not limited to, orally requesting a logout, pressing a logout button, etc.). In some embodiments, authorization occurs each time a command is made. In some embodiments, authorization occurs in stages even when interpreting a single command. In a first authorization stage, it may be determined whether the user has authorization to make any changes on the network, and in a second authorization stage, it may be determined whether the user has authorization to make the particular change that the user has requested and/or initiated.

[0160] In some embodiments, the authorization process is used to limit the dictionaries used to interpret the voice and/or gesture commands. For example, the dictionary or dictionaries for a particular user may exclude one or more specified targets (e.g., optically switchable devices (or groups/zones of such devices)) that the user is not authorized to control. In one example, a user may be only authorized to control the optically switchable devices in zone1 and zone 2, so the dictionary or dictionaries used to interpret commands for this user may include “zone 1” and “zone 2” while excluding “zone 3.” Any other words needed to interpret and/or understand the command may also be included in the dictionary.

[0161] In some embodiments, a control system (e.g., voice control and/or external behavior control) includes an authentication module which is used to practice the authorization and/or security techniques discussed herein. For example, the authorization module may be used to ensure that the person giving the command is authorized to make the command. The authentication module may comprise a blockchain procedure and/or embedded encryption key(s). The blockchain procedure may comprise (e.g., peer-to-peer) voting. The encryption key(s) may be linked to a target (e.g., a device). The authentication module may be designed to ensure that only authorized devices can connect to a given network, facility, and/or service. The module may compare the optically switchable device identified in the command to a list of optically switchable devices that the user is authorized to control. In cases where a user tries to

control an optically switchable device that they are not authorized to control, the authentication module may be configured to notify the user (e.g., visually, in print, and/or aurally) that they are not authorized to control the relevant optically switchable device. In other cases, no action is taken when an un-authorized command is given (e.g., no notification to the user, and no change to the target status (e.g., no switching of the optically switchable device)). The authentication may consider the identification of the user and/or other employee data such as rank, seniority, certification, education, departmental affiliation, or a combination thereof. The identification of the user may be provided to the authentication module, e.g., via a facility entry tag of the user. The authentication module may be required to limit access to sensitive medical information, dangerous manufacturing machinery, any restricted information, or a combination thereof. Examples of authentication (e.g., using blockchain procedure) can be found in PCT patent application serial number PCT/US20/70123 that is incorporated herein by reference in its entirety.

[0162] In some embodiments, one or more sensors (e.g., sensor(s) 656) of a sensing device (e.g., sensing device 654) comprising a wearable device may include one or more biometric sensors used to collect biometric data of a user wearing the wearable device. Biometric data may be used, for example, to verify user identity (e.g., based on biometric sensor data unique to the user) for purposes of voice and/or external behavior control of a target or building system, as previously described. In some embodiments, biometric data from a wearable device may be used (e.g., by the sensing device and/or a processor or computer communicatively coupled therewith) to determine a physiological condition. The physiological condition may be used to control a target or building system (e.g., room environment) within a building. For example, a patient within a hospital or other health facility may be tracked within the facility using the wearable device, which may further collect the patient's biometric data. This biometric data can be monitored and one or more aspects of the patient's environment (e.g., temperature, oxygen levels, CO2 levels, lighting, etc.) settings of a target (e.g., medical device, media display, appliance, etc.), or a combination thereof, may be adjusted accordingly (e.g., by wirelessly communicating with the target via a building network). For instance, if biometric data from a wearable device indicates that a patient's temperature has risen above a threshold, a building network can engage an HVAC system to cool the room temperature of a room in which the patient is located. Other examples are provided hereafter.

[0163] Fig. 7 is a diagram illustrating example wristbands in adult size 700 and children's size 702, which can be utilized as a sensing device (e.g., comprising a wearable device) as described herein, according to some embodiments. (Although Fig. 7 illustrates components of the adult sized wristband 700, which are described hereafter, these components also may be included in the children size wristband 702.) Depending on desired functionality, wristbands may come in more size variations (e.g., three or more sizes) and/or may include adjustable straps. Although an embodiment of a wearable device comprising a wristband 700 is pictured,

embodiments are not so limited. Other wearable devices may comprise ankle bands, rings, belts, chest bands, abdominal bands, necklaces/neck bands, watches, or the like, including electronic devices/modules disposed on or in clothing. Moreover, it will be appreciated that the wristband 700 illustrated in Fig. 7 is illustrated as a non-limiting example that generally illustrates basic functionality of a wearable sensing device, according to some embodiments. Other wearable sensing devices may have other form factors (e.g., having different dimensions, comprising different materials, etc.), additional features (e.g., a touch screen display or other UI, speaker, dials, switches, etc.), and so forth.

[0164] Electronics module 703 may comprise circuitry components embedded in or on the wristband 700. As noted, because the wristband 700 may correspond to a sensing device as previously described (e.g., sensing device 654 of Fig. 6), electronics module 703 may comprise a processor (e.g., processor 655) and one or more sensors (e.g., sensors 656). The processor may comprise a microcontroller or other programmable chip. Depending on desired functionality, the electronics module 703 may comprise electrical components disposed on a flexible PCB board, and/or distributed electrical components (e.g., discrete chips and/or distributed PCB boards) communicatively connected via flexible/malleable conductors to allow for at least some flexibility in the overall form factor without incurring damage to the electronics. The electronics module 703 may be powered by a permanent or replaceable power source (e.g. battery), which may be rechargeable via wireless and/or physical charging. The electronics module 703 also may comprise a wireless transceiver capable of obtaining sensor data from one or more sensors and transmitting the center data to a controller, sensor ensemble, facility network, other device or network external to the wristband, or a combination thereof. In some embodiments, a processor of the electronics module 703 may perform some processing of the raw sensor data before the sensor data is wirelessly transmitted. Additional description regarding example components of the electronics module 703 are provided hereafter with regard to Fig. 8.

[0165] The silicone band 704 may allow for flexibility and elasticity in the design, which may include and ergonomic shape and external service to provide a comfortable fit to the wristband user. Embodiments may include additional or alternative materials including other bonded polymers, organic polymers, plastics, woven artificial, natural fibers (nylon, polyester, cotton, wool, etc.), etc., or a combination thereof. Because the external surface may come in contact with the user's skin, the silicone band 704 may be designed to have an Ra value (roughness) at or below a threshold that renders it smooth to the average human touch sensitivity. The adjustability and/or elasticity of the silicone band 704 may be leveraged to ensure embedded sensors are positioned relative to the user (e.g., touching or within a threshold proximity of the user's skin) in a way to help ensure the sensors can obtain accurate biometric data.

[0166] The one or more sensors included in the wristband 700 may be electronically coupled with the electronics module 703 and may be used to gather biometric data and/or perform

positioning (e.g., location determination) of the wristband 700. As described hereafter, positioning may be performed, at least in part, by transmitting and/or receiving (e.g., measuring) wireless signals. Such wireless signals may be transmitted and/or received using a standard wireless technology such as Wi-Fi, UWB, cellular (4G LTE or 5G NR), or Bluetooth. Moreover, wireless signals used for positioning may be transmitted and/or received using a wireless radio also used for communicating (e.g., transmitting sensor data) to another device or network. According to some embodiments, a wristband 700 may include a Global Navigation Satellite System (GNSS) receiver for satellite-based positioning, such as a Global Positioning System (GPS) receiver. Positioning of the wristband 700 may be performed, at least in part, using dead reckoning, in which case the wristband 700 may include a pedometer and/or motion sensor, such as an IMU or a combination of one or more accelerometers, gyroscopes, or magnetometers. In some embodiments, such motion sensors additionally or alternatively may be used for other purposes, such as to determine user motion as biometric sensor data, such as steps and/or irregular movement (e.g., indicative of a fall or other movement that could indicate a potential injury to the user). Other biometric sensors may comprise medical sensors, including vital signs sensors that measure and oxygen level (e.g., oximeter), temperature, blood pressure, pulse of a user, or a combination thereof. Other medical sensors may comprise sensors to measure blood sugar, heart rate, blood pressure of a user, or a combination thereof.

[0167] The wristband 700 may also comprise a programmable button 706, which may be programmed to perform any of a variety of functions, as desired. For example, the programmable button 706 may be programmed as a call button or emergency notification that, when pressed, causes the wristband 700 to transmit an alert signal to a building network or other device, which may alert nurses or other building personnel that the user needs assistance or other attention. Some uses for the programmable button 706 may be linked to the functionality of one or more of the sensors of the wristband 700. For example, the programmable button 706 may be programmed to convey an audio message captured by a microphone of the wristband 700 when pressed, allowing a user to record an audio message (e.g., while the user presses the programmable button 706), which then may be sent (e.g., once the programmable button 706 is released) to a predetermined recipient (e.g., nurse, family member, etc.). According to some embodiments, a microcontroller of the wristband 700 may be programmed to enable the programmable button 706 to provide different functions based on different ways in which the button can be pressed (e.g., one short press, two short presses, three short presses, one long press, two long presses, etc.). The programmable button 706 may comprise a physical button, touch-sensitive button (e.g., capacitive and/or resistive button)

[0168] Fig. 8 is a diagram illustrating example electronic components of a sensing device 800, according to an embodiment. The sensing device 800 may correspond with sensing device 654 of Fig. 6, wristband 700 of Fig. 7, or another sensing device (including wearable devices) capable of communicating sensor data to a building network as described herein. For a

wearable device, components illustrated in Fig. 8 may correspond to components integrated or incorporated into an electronics module (e.g., electronics module 703). Components may be communicatively coupled via a data bus or other communication means. As previously noted, power may be provided to some or all of the electronic components of the sensing device 800 from a battery, such as permanent or replaceable batteries (e.g., lithium or alkaline), or rechargeable batteries (e.g., nickel–cadmium (NiCd), nickel–metal hydride (NiMH), lithium-ion (Li-ion), lithium iron phosphate (LiFePO4), or lithium-ion polymer (Li-ion polymer)). In some embodiments, all or some components of the sensing device 800 illustrated in FIG. 8 may be incorporated into a single integrated circuit (IC) or chip (e.g., a system on a chip (SoC). In some embodiments, some or all of the components of the sensing device 800 may be implemented as discrete chips or circuitry.

[0169] The processor 802 may comprise a microcontroller or other programmable processor, which may be programmable using a physical interface and/or over the air (OTA) updates (e.g., via the communication interface 814). The memory 804 may comprise on-board memory of the processor 802 and/or a separate memory module accessible to the processor 802 which may be used by the processor to store an operating system, application, or other computer-readable instructions, and may be used to store and/or process sensor data. The memory may comprise a computer-readable medium such as a random-access memory (RAM), read-only memory (ROM), flash-updatable memory, or other means of electronic, optical, or magnetic data storage. The UWB transceiver 806 may be used for transmitting and/or receiving RF signals via UWB for determining a position of (e.g. tracking) the sensing device 800 within a building, which is described in further detail hereafter. In alternative embodiments, a UWB transceiver 806 may be integrated into a communication interface 814 or other RF radio. The GNSS receiver 808 may comprise a receiver capable of position determination using one or more GNSS systems, including GPS, BeiDou Navigation Satellite System (BDS), Galileo, GLONASS, Indian Regional Navigation Satellite System (IRNSS), or Quasi-Zenith Satellite System (QZSS). The user interface 810 may comprise components enabling a user to interact with the sensing device 800. This can include, for example, one or more buttons (e.g., programmable button 706), dials, levers, displays, touch screens, touch pads, speakers, microphones, or the like. The medical sensor(s) 812 may comprise one or more sensors capable of obtaining medical and/or other biometric information from a user (e.g., by wearing and/or using the sensing device 800) and may comprise any of the sensors previously described with regard to the wristband 700 of FIG. 7.

[0170] Depending on desired functionality, the rates at which medical sensor data is collected and reported may vary. The sampling rate of each sensor, for example, may vary depending on sensor type. Some sensors (e.g., accelerometer or IMU) may sample on the order of microseconds or milliseconds (e.g., every 10 μs, 100 μs, 1 ms, 5 ms, 10 ms, 25 ms, 100 ms, 500 ms, etc.). Some sensors (e.g., temperature or blood pressure sensor) may sample on the

order of seconds or minutes (e.g., every second, 2 seconds, 5 seconds, 10 seconds, 25 seconds, minute, 5 minutes, 10 minutes, 30 minutes, etc.). Raw sensor data may be wirelessly sent (e.g. via communication interface 814) to a separate device or network, or may be processed (e.g., by processor 802) prior to sending. The sensor data (raw or processed) may be sent in real time (e.g., via a data stream) or sent in batches (e.g., every second, five seconds, 10 seconds, 30 seconds, minute, 2 minutes, 5 minutes, etc.).

[0171] The communication interface 814 may comprise one or more wireless transceivers capable of communicating data (e.g., sensor data) to a separate device or network. This may include transceivers capable of transmitting data via Wi-Fi, Bluetooth, cellular, other wireless means, or a combination thereof. As noted, according to some embodiments, the communication interface may also be capable of sending and/or receiving RF signals (e.g., pulses) to/from transceivers/beacons at known locations within a building for tracking the sensing device 800 within a building. Again, additional details for performing such tracking are provided hereafter.

[0172] As noted, the sensing device 800 may be used by a single user (e.g., at a time), and therefore a unique identifier may be associated with the sensing device 800 and/or user, and used in communications by the sensing device 800 to identify the sensing device/user. In some embodiments, the unique identifier may be a unique identifier of the sensing device 800, such as a serial number, MAC address, or globally unique ID (GUID) or other unique identifier of the hardware and/or software of the sensing device 800, which may be stored in memory 804 or the communication interface 814, for example. A unique identifier of the sensing device 800 may be associated (e.g., in a database by a server) with the user at a particular time, such as upon provisioning the sensing device to the user. In some embodiments, the unique identifier may be a unique identifier of the user, such as the user's name, patient ID, or other individual identifier, which may then be stored in memory 804. The unique identifier (e.g., a unique identifier of the sensing device 800 or user) may then be used in communications by the communication interface 814 to allow a receiving device or network to identify the sensing device 800 and/or user based on the unique identifier. In some embodiments, communications by the communication interface 814 may be encrypted to help address privacy concerns regarding the transmittal of the unique identifier, medical-related sensor data, positioning-related data, or a combination thereof.

[0173] Fig. 9 is a block diagram illustrating a building control system 900, according to an embodiment. As illustrated, the building control system 900 may comprise a cloud 901, wearable device 902, control device 904 with a client app 906, sensor(s) 908, controllable device(s) 910, UWB positioning transceivers 912, and a plurality of functions that may be performed by one or more computer servers and/or controllers, the functions comprising a position functionality 914, application functionality 916, environmental control functionality 918, and medical monitoring functionality 920. Double arrows indicate communication links. The

building control system 900 may be implemented, in whole or in part, at a building (or campus, facility, etc.) having one or more building systems to allow a user of the wearable device 902 to control one or more aspects of an environment within the building. The configuration of the building control system 900 illustrated in Fig. 9 is provided as a non-limiting example. Alternative embodiments may utilize alternative communication links and/or combine, separate, rearrange components illustrated in Fig. 9, or a combination thereof.

[0174] The cloud 901 may comprise a communication network used to communicatively link the various components of the building control system 900. The cloud 901 may therefore comprise a local area network (LAN) and/or wireless LAN (WLAN) local to the building in which the user of the wearable device 902 is located. The cloud 901 may comprise one or more devices or networks remote from the building, such as remote servers operating to provide one or more of the functions of 914, 916, 918, or 920. The cloud 901 may comprise public and/or private data networks, including the Internet.

[0175] The wearable device 902 may comprise a sensing device as previously described (e.g., sensing device 800, wristband 700, or sensing device 654). The wearable device 902 may therefore comprise one or more sensors capable of obtaining biometric/medical data from a user (the wearer of the wearable device 902). The wearable device 902 may additionally transmit and/or receive RF signals for positioning, which may be enabled by UWB positioning transceivers 912. The RF signals may be used, for example, to perform angle and/or range measurements to determine a position of the wearable device 902 geometrically using multiangulation and/or multilateration. Additional details regarding UWB-based positioning are provided hereafter.

[0176] The control device 904 comprises a device in (e.g. wireless) communication with the wearable device 902 that may be used to configure the wearable device 902. In some embodiments, the control device 904 may relay communications between the wearable device 902 and the cloud 901, which may save power of the wearable device 902 in cases in which the wearable device 902 is communicatively linked with the control device 904 using a relatively low-power technology (e.g., Bluetooth), and a communication link between the wearable device 902 and cloud 901 may consume relatively higher power (e.g., Wi-Fi). The client app 906 may comprise a software application executed by the control device 904 to configure the wearable device 902. For example, because a wearable device 902 may have a minimal user interface, a control device 904 may comprise a mobile phone, tablet, or other device having a touchscreen display or other complex user interface enabling the wearer of the wearable device 902 or another operator (e.g., medical provider, IT servicer, etc.) to configure the wearable device 902. The configuration may comprise provisioning the wearable device 902 to be used by particular user (e.g., associating the wearable device 902 with the user), configuring sensor settings (e.g., sampling rate, scheduled/periodic sensing times, activation/deactivation of sensors, reporting time/format of sensor data, etc.) of sensors (not shown in FIG. 9) of the wearable device 902.

[0177] The sensor(s) 908 comprise one or more sensors that may be distributed throughout the building, as part of the building control system 900. These sensors may provide data to various devices (e.g., the control device 904, one or more servers and/or controllers controlling the functionality shown at blocks 914-920 (described hereafter), etc.), which may provide feedback for one or more control systems. For example, the sensor(s) 908 may comprise a thermometer in a room where a patient wearing the wearable device 902 is located. This can allow a server, controller, or other device executing the environmental control functionality 918 to precisely control the temperature by controlling HVAC systems to heat or cool the room until the thermometer reads a desired temperature or temperature range. In some embodiments, the sensor(s) 908 may include other sensors to control other environmental aspects, such as CO2 levels, humidity, lighting (e.g., brightness, temperature/color, etc.), and so forth. The sensor(s) 908 may include sensors to detect non-environmental aspects as well, such as medical sensors (e.g., in addition to sensors of the wearable device 902 one by patient) capable of obtaining medical data from a patient. These sensors may include, for example, sensors of medical devices used to monitor a patient.

[0178] The controllable device(s) 910 comprise one or more devices that may be controlled using one or more inputs. One such input may comprise an input by a patient or healthcare worker via the control device 904 and/or wearable device 902. Other inputs may include inputs from the sensor(s) 908 and/or one or more remote devices executing one or more of the functionalities of blocks 914-920. Controllable device(s) 910 may comprise one or more controllable targets (e.g., tintable window, media (e.g., projector/TV, radio/speaker, white noise machine, etc.), or other appliance) described hereafter.

[0179] UWB positioning transceivers 912 may comprise transceivers distributed throughout a building at known locations for determining a position of the wearable device 902. Although described as “transceivers” in Fig. 9, positioning transceivers 912 may comprise transmitters, receivers, or any combination thereof, used to transmit and/or receive RF signals from the wearable device 902 to determine the position of the wearable device 902. As such, in some embodiments, the UWB positioning transceivers 912 may comprise antenna arrays for determining angle of arrival (AoA) and/or angle of departure (AoD) measurements, which may be used for triangulation, multiangulation, or other angle-based positioning techniques. In some embodiments, UWB positioning transceivers 912 and/or wearable device 902 may be configured to perform ranging measurements (e.g., round-trip Time (RTT), received signal strength indicator (RSSI), time difference of arrival (TDOA), etc.), which may be used for trilateration, multilateration, or other distance-based positioning techniques. In some embodiments, the building control system 900 may be capable of determining a location of the wearable device 902 with UWB positioning transceivers 912 using angle-based positioning techniques, distance-based positioning techniques, or hybrid (combination) thereof.

[0180] The determination of the position of the wearable device 902 within a building may be

facilitated by positioning functionality 914. As previously noted, positioning functionality 914 (and/or the functionality at blocks 916-920) may be performed by one or more servers and/or controllers communicatively coupled with the cloud 901. The positioning functionality 914 may comprise a server or controller capable of coordinating positioning sessions between the wearable device 902 and UWB positioning transceivers 912, enabling the wearable device 902 and/or UWB positioning transceivers 912 to perform measurements of RF signals from which the position of the wearable device 902 may be determined (e.g., geometrically). In some embodiments, the wearable device 902 and/or UWB positioning transceivers 912 may report measurements to the positioning functionality 914, enabling the positioning functionality 914 to calculate the position of the wearable device 902. In some embodiments, positioning functionality 914 may provide information to the wearable device 902 and/or UWB positioning transceivers 912 to enable the wearable device 902 and/or UWB positioning transceivers 912 to calculate the position of the wearable device 902. Such information can include, for example, the known position of the UWB positioning transceivers 912, precise timing of the transmission of RF signals, etc. In some embodiments, UWB positioning transceivers 912 may transmit RF signals for positioning in a synchronized manner. In such embodiments, the positioning functionality 914 may be used to synchronize the UWB positioning transceivers 912. Additional details regarding UWB positioning are provided hereafter.

[0181] Application functionality 916 may comprise server-side functionality for supporting the client app 906 executed by the control device 904 and/or applications executed by other devices that may be used to control one or more aspects of the building control system 900 and/or obtain information from the building control system 900. In some embodiments, an application may be provided to a healthcare provider (e.g., primary care physician), staff member, family member, or other interested party, who may be local to or remote from the building of the building control system 900, in which the patient (wearer of the wearable device 902) is located. This can allow interested parties to monitor certain data of the patient, such as health-related information (e.g., from sensor data of sensors of the wearable device 902), location information (e.g., a specific location of the patient within the building), and so forth. The application functionality 916 can gather this information (e.g., from the wearable device 902, positioning functionality 914, etc.) and relay it to authorized interested parties via applications and/or the Internet. Additional details regarding the application are provided hereafter with respect to Fig. 11.

[0182] Environmental control functionality 918 may comprise computer-controlled monitoring, oversight, or control of one or more environmental systems of the building control system 900, or a combination thereof. Environmental systems within the building control system 900 (also referred to as “building systems” herein) may comprise any system capable of altering an environmental aspect of one or more spaces within the building. This can include, for example, HVAC systems, lighting systems, window control systems, and the like. According to some

embodiments, the environmental control functionality 918 may allow a user (e.g., patient, staff member, etc.) to control temperature, humidity, light, brightness, tinting of a window, other environmental aspects, or a combination thereof, of one or more rooms within a building. This may be conditioned, for example, on user authorization for such control. According to some embodiments, environmental control functionality 919 may therefore comprise a database that can be used to maintain and update authorization for environmental control of different users. According to some embodiments, environmental control functionality 918 may comprise a database to store user profiles, which may include preferences for particular profile of environmental settings (temperature, humidity, lighting, etc.). In some embodiments, the building control system 900 may automatically adjust one or more environmental aspects of a room in which the wearable device 902 is located based on one or more preferences of a user of the wearable device 902, based on an identity of the user and the user's corresponding preferences. In some embodiments, the building control system 900 may adjust the one or more environmental aspects in a particular room only if the patient has been granted authorization for adjusting environmental aspects of that room. In some embodiments, for example, a patient may be limited to adjusting environment aspects of the patient's individual room. Additionally or alternatively, the building control system 900 may adjust the one or more environmental aspects in a particular room in which the wearable device 902 is located based on a physiological condition of the user (e.g., as determined from sensors of the wearable device 902) in addition to a voice command and/or physical gesture. In some embodiments, for instance, an audio and/or visual prompt may be given to the user (the e.g., via the wearable device and/or a device in the room, such as a TV, touchscreen device, smart speaker, etc.) once a certain physiological condition of the user has been detected. (E.g., asking whether the user wants to cool the room if it is determined that the user's temperature is above a certain threshold.)

[0183] The user's preferences may be obtained in various ways. In some embodiments, the user (patient) may enter preferences directly using a client app 906 executed by control device 904. Other authorized personnel (e.g., a physician, caregiver, family member, etc.) may enter preferences for the user as well, using a control device 904 and/or a remote device (e.g., via a web portal). In some embodiments, user preferences may be derived from historical data of the user's input/settings for different building systems (e.g., temperature settings, media settings, etc.). As described in more detail hereafter, machine learning may be used to derive user preferences from historical data.

[0184] Medical monitoring functionality 920 may comprise computer-controlled monitoring of patient health based on sensor data (e.g., from the wearable device 902 and/or sensor(s) 908). Medical monitoring functionality 920 may track vital signs for a patient wearing the wearable device 902 as well as performing other analysis of sensor data for current and/or historical data or trends that may be indicative of patient health. In some embodiments, medical monitoring functionality 920 may also analyze medical data to determine a comfort level of the patient. For

example, the medical monitoring functionality 920 may monitor the patient's temperature to determine whether the patient may feel too hot or too cold, in which case the medical monitoring functionality 920 may communicate with the environmental control functionality 918 to adjust the temperature of the room accordingly (this may include controlling HVAC systems to control the flow of heat or air conditioning into the location and/or controlling one or more tintable windows at or near the location to increase or decrease tinting and thereby decrease or increase, respectively, the heat gain through the one or more tintable windows). In another example, medical monitoring functionality 920 may monitor the patient's oxygen levels and communicate with the environmental control functionality 918 to increase oxygen to the room (e.g., via HVAC systems) or to the patient (e.g., via a controllable device 910 administering oxygen to the patient) if the patient's oxygen levels drop below a threshold.

[0185] In some embodiments, data analysis performed by the blocks 914-920 and/or other devices described herein may use machine learning (ML).

[0186] Fig. 10 is a block diagram of a building control system 1000 (similar to Fig. 9) superimposed on a simplified overhead view of a facility 1005, to provide some physical context for various components of a building control system in an example use case. In this example, a patient 1010 wearing a wearable device 1015 is located within a room 1020 of the facility 1005. As discussed in the previously-described embodiments, the wearable device 1015, may be communicatively coupled with a control device 1017 executing a client application, which may allow the patient 1010 to control at least some functionality of the wearable device 1015 via a user interface (e.g., a graphical user interface (GUI) shown on a touchscreen of the control device 1017). The functionality of the application at the control device 1017 may be enabled, in part, by application functionality 1018. The control device 1017 may be communicatively coupled with the application functionality 1018 via a communication link with the cloud 1019. The control device 1017 (and, in some embodiments, the wearable device 1015) may be communicatively coupled with the cloud 1019 via a wireless LAN and/or other wireless communication network of the facility 1005.

[0187] As previously indicated, the wearable device 1015 may wirelessly communicate with at least one UWB positioning transceiver 1025 to determine the location of the patient 1010. (In some instances, the wearable device 1015 may communicate with multiple UWB positioning transceivers to geometrically determine the 2D or 3D position of the wearable device 1015 (and a location of the patient 1010).) As previously discussed, the UWB positioning transceiver 1025 may be communicatively linked to the positioning functionality 1027 via the cloud 1019. According to some embodiments, portions of the cloud 1019, which may include positioning functionality 1027, may be executed by physical servers and/or other computing devices in the facility 1005.

[0188] As noted, sensors may be located throughout the facility 1005. This may include a sensor 1030 within the patient's room 1020 and/or a sensor 1035 elsewhere within the facility

1005. Including 1030 may be located in the patient's room 1020 (or other environment within the facility 1005), as well as elsewhere within the facility 1005. These sensors 1030, 1035 may sense environmental characteristics (e.g., lighting, temperature, humidity, oxygen, CO2, noise, or a combination thereof). Further, sensors 1030, 1035 may be integrated into a larger sensor ensemble, as previously discussed with regard to Fig. 6.

[0189] In the example shown in Fig. 10, the room 1020 includes a first controllable device 1040 comprising a tintable window. Additionally, a second controllable device 1045 is located within the room 1020. The second controllable device 1045 may comprise, for example, a light, a TV, a noise machine, a thermostat, etc. According to some embodiments, the patient 1010 may control the first controllable device 1040 and/or second controllable device 1045 via movement (e.g., gestures), voice commands, medical sensor data (e.g., of medical sensors of the wearable device 1015), or a combination thereof. This control may be facilitated via the environmental control functionality 1050, which may be communicatively linked to sensors 1030/1035, controllable devices 1040/1045, wearable device 1015, or any combination thereof (including other devices illustrated in FIG. 10) via the cloud 1019.

[0190] Medical monitoring functionality 1055 also may be communicatively linked with the wearable device 1015, and configured to collect medical sensor data from the wearable device 1015. As described in the embodiments herein, this can be used to control controllable devices 1040/1045 and/or enable monitoring (e.g., by nurses, staff, family, doctors, etc.) of the health status of the patient 1010.

[0191] Data analysis using ML may be performed by a machine-based system (e.g., comprising a circuitry) that may use known data (e.g., positive and/or negative datasets) to train one or more models for pose extraction, pose tracking, and/or external behavior learning, which may be used to subsequently analyze new data in the field. The model may be implemented using circuitry, such as the circuitry of a processor and/or software, such as those previously described with respect to Figs. 2-4, 6, and 8. Data analysis may include linear regression, least squares fit, Gaussian process regression, kernel regression, nonparametric multiplicative regression (NPMR), regression trees, local regression, semiparametric regression, isotonic regression, multivariate adaptive regression splines (MARS), logistic regression, robust regression, polynomial regression, stepwise regression, ridge regression, lasso regression, elasticnet regression, principal component analysis (PCA), singular value decomposition, fuzzy measure theory, Borel measure, Han measure, risk-neutral measure, Lebesgue measure, group method of data handling (GMDH), Naive Bayes classifiers, k-nearest neighbors algorithm (k-NN), support vector machines (SVMs), neural networks, support vector machines, classification and regression trees (CART), random forest, gradient boosting, or generalized linear model (GLM) technique. The data analysis may include a deep learning algorithm and/or artificial neural networks (ANN), including convolutional neural networks (CNN). The data analysis may comprise a learning schemes with a plurality of layers in the network (e.g., ANN), which may be

supervised, semi-supervised, or unsupervised. A deep learning architecture may comprise deep neural networks, deep belief networks, recurrent neural networks, or convolutional neural networks.

[0192] Fig. 11 is an illustration of screenshots of a patient interface 1100 and a doctor/nurse interface 1110 of an application, according to an embodiment. Although the illustration of 11Fig. 11 shows the screenshots on mobile phones, embodiments are not so limited. According to some embodiments, the application may be installed on any of a variety of devices, including laptops, tablets, smart phones, or the like. In some embodiments, the application may comprise a standalone software application. In some embodiments, the application may comprise a web browser, in which case the functionality of the application described herein may be provided by a web portal. As noted, the application may be executed on a control device communicatively coupled with a wearable device (e.g., control device 904/1017 connected with wearable device 902/1015).

[0193] As noted, the application may provide different information and/or functionality to different user, which may be dependent on an authorization level (e.g., permission level) of a user. Depending on desired functionality, each user may be allowed to create a user profile with a username and password. If a user profile is associated with a patient and/or a family member of the patient, for example, the application may provide the patient with the patient interface 1100. If the user profile is associated with a doctor, nurse, or other healthcare worker, the doctor/nurse interface 1110 may be provided. In some embodiments, a patient may grant a family member access to the patient interface 1100 via user settings, which may enable the patient to send a family member (e.g., via email or text) a URL with which the family member is able to set up a profile with authorization to access at least some functions of the patient interface 1100 of the patient.

[0194] The application can provide any of a variety of features to a user, depending on desired functionality, the user's authorization, etc. For example, the patient interface 1100, which may be provided to the patient and/or other authorized users, may provide real-time or near-real-time sensor data from one or more health sensors of the wearable device, such as heart rate, oxygen saturation level, etc. According to some embodiments, position information (e.g., based on GPS and/or UWB positioning) also may be provided. As illustrated, this may include a floor map with a position indicator of the patient. In some embodiments, position information may include additional or alternative information, such as a room number, floor number, latitude/longitude, etc. In some embodiments, the patient interface 1100 may also include a call button that enables the patient (or other authorized user) to call a nurse or other caregiver to the patient. The doctor/nurse interface 1110 may provide information accessible via the patient interface 1100 and/or additional information, such as historical and/or live medical sensor data, other medical information related to the patient (e.g., stored in a file of the patient), or the like.

[0195] As noted, in some embodiments, the application may allow a user to adjust one or more

environmental aspects of a room or other space within a building. For example, the application may allow a user (e.g., the patient 1010) to adjust temperature, lighting, window tint, humidity, smell, etc. of a room (e.g., room 1020) in which the patient is located. This location may be based, for example, on a current detected location of the patient (e.g., the detected location of the wearable device 1015), or based on an association of the patient with a particular room (e.g., a room to which the patient has been assigned by an authorized healthcare member). Settings made by the patient may be stored as preferences of the patient (e.g., by the environmental control functionality 1050).

[0196] Fig. 12 illustrates the different types of user groups that the application may accommodate, according to an example. These groups include medical personnel 1202, the hospital 1204, the patient 1206, a caregiver 1208, and other authorized personnel 1210. As previously indicated, the medical personnel 1202 may include a doctor, nurse, or other health provider. As such, the application may provide medical personnel 1202 with location data, medical data, and other patient-related information for locating the patient and making decisions related to the patient's health. The application may further provide medical personnel 1202 with an alert if medical sensor data is indicative of an urgent situation, such as if the heart rate or oxygen level falls below a threshold. The hospital 1204 and caregiver 1208 also may be given access to similar information to allow the hospital 1204 (or other healthcare facility) and caregiver 1208 to make informed decisions regarding the patient's health. As previously noted, the application may provide the patient 1206 health information (e.g., from the medical sensor data), location information, and access to control one or more devices and/or environmental aspects of the patient's room. This may include control of one or more devices to adjust video, music, lighting, temperature, humidity, etc. Other authorized personnel 1210 may include family members, who may be given access to the patient's location and/or health sensor information, as previously noted.

[0197] Benefits provided by the use of a wearable device according to embodiments herein may vary. For example, a system comprising a wearable device and facility network described herein can help ensure a patient is attended to and healthy at least in part by tracking the patient's vital medical information, which can be provided to doctors and nurses (and other authorized supervisors). Tracking a patient's location (e.g., in conjunction with the location of other people within a facility) can also enable contract tracing for tracking possible disease transmission. Embodiments may also enable decreasing stress and anxiety for staff by providing a positive patient experience, in part, by providing in ability to adjust entertainment and window tinting (and other aspects of the patient's environment) that can affect the patient's mood and emotions. Embodiments may enable a quick emergency response at least in part by providing location tracking of the patient and a call button (e.g., on the wearable device). Embodiments may further provide short turnaround time for a patient's vitals via live data (e.g., real time or nearly real-time medical sensor data from the wearable device) to healthcare

providers. Automatically collected medical data from a wearable device may further save time on performing tests and data entry. Medical data processed automatically using AI/ML may further facilitate analyzing and/or learning patient data. Further, some embodiments may also provide a positive patient at least in part by enabling an application to enable a control device (e.g., tablet or mobile phone) and/or wearable device to become remote control to control various devices in and/or environmental aspects of a room.

[0198] Among other benefits provided by embodiments of a wearable device coupled to a facility network as described herein, embodiments may allow for automatically controlling one or more building systems based at least in part on medical center data from the wearable device. Fig. 13 illustrates an example.

[0199] Fig. 13 is a flow diagram illustrating an example method in which building systems of a facility network are automatically controlled by data from a wearable device, according to an embodiment. Wearable device in this example may correspond with other wearable devices and sensing devices as previously described, such as sensing device 654, wristbands 700 and 702, sensing device 800, and wearable device 902/1015. In this example, the method begins with the functionality illustrated at block 1302, where a patient enters a room wearing the wearable device. Using the positioning techniques described herein (e.g., GPS and/or UWB-based positioning applied to a building map), the location of the wearable device (and thereby the location of the patient) within a building can be determined (e.g., by the wearable device, a controlling device, or a remote device, such as a positioning or application server). If the position of the patient is located within a room that may be controlled by one or more building systems, patient preferences can be used to control the one or more building systems. For example, as indicated at block 1304, application preferences can allow window tint to adjust to “tint 4” in accordance with user-specific preferences. These preferences may be based on user input into the application (e.g., specifying a particular window tint preference) and/or obtained via an analysis of historical data of settings made by the user (e.g., the patient previously setting the window tint in this room and/or other rooms to “tint 4”). According to some embodiments, preferences of a medical provider for a patient may be implemented. A medical provider, for example, may set a preference for a particular patient to have particular oxygen levels, CO2 levels, temperature, humidity etc., which may be based on a medical condition of the patient. In some embodiments, a medical provider may override specific preferences of a patient encases, for example, in which specific preferences of the patient may be detrimental to the patient’s medical condition and/or in cases where the medical provider has provided a specific preference. In this way, one or more aspects of a patient’s environment may be adjusted according to jurisdiction and/or medical requirements.

[0200] In addition to, or alternatively to, automatically implementing a patient’s preferences based on the patient’s location, embodiments may control/modify environmental aspects based on medical sensor data. For example, as indicated at block 1306, the wearable device may

further track the patient's heart rate to determine that it exceeds a given threshold for the patient. This threshold may be set, for example, based on historical data of the patient (e.g., at rest, during exercise, etc.) and/or input from a user (e.g., the patient, a doctor, etc.). Because the increased heart rate may be caused in part by increased anxiety or stress, the application may prompt a patient with a question asking if the patient would like to play calming music, as shown at block 1308. For example, the application may cause a control device (e.g., mobile device or tablet communicatively coupled with the wearable device) to display a prompt to play calming music on a touchscreen. This determination may be made at the control device, for example, based on a determination that the heart rate exceeded a threshold (at block 1306). At block 1310, responsive to a user providing input to play the music (e.g., selecting to play music via a touchscreen), the music is played to keep the patient comfortable. To play the music, a control device executing the client application may communicate directly with an in-room device to play music, or may communicate with a server and/or controller of the building (e.g., executing application functionality and/or environmental control functionality) that controls a device that plays music (e.g., television, radio, or speaker) in the room in which the patient is located. At block 1312, the patient further has the option to change or modify one or more aspects of the environment. That is, as previously explained, the application may provide further functionality to a patient to control devices in and/or environmental aspects of a room in which the patient is located. This can include causing a control device to operate as a remote control for various devices within the room, as well as a control for window tint, lighting, temperature, humidity, oxygen and/or CO2, other environmental aspects of the room, or a combination thereof.

[0201] Fig. 14 shows a flowchart of an example method 1400 for sensor-based control of one or more aspects of an environment of a facility, according to an embodiment. Operations may be performed, for example, by a server or other computer system (e.g., as depicted in Fig. 2), controller (e.g., as depicted in Figs. 3 and 4), sensor ensemble (e.g., as depicted in Fig. 6), control device (e.g., as depicted in Figs. 9 and 10), or the like. Some operations may also be performed by a wearable device or sensing device as described herein (e.g., as depicted in in Figs. 6-10). The method 1400 may begin with the functionality illustrated in block 1402, where biometric sensor data is obtained from one or more sensors of the wearable device worn by a user in a facility. As described in previous embodiments, the one or more sensors may comprise biometric or medical sensors capable of obtaining various biometric/medical data from the user. As such, in some embodiments, the one or more sensors may comprise a sensor configured to measure a sugar level of the user, a heart rate of the user, a step count of the user, a blood pressure of the user, a blood oxygen level of the user, a temperature of the user, a pulse of the user, or a combination thereof. In some embodiments, obtaining the sensor data may comprise receiving the sensor data from the wearable device and/or from a control device communicatively coupled with the wearable device. The control device may comprise a

controller of the facility, a mobile phone, laptop, or tablet.

[0202] At block 1404, the functionality comprises determining, based on the sensor data, a physiological condition of the user. As noted in previously described embodiments, such physiological conditions may comprise physiological conditions indicative of an unhealthy or undesirable state of health. Such physiological conditions may include low oxygen level or blood pressure, heart rate, temperature, or a combination thereof, outside of healthy ranges, or may include conditions correlated with such data, such as stress, anxiety, etc. Physiological conditions may be heuristically determined based on various thresholds and/or ranges for sensor values, which may be personalized to a particular patient or set globally for all patients. In some embodiments, ML/AI may be used to analyze sensor data and learn physiological conditions of a particular patient.

[0203] At block 1406, the functionality comprises determining a location of the user within the facility based on one or more RF signals transmitted from the wearable device and/or one or more RF signals received by the wearable device. As described in previous embodiments, RF signals received by the wearable device used to determine the position of the wearable device may comprise RF signals from GPS (and/or other GNSS) satellites and/or signals transmitted by wireless beacons (e.g., UWB beacons) within the facility. RF signals transmitted by the wearable device may be sent to receivers (e.g., UWB receivers) located throughout the building. The position of the wearable device may be determined using geometric techniques, such as multi-angulation and/or multi-lateration. In some embodiments, the location of the wearable device may be determined by the wearable device and sent to a controller or server. In some embodiments, the location of the wearable device may be determined by a controller or server. A location of the wearable device may then be mapped to a location within a building (e.g., a room or other enclosure within the building) to identify where, within the facility, the user is located.

[0204] At block 1408, the functionality comprises adjusting an environmental control of the location based at least in part on the physiological condition of the user. Adjusting an environmental control of the location may comprise adjusting a setting of a building system that controls an environmental aspect of the location. Thus, according to some embodiments of the method 1400, adjusting the environmental control of the location may comprise determining a building system associated with the location and causing the building system to adjust the environmental control. The building system may comprise a system controlling heating, ventilation, and air conditioning (HVAC) of the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a degree of window tint at the location; or a combination thereof. The building system may comprise a device ensemble having a housing that encloses the one or more devices that comprise: (i) sensors, (ii) a transceiver, (iii) a sensor and an emitter, or (iv) a combination thereof. The device ensemble may be disposed in or on a fixture of the facility or may be

attached to a fixture of the facility. The building system may comprise a tintable window. The tintable window may comprise an electrochromic window. In some embodiments, adjusting the environmental control of the location comprises adjusting a temperature, window tint, lighting, or a combination thereof, at the location. The environmental control of the location may be further based on a user preference. In some embodiments, the method 1400 may further comprise determining an identity of the user based on an association of the user with the wearable device; and determining the user preference based on the identity of the user wherein adjusting the environmental control of the location is further based on the user preference. In some embodiments, the user preference may comprise a temperature setting, a window tint setting, a lighting setting, or a combination thereof. In some embodiments the lighting setting comprises a brightness and/or color of light.

[0205] Fig. 15A shows an example of a user interacting with a device 1505 for controlling status of a target that is the optical state of electrochromic windows 1500a-1500d. In this example, the device 1505 is a wall device as described above. In some embodiments, the wall device is or includes a smart device such as an electronic tablet or similar device. Device 1505 may be a device configured to control the electrochromic windows 1500a-1100d, including but not limited to a smartphone, tablet, laptop, PC, etc. The device 1505 may run an application/program that is configured to control the electrochromic windows. In some embodiments, the device 1505 communicates with an access point 1510, for example through a wired connection or a wireless connection (e.g., WiFi, Bluetooth, Bluetooth low energy, ZigBee, WiMax, etc.). The wireless connection can allow at least one apparatus (e.g., target apparatus) to connect to the network, connect to the internet, communicate with one another wirelessly within an area (e.g., within a range), or a combination thereof. The access point 1510 may be a networking hardware device that allows a Wi-Fi compliant device to connect to a wired network. The device 1505 may communicate with a controller (e.g., a window controller, NC, MC, or a combination thereof) through a connection scheme.

[0206] In some embodiments, the access point is connected to a switch to accomplish network communication between the control device of a user (e.g., a mobile circuitry) and a control unit for the target (e.g., window, media, or other appliance) to receive a command. For example, the switch may be connected to a router and/or the control unit. The connections between the different elements may be wired and/or wireless, as appropriate for a particular application. For example, the access point may be a wireless access point, and the connection between the access point and the device may be wireless. In some embodiments, the device may be any number of electronic devices configured to control a status of a target (e.g., such as a media, or the electrochromic windows). The router may include firewall protection to enhance security. The control unit may be a window controller, NC, or MC. If the control unit is not a window controller, it may relay instructions to relevant window controllers over the network, for example.

[0207] Fig. 15B shows an example of a device 1505 connected to an access point 1510, which

is further connected to a switch 1515. Switch 1515 may be connected to both router 1520 and controller (i.e., control unit) 1525. Router 1520 may include firewall protection to enhance security. The controller 1525 may be a window controller, NC, or MC. If the controller 1525 is not a window controller, the controller 1525 may relay instructions to relevant window controllers over the network.

[0208] Fig. 16A shows an example wherein the device 1605 is connected to access point 1610, which is connected to controller 1625. Each of these connections may be wired and/or wireless. Fig. 16B shows an example wherein the device 1605 is directly connected to the controller 1625. This connection may be wired and/or wireless. Fig 16C shows an example wherein device 1605 is connected to the cloud 1630 (e.g., the Internet). The cloud 1630 is also connected with router 1620, which is connected to switch 1615, which is connected to controller 1625. The connections may be wired and/or wireless, as appropriate for a particular application. In a particular example, the device 1605 can be a smartphone, which connects wirelessly (e.g., via a communication network that is capable of transmitting at least a third, fourth, or fifth generation communication (e.g., 3G, 4G, or 5G communication)) with the cloud 1630.

[0209] In some embodiments, the interactive systems to be controlled by a user include media (e.g., visual and/or audio content) for display, e.g., to building occupants. The display may include stills or video projection arrangements. The display may include transparent organic light-emitting devices (TOLED). The display may be integrated as a display construct with window panel(s) (e.g., frame(s)). Examples of display constructs can be found in U.S. provisional patent application serial number 62/975,706 filed on February 12, 2020, titled "TANDEM VISION WINDOW AND MEDIA DISPLAY," that is incorporated herein in its entirety.

[0210] In some embodiments, a display construct is coupled with a viewing (e.g., a tintable viewing) window. The viewing window may include an insulated glass unit (IGU). The display construct may include one or more glass panes. The display (e.g., display matrix) may comprise a light emitting diode (LED). The LED may comprise an organic material (e.g., organic light emitting diode abbreviated herein as "OLED"). The OLED may comprise a transparent organic light emitting diode display (abbreviated herein as "TOLED"), which TOLED is at least partially transparent. The display may have at its fundamental length scale 2000, 3000, 4000, 5000, 6000, 7000, or 8000 pixels. The display may have at its fundamental length scale any number of pixels between the aforementioned number of pixels (e.g., from about 2000 pixels to about 4000 pixels, from about 4000 pixels to about 8000 pixels, or from about 2000 pixels to about 8000 pixels). A fundamental length scale may comprise a diameter of a bounding circle, a length, a width, or a height. The fundamental length scale may be abbreviated herein as "FLS." The display construct may comprise a high resolution display. For example, the display construct may have a resolution of at least about 550, 576, 680, 720, 768, 1024, 1080, 1920, 1280, 2160, 3840, 4096, 4320, or 7680 pixels, by at least about 550, 576, 680, 720, 768, 1024, 1080, 1280, 1920, 2160, 3840, 4096, 4320, or 7680 pixels (at 30Hz or at 60Hz). The first number of pixels

may designate the height of the display and the second pixels may designates the length of the display. For example, the display may be a high resolution display having a resolution of 1920 × 1080, 3840 × 2160, 4096 × 2160, or 7680 × 4320. The display may be a standard definition display, enhanced definition display, high definition display, or an ultra-high definition display. The display may be rectangular. The image projected by the display matrix may be refreshed at a frequency (e.g., at a refresh rate) of at least about 20 Hz, 30 Hz, 60 Hz, 70 Hz, 75 Hz, 80 Hz, 100 Hz, or 120 Hertz (Hz). The FLS of the display construct may be at least 20", 25", 30", 35", 40", 45", 50", 55", 60", 65", 80", or 90 inches ("). The FLS of the display construct can be of any value between the aforementioned values (e.g., from about 20" to about 55", from about 55" to about 100", or from about 20" to about 100").

[0211] In some embodiments, at least a portion of a window surface in a facility is utilized to display the various media using the glass display construct. The display may be utilized for (e.g., at least partial) viewing an environment external to the window (e.g., outdoor environment), e.g. when the display is not operating. The display may be used to display media (e.g., as disclosed herein), to augment the external view with (e.g., optical) overlays, augmented reality, lighting (e.g., the display may act as a light source), or a combination thereof. The media may be used for entertainment and non-entertainment purposes. The media may be used for video conferencing. For example, the media may be used for work (e.g., data analysis, drafting, video conferencing, or a combination thereof). For example, the media may be used for educational, health, safety, purchasing, monetary, or entertainment purposes. The media may present personnel not at the enclosure in which the media display is disposed (e.g., remote employees). The media may present personnel at the enclosure in which the media display is disposed. For example, the media display may mirror the personnel (e.g., and their actions such as in real time) in the enclosure in which the media display and the local personals are disposed. The media may be used as a coaching tool by mirroring the local personnel. For example, the mirroring media may serve as a fitness coaching tool, a speech coaching tool, a posture coaching tool, a behavioral coaching tool, or a combination thereof. The media may present personnel at the enclosure in which the media display is disposed and remote personnel, e.g., in a collage, overlayed, or bifurcated display, or a combination thereof. The media may be manipulated (e.g., by utilizing the display construct). Utilizing the display construct can be direct or indirect. Indirect utilization of the media may be using an input device such as an electronic mouse, or a keyboard. The input device may be communicatively (e.g., wired and/or wirelessly) coupled to the media. Direct utilization may be by using the display construct as a touch screen using a user (e.g., finger) or a contacting device (e.g., an electronic pen or stylus).

[0212] In some embodiments, the media may be displayed by a transparent media display construct. The transparent display construct that is configured to display media, may be disposed on, or coupled (e.g., attached) to, a window, a door, a wall, a divider, or to any other

architectural element of a facility. The architectural element may be a fixture or a non-fixture. The architectural element (e.g., window, wall, or divider) may be static or mobile (e.g., a moving window or door). The architectural element may comprise a tintable window. The architectural element may comprise a tintable substance (e.g., an optically switchable device such as an electrochromic device). The optically switchable device may alter its transparency, absorbance, or color, e.g., at least in the visible spectrum. A user may control the usage of the media and/or tint state of the architectural element, e.g., separately or as linked to each other. A user in one enclosure looking out of the enclosure through the transparent media display, may optionally see both the media, and the external environment of the enclosure through the media display.

[0213] Embodiments described herein relate to vision windows with a tandem (e.g., transparent) display construct. In certain embodiments, the vision window is an electrochromic window. The electrochromic window may comprise a solid state and/or inorganic electrochromic (EC) device. The vision window may be in the form of an IGU. When the IGU includes an electrochromic (abbreviated herein as “EC”) device, it may be termed an “EC IGU.” The EC IGU can tint (e.g., darken) a room in which it is disposed and/or provide a tinted (e.g., darker) background as compared to a non-tinted IGU. The tinted IGU can provide a background preferable (e.g., necessary) for acceptable (e.g., good) contrast on the (e.g., transparent) display construct. In another example, windows with (e.g., transparent) display constructs can replace televisions (abbreviated herein as “TVs”) in commercial and residential applications. Together, the (e.g., transparent) display construct and EC IGU can provide visual privacy glass function, e.g. because the display can augment the privacy provided by EC glass alone.

[0214] Fig. 17A shows an example of a window 1702 framed in a window frame 1703, and a fastener structure 1704 comprising a first hinge 1705a and a second hinge 1705b, which hinges facilitate rotating display construct 1701 about the hinge axis, e.g., in a direction of arrow 1711. The window may be a smart window such as an electrochromic (EC) window. The window may be in the form of an EC IGU. In one embodiment, mounted to window frame (e.g., 1703) is one or more display constructs (e.g., transparent display) (e.g., 1701) that is transparent at least in part. In one embodiment, the one or more display constructs (e.g., transparent display) comprises T-OLED technology, but it should be understood that the present invention should not be limited by or to such technology. In one embodiment, one or more display constructs (e.g., transparent display) is mounted to frame (e.g., 1703) via a fastener structure (e.g., 1704). In one embodiment the fastener structure (also referred to herein as a “fastener”) comprises a bracket. In one embodiment, the fastener structure comprises an L-bracket. In one embodiment, L-bracket comprises a length that approximates or equals a length of a side of window (e.g., and in the example shown in Fig13A, also the length of the fastener structure 1704). In embodiments, the fundamental length scale (e.g., length) of a window is at most about 60 feet (‘), 50’, 40’, 30’, 25’, 20’, 15’, 10’, 5’ or 1’. The FLS of the window can be of any value between the aforementioned values (e.g., from 1’ to 60’, from 1’ to 30’, from 30’ to 60’, or from 10’ to 40’).

In embodiments, the fundamental length scale (e.g., length) of a window is at least about 60', 80', or 100'. In one embodiment, the display construct (e.g., transparent display) encompasses an area that (e.g., substantially) matches a surface area of the lite (e.g., pane).

[0215] Fig. 17B shows an example of various windows in a facade 1720 of a building, which facade comprises windows 1722, 1723, and 1721, and display constructs 1, 2, and 3. In the example shown in Fig. 17B, display construct 1 is transparent at least in part and is disposed over window 1723 (e.g., display construct 1 is super positioned over window 1723) such that the entirety of window 1723 is covered by the display construct, and a user can view through the display construct 1 and the window 1723 the external environment (e.g., flowers, glass, and trees). Display construct 1 is coupled to the window with a fastener 1731 that facilitates rotation of the display construct about an axis parallel to the window top horizontal edge 1730, which rotation is in the direction of arrow 1727. In the example shown in Fig. 17B, display constructs 2 and 3 are transparent at least in part and are disposed over window 1721 such that the entirety of window 1721 is covered by the two display construct each covering (e.g., extending to) about half of the surface area of window 1721, and a user can view through the display constructs 2 and 3 and the window 1721 the external environment (e.g., flowers, glass, and trees). Display construct 2 is coupled to the window 1721 with a fastener that facilitates rotation of the display construct about an axis parallel to the window left vertical edge, which rotation is in the direction of arrow 1726. Display construct 3 is coupled to the window with a fastener that facilitates rotation of the display construct about an axis parallel to the window 1721 right vertical edge, which rotation is in the direction of arrow 1725.

[0216] In some embodiments, the display construct comprises a hardened transparent material such as plastic or glass. The glass may be in the form of one or more glass panes. For example, the display construct may include a display matrix (e.g., an array of lights) disposed between two glass panes. The array of lights may include an array of colored lights. For example, an array of red, green, and blue colored lights. For example, an array of cyan, magenta, and yellow colored lights. The array of lights may include light colors used in electronic screen display. The array of lights may comprise an array of LEDs (e.g., OLEDs, e.g., TOLEDs). The matrix display (e.g., array of lights) may be at least partially transparent (e.g., to an average human eye). The transparent OLED may facilitate transition of a substantial portion (e.g., greater than about 30%, 40%, 50%, 60%, 80%, 90% or 95%) of the intensity and/or wavelength to which an average human eye senses. The matrix display may form minimal disturbance to a user looking through the array. The array of lights may form minimal disturbance to a user looking through a window on which the array is disposed. The display matrix (e.g., array of lights) may be maximally transparent. At least one glass pane of the display construct may be of a regular glass thickness. The regular glass may have a thickness of at least about 1 millimeters (mm), 2mm, 3mm, 4mm, 5mm, or 6 mm. The regular glass may have a thickness of a value between any of the aforementioned values (e.g., from 1mm to 6mm,

from 1mm to 3mm, from 3mm to about 4mm, or from 4mm to 6mm). At least one glass pane of the display construct may be of a thin glass thickness. The thin glass may have a thickness of at most about 0.4 millimeters (mm), 0.5 mm, 0.6 mm, 0.7 mm, 0.8mm, or 0.9mm thick. The thin glass may have a thickness of a value between any of the aforementioned values (e.g., from 0.4mm to 0.9mm, from 0.4mm to 0.7mm, or from 0.5mm to 0.9mm). The glass of the display construct may be at least transmissive (e.g., in the visible spectrum). For example, the glass may be at least about 80%, 85%, 90%, 95%, or 99% transmissive. The glass may have a transmissivity percentage value between any of the aforementioned percentages (e.g., from about 80% to about 99%). The display construct may comprise one or more panes (e.g., glass panes). For example, the display construct may comprise a plurality (e.g., two) of panes. The glass panes may have (e.g., substantially) the same thickness, or different thickness. The front facing pane may be thicker than the back facing pane. The back facing pane may be thicker than the front facing pane. Front may be in a direction of a prospective viewer (e.g., in front of display construct 101, looking at display construct 101). Back may be in the direction of a (e.g., tintable) window (e.g., 102). One glass may be thicker relative to another glass. The thicker glass may be at least about 1.25*, 1.5*, 2*, 2.5*, 3*, 3.5*, or 4* thicker than the thinner glass. The symbol "*" designates the mathematical operation of "times." The transmissivity of the display construct (that including the one or more panes and the display matrix (e.g., light-array or LCD)) may be of at least about 20%, 30%, 35%, 40%, 45%, 50%, 60%, 70%, 80%, or 90%. The display construct may have a transmissivity percentage value between any of the aforementioned percentages (e.g., from about 20% to about 90%, from about 20% to about 50%, from about 20% to about 40%, from about 30% to about 40%, from about 40% to about 80%, or from about 50% to about 90%). A higher transmissivity parentage refers higher intensity and/or broader spectrum of light that passes through a material (e.g., glass). The transmissivity may be of visible light. The transmissivity may be measured as visible transmittance (abbreviated herein as "Tvis") referring to the amount of light in the visible portion of the spectrum that passes through a material. The transmissivity may be relative to the intensity of incoming light. The display construct may transmit at least about 80%, 85%, 90%, 95%, or 99% of the visible spectrum of light (e.g., wavelength spectrum) therethrough. The display construct may transmit a percentage value between any of the aforementioned percentages (e.g., from about 80% to about 99%). In some embodiments, instead of an array of lights, a liquid crystal display is utilized.

[0217] Fig. 18 shows a schematic example of a display construct assembly 1800 prior to its lamination, which display construct that includes a thicker glass pane 1805, a first adhesive layer 1804, a display matrix 1803, a second adhesive layer 1802, and a thinner glass pane 1801, which matrix is connected via wiring 1811 to a circuitry 1812 that controls at least an aspect of the display construct, which display construct is coupled to a fastener 1813.

[0218] In some embodiments, diverse types of interfaces are employed for providing user

control of interactive targets (e.g., systems, devices, media, or a combination thereof). The interactive targets can be controlled, e.g., using control interface(s). The control interface may be local and/or remote. The control interface may be communicated through the network. The control system may be communicatively coupled to the network, to which the target(s) are communicatively coupled. An example of a control interface comprises manipulating a digital twin (e.g., representative model) of a facility. For example, one or more interactive devices (e.g., optically switchable windows, sensors, emitters, media displays, or a combination thereof) may be controlled using a mobile circuitry. The mobile circuitry may comprise a gaming-type controller (e.g., a pointing device) or a virtual reality (VR) user interface. When an additional new device is installed in the facility (e.g. in a room thereof) and is coupled to the network, the new target (e.g., device) may be detected (e.g., and included into the digital twin). The detection of the new target and/or inclusion of the new target into the digital twin may be done automatically and/or manually. For example, the detection of the new target and/or inclusion of the new target into the digital twin may be without requiring (e.g., any) manual intervention.

[0219] In some embodiments, a digital twin comprises a digital model of the facility. The digital twin is comprised of a virtual three dimensional (3D) model of the facility. The facility may include static and/or dynamic elements. For example, the static elements may include representations of a structural feature of the facility and the dynamic elements may include representations of an interactive device with a controllable feature. The 3D model may include visual elements. The visual elements may represent facility fixture(s). The fixture may comprise a wall, a floor, wall, door, shelf, a structural (e.g., walk-in) closet, a fixed lamp, electrical panel, elevator shaft, or a window. The fixtures may be affixed to the structure. The visual elements may represent non-fixture(s). The non-fixtures may comprise a person, a chair, a movable lamp, a table, a sofa, a movable closet or a media projection. The visual elements may represent facility features comprising a floor, wall, door, window, furniture, appliance, people, or interactive target(s), or a combination thereof). The digital twin may be similar to virtual worlds used in computer gaming and simulations, representing the environment of the real facility. Creation of a 3D model may include the analysis of a Building Information Modeling (BIM) model (e.g., an Autodesk Revit file having *.RVT format), e.g., to derive a representation of (e.g., basic) fixed structures and movable items such as doors, windows, and elevators. The 3D mode may comprise architectural details related to the design of the facility, such as a 3D model, elevation details, floor plans, project settings, or a combination thereof, related to the facility. The 3D model may comprise annotation (e.g., with two dimensional (2D) drafting element(s)). The 3D model may facilitate access to information from a model database of the facility. The 3D model may be utilized for planning and/or tracking various stages in the lifecycle of the facility (e.g., facility concept, construction, maintenance, demolition, or a combination thereof). The 3D model may be updated during the lifecycle of the facility. The update may be periodically, intermittently, on occurrence of an event (e.g., relating to the structural status of the facility), in real time, on

availability of manpower, at a whim, or a combination thereof. The digital twin may comprise the 3D model, and may be updated in relation to (e.g., when) the 3D model of the facility is updated. The digital twin may be linked to the 3D model (e.g., and thus linked to its updates). In real time may include within at most 15seconds (sec.), 30sec., 45sec., 1minute (min), 2min., 3min. 4min., 5min, 10min., 15min. or 30min. from the occurrence of a change in the enclosure (e.g., a change initiated by the user).

[0220] In some embodiments, the digital twin (e.g., 3D model of the facility) is defined at least in part by using one or more sensors (e.g., optical, acoustic, pressure, gas velocity, or distance measuring sensor(s), or a combination thereof), to determine the layout of the real facility. Usage of sensor data can be used exclusively to model the environment of the enclosure. Usage of sensor data can be used in conjunction with a 3D model of the facility (e.g., (BIM model) to model the environment of the enclosure. The BIM model of the facility may be obtained before, during, or after the facility has been constructed, or a combination thereof. The BIM model of the facility can be updated (e.g., manually and/or using the sensor data) during operation of the facility (e.g., in real time). In real time may include, during occurrence of a change of, or in, the facility. In real time may include within at most 2h, 4h, 6h, 8h, 12h, 24h, 36h, 48h, 60h, or 72h from the occurrence of a change of, or in, the facility.

[0221] In some embodiments, dynamic elements in the digital twin include target (e.g., device) settings. The target setting may comprise (e.g., existing and/or predetermined): tint values, temperature settings, light switch settings, or a combination thereof. The target settings may comprise available actions in media displays. The available actions may comprise menu items or hotspots in displayed content. The digital twin may include virtual representation of the target and/or of movable objects (e.g., chairs or doors), and/or occupants (actual images from an imaging system or from stored avatars). In some embodiments, the dynamic elements can be targets (e.g., devices) that are newly plugged into the network, and/or disappear from the network (e.g., due to a malfunction or relocation). The digital twin can reside in any circuitry (e.g., processor) operatively coupled to the network. The circuitry in which the digital circuitry resides may be in the facility, outside of the facility, in the cloud, or a combination thereof. In some embodiments, a two-way link is maintained between the digital twin and a real circuitry. The real circuitry may be part of the control system. The real circuitry may be included in the MC, NC, floor controller, local controller, or in any other node in a processing system (e.g., in the facility or outside of the facility). For example, the two-way link can be used by the real circuitry to inform the digital twin of changes in the dynamic and/or static elements so that the 3D representation of the enclosure can be updated, e.g., in real time. In real time may include, during occurrence of a change of, or in, the enclosure. In real time may include within at most 15seconds (sec.), 30sec., 45sec., 1minute (min), 2min., 3min. 4min., 5min, 10min., 15min. or 30min. from the occurrence of a change in, the enclosure. The two-way link may be used by the digital twin to inform the real circuitry of manipulative (e.g., control) actions entered by a user on

a mobile circuitry. The mobile circuitry can be a remote controller (e.g., comprising a handheld pointer, manual input buttons, or touchscreen).

[0222] In some embodiments, one or more mobile circuitry devices of a user are aligned with (e.g., linked to) the virtual 3D "digital twin" model of the facility (or any portion thereof), e.g., via WiFi or other network connections. The mobile circuitry may comprise a remote (e.g., mobile) control interface. The mobile circuitry may include a pointer, gaming controller, virtual reality (VR) controller, or a combination thereof. For example, the mobile circuitry may have no interaction with the physical facility, e.g., other than forwarding network communications via the aligned communication channel to and/or from the digital twin. The user interaction may not be direct and/or physical with any device being controlled in the enclosure. The user interaction of the user with the target may be indirect. The interaction of the user with the target may be devoid of tactile touch, optical ray projection, vocal sound, or a combination thereof. The control actions taken by the user to control the target may be based at least in part on a relative position of the digital circuitry manipulated by a user, relative to the modeled space in the digital twin (e.g., virtual movement within the modeled enclosure). The control actions taken by the user to control the target may be not based on (e.g. and are oblivious to) the spatial relationship between the user and the digital twin. For example, a user may use a remote control pointing device, and point to a presentation portion. The presentation may be displayed on a TOLED display construct disposed in the line of sight between a user and a window (e.g., smart window). The coupling between the mobile circuitry and the target may be time based and/or may be action based. For example, the user may use the point the remote controller to the presentation, and by this couple with the presentation. The coupling may initiate on pointing in a duration that exceeds a duration threshold. The coupling may initiate by clicking the remote controller while pointing. The user may then point to a position that triggers a dropdown menu in the presentation. The dropdown menu may be visible (i) when the pointing may exceed a time threshold (ii) when the user presses button(s) on the remote controller (e.g., action based), (iii) when the user performs a gesture (e.g., as disclosed herein), or (iv) a combination thereof. The user may then choose from the menu. The choice may be initiated (i) when the pointing may exceed a time threshold (ii) when the user presses button(s) on the remote controller (e.g., action based), (iii) when the user performs a gesture (e.g., as disclosed herein), or (iv) a combination thereof. The actions of the user done in conjunction with the mobile circuitry (e.g., remote controller) may be communicated to the network, and thereby to the digital twin that is in turn communicated to the target. And thus, the user may indirectly communicate with the target through the digital twin. The mobile circuitry (e.g., remote controller) may be located with respect to the enclosure at one time, at time intervals, continuously, or a combination thereof. Once a relative location of the mobile circuitry (e.g., remote controller) with the enclosure is determined, the user may use the remote controller anywhere (e.g., inside the enclosure, or outside of the enclosure). Outside of the enclosure may comprise in the facility or outside of the

facility. For example, a conference room may establish its relative location with a remote controller. Thereafter, a user may use the relatively located remote controller to manipulate a light intensity of a light bulb disposed in the conference room while in the conference room, or while outside of the conference room (e.g., from home).

[0223] In some embodiments, the mobile circuitry (e.g., remote controller) can control a (e.g., any) interactive and/or controllable target (e.g., device) in the facility or any portion thereof, as long as (i) the target and (ii) the mobile circuitry (e.g., remote controller) are communicatively coupled to the digital twin (e.g., using the network). For example, the facility may comprise interactive targets comprising one or more sensors, emitters, tintable windows, or media displays, which devices are coupled to a communication network. In some embodiments, the user interacts with the digital twin from within the facility or from an (e.g., arbitrary) location outside the facility. For example, a remote controller device can comprise a virtual reality (VR) device, e.g., having a headset (e.g., a binocular display) and/or a handheld controller (e.g., motion sensor with or without input buttons). The mobile circuitry may comprise an Oculus Virtual Reality Player Controller (OVRPlayerController). In some embodiments, a remote control interface may be used which provides (i) visual representation to the user of the digital twin for navigation in the virtual facility, and/or (ii) user input actions for movement within the 3D model. The user input actions may include (1) pointing to an intended interactive target to be controller (e.g., to alter status of the target), (2) gestures, (3) button presses, or (4) a combination thereof, to indicate a selection action to be taken with the mobile circuitry (e.g., remote controller). The remote controller may be used to manipulate an interactive target by pointing towards them (e.g., for coupling), gesturing in other directions, pressing one or more buttons operatively coupled to the mobile circuitry (e.g., buttons disposed on an envelope of the mobile circuitry), or a combination thereof. Interfacing between the mobile circuitry and the digital twin may not be carried out through a screen depicting the digital twin. Interfacing between the user and the digital twin may not be carried out through a screen showing the digital twin. Interfacing between the mobile circuitry and the digital model may not require (e.g., any) optical sensor as facilitator). Some embodiments employ a different mode of input from augmented reality applications that operate through interaction with a screen (e.g., by using an optical sensor such as a camera).

[0224] In some embodiments, a mobile circuitry (e.g., handheld controller) without any display or screen is used, which display or screen may depict a digital representation of the enclosure and/or the target. For example, instead of virtual navigation within the enclosure by the user, the actual location of the user can be determined in order to establish the location of the user in the digital twin, e.g., to use as a reference in connection with a pointing action by the user. For example, the mobile circuitry (e.g., handheld controller) may include geographic tracking capability (e.g., GPS, UWB, BLE, dead-reckoning, or a combination thereof) so that location coordinates of the mobile circuitry can be transmitted to the digital twin using any suitable network connection established by the user between the mobile circuitry and the digital twin. For

example, a network connection may at least partly include the transport links used by a hierarchical controller network within a facility. The network connection may be separate from the controller network of the facility (e.g., using a wireless network such as a cellular network).

[0225] In some embodiments, a user may couple to a requested target. The coupling may comprise a gesture using the mobile circuitry. The coupling may comprise an electronic trigger in the mobile circuitry. The coupling may comprise a movement, pointing, clicking gesture, or any combination thereof. For example, the coupling may initiate at least in part by pointing to the target for a period of time above a threshold (e.g., that is predetermined). For example, the coupling may initiate at least in part by clicking a button (e.g., a target selection button) on a remote controller that includes the mobile circuitry. For example, the coupling may initiate at least in part by moving the mobile circuitry towards a direction of the target. For example, the coupling may initiate at least in part by pointing a frontal portion of the mobile circuitry in a direction of the target (e.g., for a time above a first threshold) and clicking a button (e.g., for a time above a second threshold). The first and second thresholds can be (e.g., substantially) the same or different.

[0226] Fig. 19 shows an example embodiment of a control system in which a real, physical enclosure (e.g., room) 1900 includes a controller network for managing interactive network devices under control of a processor 1901 (e.g., an MC). The structure and contents of enclosure 1900 are represented in a 3-D model digital twin 1902 as part of a modeling and/or simulation system executed in a computing asset. The computing asset may be co-located with or remote from enclosure 1900 and processor (e.g., MC) 1901. A network link 1903 in enclosure 1900 connects processor 1901 with a plurality of network nodes including an interactive target 1905. Interactive target 1905 is represented as a virtual object 1906 within digital twin 1902. A network link 1904 connects processor 1901 with digital twin 1902.

[0227] In the example of Fig. 19, a user located in enclosure 1900 carries a handheld control 1907 having a pointing capability (e.g., to couple with the target 1905). The location of handheld control 1907 may be tracked, for example, via a network link with digital twin 1902 (not shown). The link may include some transport media contained within network link 1903. Handheld controller 1907 is represented as a virtual handheld controller 1908 within digital twin 1902. Based at least in part on the tracked location and pointing capability of handheld controller 1907, when the user initiates a pointing event (e.g., aiming at a particular target and pressing an action button on the handheld controller) it is transmitted to digital twin 1902. Accordingly, digital twin 1902 with the target (e.g., represented as a digital ray 1909 from the tracked location within digital twin 1902). Digital ray 1909 intersects with virtual object 1906 at a point of intersection 1910. A resulting interpretation of actions made by the user in the digital twin 1902 is reported by digital twin 1902 to processor 1901 via network link 1904. In response, processor 1901 relays a control message to interactive device 1905 to initiate a commanded action in in accordance with a gesture (or other input action) made by the user.

[0228] In some embodiments, network communication among a controller (e.g., MC), digital twin, user mobile circuitry (e.g., remote controller), and local interactive devices includes mono- or bi-directional messaging capability. For example, a combination of local area networks and/or wide area networks with appropriate gateways may be configured to facilitate (i) exchanging messages, (ii) updating of a digital twin, and/or (ii) user remote interaction with a target (e.g., for remotely controlling the interactive target). The messages may be relevant to a status change of the target, and/or to users of a meeting (without or with relation to the target, without or with relation to the enclosure in which the target is disposed, and with or without relation to the subject matter of the meeting). The controller may be configured (e.g., by appropriate software programming) to interact with the digital twin. The interaction may be for providing data identifying changes to static elements and the states of dynamic elements included in the digital twin. The digital twin may be configured to provide (i) intuitive capabilities to manipulate a target remotely, (ii) a virtual reality experience to at least one user to navigate a virtual 3D model of the enclosure, (iii) to investigate various dynamic states in the digital twin, (iv) to exchange interactive (e.g., control) actions (e.g., events) related to the target, or (v) a combination thereof, which actions are initiated by at least one user, e.g., via a virtual-reality interface. The remote manipulation may or may not comprise an electromagnetic and/or acoustic beam directed from the remote controller to the target. In some embodiments, remote manipulation may be devoid of an electromagnetic and/or acoustic beam directed from the remote controller to the target. In some embodiments, the communication coupling of the remote controller with the target may be (e.g., only) through the network that is communicatively coupled to the digital twin. In some embodiments, the communication coupling of the remote controller with the target may be (e.g., only) through the digital twin (e.g., using the network as a communication pathway that communicatively coupled the target, the digital twin, and the remote controller (comprising the mobile circuitry). The communication coupling may comprise wired and/or wireless communication. The digital twin may be configured to process a user input event, e.g., (i) to identify whether it corresponds to a valid command related to the target (e.g., from a predetermined list of valid control actions of the target) and/or (ii) to forward valid commands (e.g., to at least one controller or directly to the target) for manipulating the target (e.g., manipulating a state of the target that is manipulatable). In some embodiments, at least one controller monitors its ongoing exchange of data and/or commands with the local interactive target, e.g., to collect and/or forward updated information for the digital twin. The updated information may include any dynamic change of state, e.g., resulting from remote event(s) initiated by the user(s).

[0229] In some embodiments, messaging sequences include one or more data messages and one or more command messages exchanges between (i) one or more local targets and the processor, (ii) the processor and the digital twin, (iii) the digital twin and the mobile circuitry, or (iv) a combination thereof. For example, a processor (e.g., a controller such as a MC) may send

a data message to the digital twin when one or more new targets join the network from time to time. The data may represent new static and/or dynamic elements for inclusion in the digital twin 3D model of the facility. The data may represent changes in a (e.g., system) state for a dynamic element of a target.

[0230] In some embodiments, the mobile circuitry and the digital twin exchange one or more messages that enable a user to control (including to monitor and/or alter) operation of real targets (e.g., by manipulating their virtual twin elements in digital twin). For example, a user may activate their mobile circuitry (e.g., a remote gaming controller such as a VR headset and handheld VR controller (e.g., a point and click button)) to create a link with the digital twin. In some embodiments, upon an initial connection the digital twin and mobile circuitry exchange data messages with data for displaying a simulated scene in the digital twin, e.g., according to a default starting position. For example, a virtual simulation may begin at an entrance to the enclosure, or at any other point of interest (e.g., chosen by a user). In some embodiments when the user is actually located in the enclosure being represented, the starting position may correspond to the current location of the user (e.g., an initiate message may provide geographic coordinates of a GPS-equipped user remote controller). Data or commands within messages between the mobile circuitry and the digital twin may include navigation actions (resulting in updated views being returned from the digital twin) and/or control actions (e.g., point and click) to indicate a desired change in an alterable state of a target.

[0231] In some embodiments, the digital twin validates a received control action, e.g., by mapping the control action to an indicated location in the digital twin and/or checking against a list of valid actions. For example, the digital twin may only send a message to the processor (e.g., controller) when the control action event of the user corresponds to an identifiable and authorized interaction. When a valid interaction is found, a command message may be transmitted from the digital twin to the processor (e.g., controller), and forwarded to the affected target. After executing the command, one or more acknowledgement messages may propagate back to the digital twin and the 3D model of the digital twin may optionally be updated accordingly. For example, after executing a change in a tint value of an IGU, the digital twin model of the IGU may be adjusted to show a corresponding change in tint level.

[0232] At time, it may be requested and/or advantageous to reduce (e.g., eliminate) direct contact between a user and a target apparatus (e.g., surface of the target apparatus). For example, reducing direct user interaction between the user and a target apparatus may reduce a risk of pathogen infection (e.g., fungi, virus, bacteria, or a combination thereof), which pathogen resides in the (e.g., surface) of the device. The pathogen may be contagious and/or disease causing. The target apparatus may be an interactive target. The target apparatus may be disposed in an enclosure. The target apparatus may be a third party apparatus. The target apparatus may be a service device (e.g., a device offering service(s) to a user).

[0233] In some embodiments, the target apparatus is operatively coupled to a network. The

network is operatively coupled, or includes, a control system (e.g., one or more controllers such as a hierarchal control system). In some embodiments, a mobile circuitry of a user is paired to a target apparatus (e.g., service device). The target apparatus may receive an identification tag when operatively (e.g., communicatively) coupled to the network (e.g., and to the control system). The target apparatus may be operatively coupled to a mobile circuitry through the network (e.g., using indirect coupling). The coupling between the mobile circuitry and the target apparatus may be through an application of the facility and/or of the target apparatus. There may not be a requirement for a physical proximity between the target apparatus and the mobile circuitry (e.g., and the user). The target apparatus may be selected using information related to a location of the user and/or the mobile circuitry of the user. The user may be located at a distance of at most 50 meters (m), 25m, 10 m, 5 m, 2 m, or 1.5m from the target apparatus. The user may be located at a distance between any of the above mentioned distances from the target apparatus (e.g., from about 50m to about 1.5m, from about 50m to about 25m, from about 25m to about 1.5m). The distance between the user and the target apparatus may be larger than the distance requires for pairing between devices (e.g., Bluetooth type pairing). There may be no need for any physical proximity between the user (and/or the mobile circuitry of the user), and the target apparatus (e.g., service device). The user may select the target apparatus (e.g., service device) from a list (e.g., dropdown menu). The user may be required to operatively coupled the mobile circuitry to the network to which the target apparatus is coupled. The communication between the mobile circuitry and the service device can be mono-directional (e.g., from the mobile circuitry to the target apparatus, or vice versa), or bidirectional between the target apparatus and the mobile circuitry (e.g., through the network). One user may control one or more target apparatuses (e.g., service device). One target apparatus may be controlled by one or more users. A plurality of users may send requests to one target apparatus, which requests may be placed in a que (e.g., based on a prioritization scheme such as time of receipt, urgency, user seniority, or a combination thereof).

[0234] In some embodiments, the target apparatus is identified by the network upon connection to the network (which connection may be wired and/or wireless). The target apparatus may be identified via an identification code (e.g., RFID, QR-ID, barcode). In some embodiments, the identification code is not a visible (e.g., scannable) identification code. The identification code may comprise non-contact identification (e.g., electromagnetic and/or optical). The optically recognized identification may be a machine-readable code, e.g., consisting of an array of black and white squares or lines (e.g., barcode or a Quick Response (QR) code). The electromagnetic identifier may comprise radio-frequency identification (RFID). The RFID may be ultra-high frequency RFID. The identifier may comprise a transponder (e.g., RF transponder), a receiver, a transmitter, or an antenna. The identifier may be passive or active (e.g., transmit electromagnetic radiation). The identifier may comprise near field communication (NFC).

[0235] In some embodiments, a user may control the target apparatus (e.g., service device).

For example, a user may control mechanical, electrical, electromechanical, or electromagnetic (e.g., optical and/or thermal) actions, or a combination thereof, of the target apparatus. For example, the user may control a physical action of the target apparatus. For example, the user may control if the target apparatus is turned on or off, if any controllable compartment thereof is open or closed, direct directionality (e.g., left, right, up, down), enter and/or change settings, enable or deny access, transfer data to memory, reset data in the memory, upload and/or download software or executable code to the target apparatus, cause executable code to be run by a processor associated with and/or incorporated in the target apparatus, change channels, change volume, causing an action to return to a default setting and/or mode. The user may change a set-point stored in a data set associated with the target apparatus, configure or reconfigure software associated with the target apparatus. The memory can be associated with and/or be part of the target apparatus.

[0236] In some embodiments, the target apparatus is operatively (e.g., communicatively) coupled to the network (e.g., communication, power, or control network, or a combination thereof) of the enclosure. Once the target apparatus becomes operatively coupled to the network of the enclosure, it may be part of the targets controlled via the digital twin. The new target (e.g., third party target) may offer one or more services to a user. For example, the target (e.g., target apparatus) may be a dispenser. The dispenser may dispense food, beverage, equipment, or a combination thereof, upon a command. The service device may include media players (e.g., which media may include music, video, television, internet, or a combination thereof), manufacturing equipment, medical device, exercise equipment, or a combination thereof. The target apparatus may comprise a television, recording device (e.g., video cassette recorder (VCR), digital video recorder (DVR), or any non-volatile memory), Digital Versatile Disc or Digital Video Disc (DVD) player, digital audio file player (e.g., MP3 player), cable and/or satellite converter set-top box (“STBs”), amplifier, compact disk (CD) player, game console, home lighting, electrically controlled drapery (e.g., blinds), tintable window (e.g., electrochromic window), fan, HVAC system, thermostat, personal computer, dispenser (e.g., soap, beverage, food, or equipment dispenser), washing machine, or dryer. In some embodiments, the target apparatus excludes entertainment an entertainment device (e.g., a television, recording device (e.g., video cassette recorder (VCR), digital video recorder (DVR), or any non-volatile memory), Digital Versatile Disc or Digital Video Disc (DVD) player, digital audio file player (e.g., MP3 player), cable and/or satellite converter set-top box (“STBs”), amplifier, compact disk (CD) player, and/or game console). The command may be initiated by contacting the target, or by communicating (e.g., remotely) with the target. For example, a user may press a button on the target apparatus to dispense item(s) (e.g., food, beverage, equipment, or a combination thereof). For example, a user may interact with the target apparatus through usage of the mobile circuitry. The mobile circuitry may comprise a cellular phone, a touchpad, or a laptop computer.

[0237] In some embodiments, the network may be a low latency network. The low latency network may comprise edge computing. For example, at least one (e.g., any) controller of the (e.g., hierarchal) control system can be a part of the computing system. For example, at least one (e.g., any) circuitry coupled to the network can be a part of the computing system. Latency (e.g., lag or delay) may refer to a time interval between a cause and its effect of some physical change in the system being observed. For example, latency and physically be a consequence of the limited velocity which any physical interaction can propagate. For example, latency may refer to a time interval between a stimulation and a response to the stimulus. For example, the latency may refer to a delay before a transfer of data begins following an instruction for transfer of the data. The network may comprise fiber optics. The latency may be at least about 3.33 microseconds (μs), or 5.0 μs for every kilometer of fiber optic path length. The latency of the network may be at most about 100 milliseconds (ms), 75ms, 50ms, 25ms, 10ms, 5ms, 4ms, 3ms, 2ms, 1ms, or 0.5ms. The latency of the network may be of any value between the aforementioned values (e.g., from about 100ms to about 0.5ms, from about 100ms to about 50ms, from about 50ms to about 5ms, or from about 5ms to about 0.5ms). The network may comprise a packet-switched network. The latency may be measured as he time from the source sending a packet to the destination receiving it (e.g., one way latency). The latency may be measured one-way latency from source to destination plus the one-way latency from the destination back to the source (e.g., round trip latency).

[0238] In some embodiments, the mobile circuitry includes an application related to the target apparatus (e.g., third party device). The application may depict one or more service options offered by the target apparatus. For example, if the target apparatus is a beverage dispenser, the application may offer a selection of the various beverage options offered by the target apparatus, that are available to the user. For example, if the target apparatus is a food dispenser, the application may offer a selection of the various food options offered by the target apparatus, that are available to the user. For example, if the target apparatus is a mask dispenser, the application may offer dispensing of one mask option that is available to the user.

[0239] In some embodiments, a user is locatable in the enclosure (e.g., facility such as a building). The user can be located using one or more sensors. The user may carry a tag. The tag may include radio frequency identification (e.g., RFID) technology (e.g., transceiver), Bluetooth technology, Global Positional System (GPS) technology, or a combination thereof. The radio frequency may comprise ultrawide band radio frequency. The tag may be sensed by one or more sensors disposed in the enclosure. The sensor(s) may be disposed in a device ensemble. The device ensemble may comprise a sensor or an emitter. The sensor(s) may be operatively (e.g., communicatively) coupled to the network. The network may have low latency communication, e.g., within the enclosure. The radio waves (e.g., emitted and/or sensed by the tag) may comprise wide band, or ultra-wideband radio signals. The radio waves may comprise pulse radio waves. The radio waves may comprise radio waves utilized in communication. The

radio waves may be at a medium frequency of at least about 300 kilohertz (KHz), 500 KHz, 800 KHz, 1000 KHz, 1500 KHz, 2000 KHz, or 2500 KHz. The radio waves may be at a medium frequency of at most about 500 KHz, 800 KHz, 1000 KHz, 1500 KHz, 2000 KHz, 2500 KHz, or 3000 KHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 300KHz to about 3000 KHz). The radio waves may be at a high frequency of at least about 3 megahertz (MHz), 5 MHz, 8 MHz, 10 MHz, 15 MHz, 20 MHz, or 25 MHz. The radio waves may be at a high frequency of at most about 5 MHz, 8 MHz, 10 MHz, 15 MHz, 20 MHz, 25 MHz, or 30 MHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 3MHz to about 30 MHz). The radio waves may be at a very high frequency of at least about 30 Megahertz (MHz), 50 MHz, 80 MHz, 100 MHz, 150 MHz, 200 MHz, or 250 MHz. The radio waves may be at a very high frequency of at most about 50 MHz, 80 MHz, 100 MHz, 150 MHz, 200 MHz, 250 MHz, or 300 MHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 30MHz to about 300 MHz). The radio waves may be at an ultra-high frequency of at least about 300 kilohertz (MHz), 500 MHz, 800 MHz, 1000 MHz, 1500 MHz, 2000 MHz, or 2500 MHz. The radio waves may be at an ultra-high frequency of at most about 500 MHz, 800 MHz, 1000 MHz, 1500 MHz, 2000 MHz, 2500 MHz, or 3000 MHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 300MHz to about 3000 MHz). The radio waves may be at a super high frequency of at least about 3 gigahertz (GHz), 5 GHz, 8 GHz, 10 GHz, 15 GHz, 20 GHz, or 25 GHz. The radio waves may be at a super high frequency of at most about 5 GHz, 8 GHz, 10 GHz, 15 GHz, 20 GHz, 25 GHz, or 30 GHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 3GHz to about 30 GHz).

[0240] In some embodiments, the identification tag of the occupant comprises a location device. The location device (also referred to herein as “locating device”) may compromise a radio emitter and/or receiver (e.g., a wide band, or ultra-wide band radio emitter and/or receiver). The locating device may include a Global Positioning System (GPS) device. The locating device may include a Bluetooth device. The locating device may include a radio wave transmitter and/or receiver. The radio waves may comprise wide band, or ultra-wideband radio signals. The radio waves may comprise pulse radio waves. The radio waves may comprise radio waves utilized in communication. The radio waves may be at a medium frequency of at least about 300 kilohertz (KHz), 500 KHz, 800 KHz, 1000 KHz, 1500 KHz, 2000 KHz, or 2500 KHz. The radio waves may be at a medium frequency of at most about 500 KHz, 800 KHz, 1000 KHz, 1500 KHz, 2000 KHz, 2500 KHz, or 3000 KHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 300KHz to about 3000 KHz). The radio waves may be at a high frequency of at least about 3 megahertz (MHz), 5 MHz, 8 MHz, 10 MHz, 15 MHz, 20 MHz, or 25 MHz. The radio waves may be at a high frequency of at most about 5 MHz, 8 MHz, 10 MHz, 15 MHz, 20 MHz, 25 MHz, or 30 MHz. The radio waves may be

at any frequency between the aforementioned frequency ranges (e.g., from about 3MHz to about 30 MHz). The radio waves may be at a very high frequency of at least about 30 Megahertz (MHz), 50 MHz, 80 MHz, 100 MHz, 150 MHz, 200 MHz, or 250 MHz. The radio waves may be at a very high frequency of at most about 50 MHz, 80 MHz, 100 MHz, 150 MHz, 200 MHz, 250 MHz, or 300 MHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 30MHz to about 300 MHz). The radio waves may be at an ultra-high frequency of at least about 300 kilohertz (MHz), 500 MHz, 800 MHz, 1000 MHz, 1500 MHz, 2000 MHz, or 2500 MHz. The radio waves may be at an ultra-high frequency of at most about 500 MHz, 800 MHz, 1000 MHz, 1500 MHz, 2000 MHz, 2500 MHz, or 3000 MHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 300MHz to about 3000 MHz). The radio waves may be at a super high frequency of at least about 3 gigahertz (GHz), 5 GHz, 8 GHz, 10 GHz, 15 GHz, 20 GHz, or 25 GHz. The radio waves may be at a super high frequency of at most about 5 GHz, 8 GHz, 10 GHz, 15 GHz, 20 GHz, 25 GHz, or 30 GHz. The radio waves may be at any frequency between the aforementioned frequency ranges (e.g., from about 3GHz to about 30 GHz).

[0241] In some embodiments, the locating device facilitates location within an error range. The error range of the locating device may be at most about 5 meters (m), 4m, 3m, 2m, 1m, 0.5m, 0.4m, 0.3m, 0.2m, 0.1m, or 0.05m. The error range of the locating device may be any value between the aforementioned values (e.g., from about 5m to about 0.05m, from about 5m to about 1m, from about 1m to about 0.3m, and from about 0.3m to about 0.05m). The error range may represent the accuracy of the locating device.

[0242] In some embodiments, a user seeks a service from a target apparatus that is a service device. The user may approach the service device, and open an application related to the facility (or services offered by and/or in the facility) on his mobile circuitry (e.g., handheld processor). The mobile circuitry may be operatively coupled (e.g., wirelessly) to the network. In parallel, and/or as a consequence to the opening of the application, the network may ascertain a location of the user. The location of the user may be ascertained via the mobile circuitry and/or via a tag carried by the user. The tag may transmit (e.g., emit) an identification of the user and/or the location of the user. The mobile circuitry can be a hand-held mobile circuitry (e.g., a cellular phone, laptop computer, tablet computer, gaming controller, virtual reality controller, or any other remote controller). The transmission may be sensed by one or more sensors disposed in the enclosure. Ascertaining a location of the user, the application may eligible targets (e.g., service devices) in a vicinity of the user. The user may select a requested target from the eligible targets presented by the application. Selection of the service device may allow opening its interface (e.g., and thus allow selection of its services). The user may select a requested service. The user selection may be transmitted to the service device through the network, and the service device may fulfil the request of the user. In this manner, the user is not required to physically contact the service device to perform service selection. The user may

then retrieve the fulfilled service. Alternatively, the user may disable the location of the service, and select the service device that is remote, to fulfil a request. The user may or may not view (e.g., in the application) a digital twin of the enclosure in which the service device is disposed. The user may employ gesture control to operate the service device. For example, the user may employ his mobile circuitry to point to a service choice visible on the service device, which service choice may be translated by the control system to a choice selection.

[0243] For example, a user seeks a café late drink from an automatic coffee dispenser that can prepare espresso, macchiato, cappuccino, café late, and mocha. The user approaches the coffee dispenser and opens a facility application on his cellular phone that is coupled to the facility network. In parallel, and/or as a consequence to the opening of the application, the network can ascertain a location of the user. The location of the user may be ascertained via the cellular phone of the user and/or via an identification tag carried (e.g., ID tag) by the user (e.g., tag that allows entry to the facility). The tag may transmit (e.g., emit) the identification of the user and/or the location of the user. The transmission may be sensed by one or more sensors disposed in the facility. Ascertaining a location of the user, the application may eligible targets (e.g., service devices) in a vicinity of the user. The user may select the coffee dispenser from the eligible targets presented by the application. In one option, selection of the coffee dispenser may allow opening an interface to allow selection between espresso, macchiato, cappuccino, café late, and mocha drinks. The user may select a café late. The user selection may be transmitted to the coffee dispenser through the network, and the coffee dispenser may fulfil the café late drink request of the user. In this manner, the user is not required to physically contact the coffee dispenser to perform service selection of the café late drink. The user may then retrieve the café late drink without contacting the coffee dispenser. In another option, selection of the coffee dispenser may allow viewing the room in which the coffee dispenser is located as a digital twin. The user may point the cellular device at a coffee drink option shown on the coffee dispenser. This gesture may be transmitted to the control system via the network and translated by the control system to a choice selection. The user selection may be transmitted to the coffee dispenser through the network, and the coffee dispenser may fulfil the café late drink request of the user. In this manner, the user is not required to physically contact the coffee dispenser to perform service selection of the café late drink. The user may then retrieve the café late drink without contacting the coffee dispenser.

[0244] In some examples, there are various target apparatuses (e.g., machines) of the same type in a facility. For example, several printers, several coffee machines, or several food dispensers. A user may send a request to a target apparatus type. The specific target apparatus of that type executing the request may be the one closest to the user. The location of the user may be ascertain via the network (e.g., using facial recognition and/or ID tag). The control system may use the location of the user to identify a specific target apparatus of the requested type for executing the requested task. A user may override such recommendation of the control

system. A user may request a specific target apparatus to execute the task. Certain target apparatuses may be dedicate to certain groups of user (e.g., departments). There may be a hierarchy in the permission provided to users to use the service apparatuses. The hierarchy may depend on the location, rank, department, of the user. The hierarchy may depend on the date and time at which the request is made, and/or requested execution time of the request. The groups of users may be identified by the control system. The group of users may be identified according to their activities at work and/or outside of work. Members of the group may be informed of other group members and/or of existence of the group. At times, certain functions may be informed of the group and/or its members (e.g., human resources, management, facilities, or a combination thereof). For example, in case of a fire in the facility, a group of firefighters in the facility may be informed. For example, in case of an emergency in the facility, a group of medical professionals in the facility may be informed.

[0245] In some embodiments, the user toggles between gesture control mode and tap control mode. In the gesture control mode, the user can utilize the mobile circuitry to point the mobile circuitry at the target apparatus in space. In the tap control mode, the user is not required to point the mobile circuitry at the target apparatus in space, but select options related on the target apparatus, which options appear on the mobile circuitry for selection (e.g., via a dropdown menu). The selection between options presented on the mobile circuitry can be by using a touchscreen of the mobile circuitry, and/or scrolling through the options such as by using scroll functionality implemented in the mobile circuitry (e.g., represented by arrows).

[0246] In some embodiments, the interactive target is operatively coupled to the network via a computing interface. The computing interface may comprise an application programming interface (API). The countering interface may define interactions between multiple software and/or hardware intermediaries. The computing interface may identify requests that can be made, how to make those requests, the data formats that should be used, and/or any particular conventions to follow. The computing interface may provide extension mechanisms to allow a user extension of existing functionality. For example, an API can be specific to a target, or it can be designed using an industry standard (e.g., to ensure interoperability). When a user requests a service (e.g., via the computing interface) from a service device via the mobile circuitry and/or via gesture control, the message is sent to the server (e.g., as part of the control system), the service device may be informed, and may pick the request from a server queue, process the service request, and deploys (e.g., provides) the service to be picked by the user. Examples of communication interface, messaging, and control can be found in U.S. provisional patent application serial number 63/000,342 filed on March 26, 2020, titled “MESSAGING IN A MULTI CLIENT NETWORK,” which is incorporated herein by reference in its entirety.

[0247] In some embodiments, target apparatus(es) (e.g., service device(s)) can be discovered within a range from a user (e.g., using the network and the control system). In some embodiments, target apparatus(es) (e.g., service device(s)) can be discovered within a range from a target apparatus. The user range and the apparatus range can intersect. The range can

be referred to herein as a “discovery range,” for example, a service apparatus discovery range. A target apparatus can be discovered by a user when the target apparatus discovery range intersects with the user discovery range. For example, a target apparatus can be discovered by a user when the user is in the target apparatus discovery range. The discovery can be using the network. The discovery can be displayed in a mobile circuitry (e.g., cellular phone) of the user. The range can be specific to a target apparatus, target apparatus type, or a set of target apparatus types. For example, a first range can be for manufacturing machines, a second range can be for media displays, and a third range can be for food service machines. The range can be specific to an enclosure, or to a portion of the enclosure. For example, a first discovery range can be for a lobby, a second discovery range can be for a cafeteria, and a third discovery range can be for an office or for a group of offices. The range can be fixed or adjustable (e.g., by a user, a manager, a facility owner, a lessor, or a combination thereof). A first target apparatus type may have a different discovery range from a second target apparatus type. For example, a larger control range can be assigned for light switches, and shorter for beverage service devices. The larger control range can be of at most about 1 meter (m), 2m, 3m, or 5m. The shorter control range can be of at most about 0.2 m, 0.3m, 0.4m, 0.5m, 0.6m, 0.7m, 0.8m, or 0.9m. A user may detect (e.g., visually and/or using a list) devices within relevant use range of the user. Visually may comprise using icons, drawings, a digital twin, or a combination thereof, of the enclosure (e.g., as disclosed herein). Usage of discovery ranges may facilitate focusing (e.g., shortening) a list of target apparatuses relevant for the user to control, e.g., and prevent the user from having to select from a long list of (e.g., largely irrelevant) target apparatuses (e.g., service devices). Controlling the range can be using a position of the user (e.g., using a geolocation device such as one comprising UWB technology), and target apparatus paring (e.g., Wi-Fi pairing) to the network. The range of discovery be unconstrained by a rage dictated by direct device-user paring technology (e.g., Bluetooth pairing range). For example, when the user is located far from the target apparatus, the user may be able to couple with the target apparatus even if the device is out of the direct device-user paring technology range (e.g., user range). The third party target apparatus selected by the user may or may not incorporate a technology for direct device-user pairing technology.

[0248] In some embodiments, pulse-based ultra-wideband (UWB) technology (e.g., ECMA-368, or ECMA-369) is a wireless technology for transmitting large amounts of data at low power (e.g., less than about 1 millivolt (mW), 0.75mW, 0.5mW, or 0.25mW) over short distances (e.g., of at most about 300 feet (‘), 250’, 230’, 200’, or 150’). A UWB signal can occupy at least about 750MHz, 500 MHz, or 250MHz of bandwidth spectrum, and/or at least about 30%, 20%, or 10% of its center frequency. The UWB signal can be transmitted by one or more pulses. A component broadcasts digital signal pulses may be timed (e.g., precisely) on a carrier signal across a number of frequency channels at the same time. Information may be transmitted, e.g., by modulating the timing and/or positioning of the signal (e.g., the pulses). Signal information

may be transmitted by encoding the polarity of the signal (e.g., pulse), its amplitude and/or by using orthogonal signals (e.g., pulses). The UWB signal may be a low power information transfer protocol. The UWB technology may be utilized for (e.g., indoor) location applications. The broad range of the UWB spectrum comprises low frequencies having long wavelengths, which allows UWB signals to penetrate a variety of materials, including various building fixtures (e.g., walls). The wide range of frequencies, e.g., including the low penetrating frequencies, may decrease the chance of multipath propagation errors (without wishing to be bound to theory, as some wavelengths may have a line-of-sight trajectory). UWB communication signals (e.g., pulses) may be short (e.g., of at most about 70cm, 60 cm, or 50cm for a pulse that is about 600MHz, 500 MHz, or 400MHz wide; or of at most about 20cm, 23 cm, 25cm, or 30cm for a pulse that is has a bandwidth of about 1GHz, 1.2GHz, 1.3 GHz, or 1.5GHz). The short communication signals (e.g., pulses) may reduce the chance that reflecting signals (e.g., pulses) will overlap with the original signal (e.g., pulse).

[0249] In some embodiments, an identification (ID) tag of a user can include a micro-chip. The micro-chip can be a micro-location chip. The micro-chip can incorporate auto-location technology (referred to herein also as “micro-location chip”). The micro-chip may incorporate technology for automatically reporting high-resolution and/or high accuracy location information. The auto-location technology can comprise GPS, Bluetooth, or radio-wave technology. The auto-location technology can comprise electromagnetic wave (e.g., radio wave) emission and/or detection. The radio-wave technology may be any RF technology disclosed herein (e.g., high frequency, ultra-high frequency, super high frequency. The radio-wave technology may comprise UWB technology. The micro-chip may facilitate determination of its location within an accuracy of at most about 25 centimeters, 20cm, 15cm, 10 cm, or 5cm. In various embodiments, the control system, sensors, antennas, or a combination thereof, are configured to communicate with the micro-location chip. In some embodiments, the ID tag may comprise the micro-location chip. The micro-location chip may be configured to broadcast one or more signals. The signals may be omnidirectional signals. One or more component operatively coupled to the network may (e.g., each) comprise the micro-location chip. The micro-location chips (e.g., that are disposed in stationary and/or known locations) may serve as anchors. By analyzing the time taken for a broadcast signal to reach the anchors within the transmittable distance of the ID-tag, the location of the ID tag may be determined. One or more processors (e.g., of the control system) may perform an analysis of the location related signals. For example, the relative distance between the micro-chip and one or more anchors and/or other micro-chip(s) (e.g., within the transmission range limits) may be determined. The relative distance, know location, and/or anchor information may be aggregated. At least one of the anchors may be disposed in a floor, ceiling, wall, or mullion of a building, or a combination thereof. There may be at least 1, 2, 3, 4, 5, 8, or 10 anchors disposed in the enclosure (e.g., in the room, in the building, and/or in the facility). At least two of the anchors may have at least of

(e.g., substantially) the same X coordinate, Y coordinate, and Z coordinate (of a Cartesian coordinate system).

[0250] In some embodiments, a window control system enables locating and/or tracking one or more devices (e.g., comprising auto-location technology such as the micro location chip) and/or at least one user carrying such device. The relative location between two or more such devices can be determined from information relating to received transmissions, e.g., at one or more antennas and/or sensors. The location of the device may comprise geo-positioning and/or geolocation. The location of the device may an analysis of electromagnetic signals emitted from the device and/or the micro-location chip. Information that can be used to determine location includes, e.g., the received signal strength, the time of arrival, the signal frequency, the angle of arrival, or a combination thereof. When determining a location of the one or more components from these metrics, a localization (e.g., using trilateration such as triangulation) module may be implemented. The localization module may comprise a calculation and/or algorithm. The auto-location may comprise geolocation and/or geo-positioning. Examples of location methods may be found in PCT Patent Application serial number PCT/US17/31106 filed on May 4, 2017 titled "WINDOW ANTENNAS," which is incorporated herein by reference in its entirety.

[0251] In some embodiments, the position of the user may be located using one or more positional sensors. The positional sensor(s) may be disposed in the enclosure (e.g., facility, building, or room). The positional sensor may be part of a sensor ensemble or separated from a sensor ensemble (e.g., standalone positional sensor). The positional sensor may be operatively (e.g., communicatively) coupled to a network. The network may be a network of the facility (e.g., of the building). The network may be configured to transmit communication and power. The network may be any network disclosed herein. The network may extend to a room, a floor, several rooms, several floors, the building, or several buildings of the facility. The network may operatively (e.g., to facilitate power and/or communication) couple to a control system (e.g., as disclosed herein), to sensor(s), emitter(s), antenna, router(s), power supply, building management system (and/or its components). The network may be coupled to personal computers of users (e.g., occupants) associated with the facility (e.g., employees and/or tenants). At least part of the network may be installed as the initial network of the facility, and/or disposed in an envelope structure of the facility. The users may or may not be present in the facility. The personal computers of the users may be disposed remote from the facility. The network may be operatively coupled to other devices in the facility that perform operations for, or associated with, the facility (e.g., production machinery, communication machinery, service machinery, or a combination thereof). The production machinery may include computers, factory related machinery, or other machinery, or a combination thereof, configured to produce product(s) (e.g., printers and/or dispensers). The service machinery may include food and/or beverage related machinery, hygiene related machinery (e.g., mask dispenser, and/or disinfectant dispensers). The communication machinery may include media projectors, media

display, touch screens, speakers, lighting (e.g., entry, exit, and/or security lighting), or a combination thereof.

[0252] In some embodiments, at least one device ensemble includes at least one processor and/or memory. The processor may perform computing tasks (e.g., including machine learning and/or artificial intelligence related tasks). In this manner the network can allow low latency (e.g., as disclosed herein) and faster response time for applications and/or commands. In some embodiments, the network and circuitry coupled thereto may form a distributed computing environment (e.g., comprising CPU, memory, and storage) for application and/or service hosting to store and/or process content close to the user's mobile circuitry (e.g., cellular device, pad, or laptop).

[0253] In some embodiments, the network is coupled to device ensemble(s). The device ensemble may perform (e.g., in real time) sensing and/or tracking of occupants in an enclosure in which the device ensemble is disposed (e.g., *in situ*), e.g., (i) to enable seamless connectivity of the user's mobile circuitry to the network and/or adjustment of network coupled machinery to requirements and/or preferences of the user, (ii) to identify the user (e.g., using facial recognition, speech recognition, and/or identification tag), and/or (iii) to cater the environment of the enclosure according to any preferences of the user. For example, when a meeting organizer enters into an allocated meeting room, the organizer may be recognized by one or more sensors (e.g., using facial recognition and/or ID tag), presentation of the organizer may appear on screens of the meeting room and/or of screens of processors of the invitees. The screen may be controlled (e.g., remotely by the organizer or invitees, e.g., as disclosed herein). The invitees can be in the meeting room, or remote. The organizer can connect to an assistant via the network. The assistant can be real or virtual (e.g., digital office assistant). The organizer can place one or more requests to the assistant, which requests may be satisfied by the assistant. The requests may require communication and/or control using the network. For example, the request may be retrieval of a file and/or file manipulation (e.g., during the meeting). The request may be altering a function controlled by the control system (e.g., dim the lights, cool the room environment, sound an alarm, shut doors of the facility, and/or halt operation of a factory machinery). The assistant (e.g., digital assistant) may take notes during the meeting (e.g., using speech recognition), schedule meetings, and/or update files. The assistant may analyze (e.g., read) emails and/or replies to them. An occupant may interact with the assistant in a contactless (e.g., remote) manner, e.g., using gesture and/or voice interactions (e.g., as disclosed herein).

[0254] Fig. 20 shows an example of a building with device ensembles (e.g., assemblies, also referred to herein as "digital architectural elements"). As points of connection, the building can include multiple rooftop donor antennas 2005, 2005b as well as a sky sensor 2007 for sending electromagnetic radiation (e.g., infrared, ultraviolet, radio frequency, visible light, or a combination thereof). These wireless signals may allow a building services network to wirelessly interface with one or more communications service provider systems. The building has a control

panel 2013 for connecting to a provider's central office 2011 via a physical line 2009 (e.g., an optical fiber such as a single mode optical fiber). The control panel 2013 may include hardware software configured to provide functions of, for example, a signal source carrier head end, a fiber distribution headend, and/or a (e.g., bi-directional) amplifier or repeater, or a combination thereof. The rooftop donor antennas 2005a and 2005b can allow building occupants and/or devices to access a wireless system communications service of a (e.g., 3rd party) provider. The antenna and/or controller(s) may provide access to the same service provider system, a different service provider system, or some variation such as two interface elements providing access to a system of a first service provider, and a different interface element providing access to a system of a second service provider.

[0255] As shown in the example of Fig. 20, a vertical data plane may include a (e.g., high capacity, or high-speed) data carrying line 2019 such as (e.g., single mode) optical fiber or UTP copper lines (of sufficient gauge). In some embodiments, at least one control panel could be provided on at least part of the floors of the building (e.g., on each floor). In some embodiments, one (e.g., high capacity) communication line can directly connect a control panel in the top floor with (e.g., main) control panel 2013 in the bottom floor (or in the basement floor). Note that in the example shown in Fig. 20, control panel 2017 directly connects to rooftop antennas 2005a, 2005b, or sky sensor 2007, or a combination thereof, while control panel 2013 directly connects to the (e.g., 3rd party) service provider central office 2011.

[0256] Fig. 20 shows an example of a horizontal data plane that may include one or more of the control panels and data carrying wiring (e.g., lines), which include trunk lines 2021. In certain embodiments, the trunk lines comprise (e.g., are made from) coaxial cable. The trunk lines may comprise any wiring disclosed herein. The control panels may be configured to provide data on the trunk lines 2021 via a data communication protocol (such as MoCA and/or d.hn). The data communication protocol may comprise (i) a next generation home networking protocol (abbreviated herein as "G.hn" protocol), (ii) communications technology that transmits digital information over power lines that traditionally used to (e.g., only) deliver electrical power, or (iii) hardware devices designed for communication and transfer of data (e.g., Ethernet, USB and Wi-Fi) through electrical wiring of a building. The data transfer protocols may facilitate data transmission rates of at least about 1 Gigabits per second (Gbit/s), 2 Gbit/s, 3 Gbit/s, 4 Gbit/s, or 5 Gbit/s. The data transfer protocol may operate over telephone wiring, coaxial cables, power lines, (e.g., plastic) optical fibers, or a combination thereof. The data transfer protocol may be facilitated using a chip (e.g., comprising a semiconductor device). At least one (e.g., each) horizontal data plane may provide high speed network access to one or more device ensembles such as 2023 (e.g., a set of one or more devices in a housing comprising an assembly of devices) and/or antennas (e.g., 2025), some or all of which are optionally integrated with device ensembles. The antennas (and associated radios, not shown) may be configured to provide wireless access by any of various protocols, including, e.g., cellular (e.g., one or more frequency

bands at or proximate 28 GHz), Wi-Fi (e.g., one or more frequency bands at 2.4, 5, and 60 GHz), CBRS, and the like. Drop lines may connect device ensembles (e.g., 2023) to trunk lines (e.g., 2021). In some embodiments, a horizontal data plane is deployed on a floor of a building. The devices in the device ensemble may comprise a sensor, emitter, or antenna. The device ensemble may comprise circuitry. The devices in the device ensemble may be operatively coupled to the circuitry. The circuitry may comprise a processor. The circuitry may be operatively coupled to memory and/or communication hub (e.g., ethernet and/or cellular communication). One or more donor antennas (e.g., 2005a, 2005b) may connect to the control panel (e.g., 2013) via high speed lines (e.g., single mode optical fiber or copper). In the depicted example of Fig. 20, the control panel 2013 is located in a lower floor of the building. The connection to the donor antenna(s) may be via one or more vRAN radios and wiring (e.g., coaxial cable).

[0257] In the example shown in Fig. 20, the communications service provider central office 2011 connects to ground floor control panel 2013 via a high speed line 2009 (e.g., an optical fiber serving as part of a backhaul). This entry point of the service provider to the building is sometimes referred to as a Main Point of Entry (MPOE), and it may be configured to permit the building to distribute both voice and data traffic.

[0258] In some cases, a small cell system is made available to a building, at least in part, via one or more antennas. Examples of antennas, sky sensor, and control systems can be found in U.S. Patent Application No. 15/287,646, filed October 6, 2016, which is incorporated herein by reference in its entirety.

[0259] In some embodiments, the target apparatus is operatively coupled to the network. The network may be operatively (e.g., communicatively) coupled to one or more controllers. The network may be operatively (e.g., communicatively) coupled to one or more processors. Coupling of the target apparatus to the network may allow contactless communication of a user with the target apparatus using a mobile circuitry of the user (e.g., through a software application installed on the mobile circuitry). In this manner, a user need not directly communicatively couple and decouple from the service device (e.g., using Bluetooth technology). By coupling the target apparatus to the network to which the user is communicatively coupled (e.g., through the mobile circuitry of the user), a user may be communicatively couple to a plurality of target apparatuses simultaneously (e.g., concurrently). The user may control at least two of the plurality of target apparatuses sequentially. The user may control at least two of the plurality of target apparatuses simultaneously (e.g., concurrently). For example, a user may have two applications of two different target apparatuses open (e.g., and running) on his mobile circuitry, e.g., available for control (e.g., manipulation).

[0260] In some example, the discovery of target apparatus by a user is not restricted by a range. The discovery of target apparatus by a user can be restricted by at least one security protocol (e.g., dangerous manufacturing machinery may be available only to permitted

manufacturing personnel). The security protocol can have one or more security levels. The discovery of target apparatus by a user can be restricted by apparatuses in a room, floor, building, or facility in which the user is located. The user may override at least one (e.g., any) range restriction and select the target apparatus from all available target apparatuses.

[0261] In some embodiments, the target apparatus is communicatively coupled to the network. The target device may utilize a network authentication protocol. The network authentication protocol may open one or more ports for network access. The port(s) may be opened when an organization and/or a facility authenticates (e.g., through network authentication) an identity of a target apparatus that attempts to operatively couple (and/or physically couples) to the network. Operative coupling may comprise communicatively coupling. The organization and/or facility may authorize (e.g., using the network) access of the target apparatus to the network. The access may or may not be restricted. The restriction may comprise one or more security levels. The identity of the target apparatus can be determined based on the credentials and/or certificate. The credentials and/or certificate may be confirmed by the network (e.g., by a server operatively coupled to the network). The authentication protocol may or may not be specific for physical communication (e.g., Ethernet communication) in a local area network (LAN), e.g., that utilizes packets. The standard may be maintained by the Institute of Electrical and Electronics Engineers (IEEE). The standard may specify the physical media (e.g., target apparatus) and/or the working characteristics of the network (e.g., Ethernet). The networking standard may support virtual LANs (VLANs) on a local area (e.g., Ethernet) network. The standard may support power over local area network (e.g., Ethernet). The network may provide communication over power line (e.g., coaxial cable). The power may be direct current (DC) power. The power may be at least about 12 Watts (W), 15 W, 25W, 30W, 40W, 48W, 50W, or 100W. The standard may facilitate mesh networking. The standard may facilitate a local area network (LAN) technology and/or wide area network (WAN) applications. The standard may facilitate physical connections between target apparatuses and/or infrastructure devices (hubs, switches, routers) by various types of cables (e.g., coaxial, twisted wires, copper cables, fiber cables, or a combination thereof). Examples of network authentication protocols can be 802.1X, or KERBEROS. The network authentication protocol may comprise secret-key cryptography. The network can support (e.g., communication) protocols comprising 802.3, 802.3af (PoE), 802.3at (PoE+), 802.1Q, or 802.11s. The network may support a communication protocol for Building Automation and Control (BAC) networks (e.g., BACnet). The protocol may define service(s) used to communicate between building devices. The protocol services may include device and object discovery (e.g., Who-Is, I-Am, Who-Has, I-Have, or a combination thereof). The protocol services may include Read-Property and Write-Property (e.g., for data sharing). The network protocol may define object types (e.g., that are acted upon by the services). The protocol may define one or more data links / physical layers (e.g., ARCNET, Ethernet, BACnet/IP, BACnet/IPv6, BACnet/MSTP, Point-To-Point over RS-232,

Master-Slave/Token-Passing over RS-485, ZigBee, LonTalk, or a combination thereof). The protocol may be dedicated to devices (e.g., Internet of Things (IoT) devices and/or machine to machine (M2M) communication). The protocol may be a messaging protocol. The protocol may be a publish – subscribe protocol. The protocol may be configured for messaging transport. The protocol may be configured for remote devices. The protocol may be configured for devices having a small code footprint and/or minimal network bandwidth. The small code footprint may be configured to be handled by microcontrollers. The protocol may have a plurality of quality of service levels including (i) at most once, (ii) at least once, (iii) exactly once, or (iv) a combination thereof. The plurality of quality of service levels may increase reliability of the message delivery in the network (e.g., to its target). The protocol may facilitate messaging (i) between device to cloud and/or (ii) between cloud to device. The messaging protocol is configured for broadcasting messages to groups of targets such as target apparatuses (e.g., devices), sensors, emitters, or a combination thereof. The protocol may comply with Organization for the Advancement of Structured Information Standards (OASIS). The protocol may support security schemes such as authentication (e.g., using tokens). The protocol may support access delegation standard (e.g., OAuth). The protocol may support granting a first application (and/or website) access to information on a second application (and/or website) without providing the second with a security code (e.g., token and/or password) relating to the first application. The protocol may be a Message Queuing Telemetry Transport (MQTT) or Advanced Message Queuing Protocol (AMQP) protocol. The protocol may be configured for a message rate of at least one (1) message per second per publisher. The protocol may be configured to facilitate a message payload size of at most 64, 86, 96, or 128 bytes. The protocol may be configured to communicate with any device (e.g., from a microcontroller to a server) that operates a protocol compliant (e.g., MQTT) library and/or connects to compliant broker (e.g., MQTT broker) over a network. Each device (e.g., target apparatus, sensor, or emitter) can be a publisher and/or a subscriber. A broker can handle millions of concurrently connected devices, or less than millions. The broker can handle at least about 100, 10000, 100000, 1000000, or 10000000 concurrently connected devices. In some embodiments, the broker is responsible for receiving (e.g., all) messages, filtering the messages, determining who is interested in each message, and/or sending the message to these subscribed device (e.g., broker client). The protocol may require internet connectivity to the network. The protocol may facilitate bi-directional, and/or synchronous peer-to-peer messaging. The protocol may be a binary wire protocol. Examples of such network protocol, control system, and network can be found in US provisional patent application serial no. 63/000,342 filed 03/26/2020 titled “MESSAGING IN A MULTI CLIENT NETWORK,” which is incorporated herein by reference in its entirety.

[0262] Examples of network security, communication standards, communication interface, messaging, coupling of devices to the network, and control can be found in U.S. provisional patent application serial number 63/000,342, and in PCT patent application serial number

PCT/US20/70123 filed June 04, 2020, titled “SECURE BUILDING SERVICES NETWORK,” each of which is incorporated herein by reference in its entirety.

[0263] In some embodiments, the network allows a target apparatus to couple to the network. The network (e.g., using controller(s) and/or processor(s)) may let the target apparatus join the network, authenticate the target apparatus, monitor activity on the network (e.g., activity relating to the target apparatus), facilitate performance of maintenance and/or diagnostics, and secure the data communicated over the network. The security levels may allow bidirectional or monodirectional communication between a user and a target apparatus. For example, the network may allow only monodirectional communication of the user to the target apparatus. For example, the network may restrict availability of data communicated through the network and/or coupled to the network, from being accessed by a third party owner of a target apparatus (e.g., service device). For example, the network may restrict availability of data communicated through the network and/or coupled to the network, from being accessed by the organization and/or facility into data relating to a third party owner and/or manufacturer of a target apparatus (e.g., service device).

[0264] In some embodiments, the control system is operatively coupled to a learning module. The learning module may utilize a learning scheme, e.g., comprising artificial intelligence. The learning module may be learn preference of one or more users associated with the facility. Users associated with the facility may include occupants of the facility and/or users associated with an entity residing and/or owning the facility (e.g., employees of a company residing in the facility). The learning modules may analyze preference of a user or a group of users. The learning module may gather preferences of the user(s) as to one or more environmental characteristics. The learning module may use past preference of the user as a learning set for the user or for the group to which the user belongs. The preferences may include preference or preferences related to one or more aspect of an environment, including preferences regarding a target apparatus (e.g., service machine and/or production machine).

[0265] In some embodiments, a control system conditions various aspects of an enclosure. For example, the control system may condition an environment of the enclosure. The control system may project environmental preferences of the user and condition the environment to these preferences in advance (e.g., at a future time). The preferential environmental characteristic(s) (or aspects(s)) may be allocated according to (i) user or group of users, (ii) time, (iii) date, (iv) space, or (v) a combination thereof. The data preferences may comprise seasonal preferences. The environmental characteristics may comprise lighting, ventilation speed, atmospheric pressure, smell, temperature, humidity, carbon dioxide, oxygen, VOC(s), particulate matter (e.g., dust), or color. The environmental characteristics may be a preferred color scheme or theme of an enclosure. For example, at least a portion of the enclosure can be projected with a preferred theme (e.g., projected color, picture or video). For example, a user is a heart patient and prefers (e.g., requires) an oxygen level above the ambient oxygen level (e.g., 20% oxygen)

and/or a certain humidity level (e.g., 70%). The control system may condition the atmosphere of the environment for that oxygen and humidity level when the heart patient occupant is in a certain enclosure (e.g., by controlling the BMS).

[0266] In some embodiments, a control system may operate a target apparatus according to preference of a user or a group of users. The preferences may be according to past behavior of the user(s) in relation to the target apparatus (e.g., settings, service selection, timing related selections, and/or location related selections). For example, a user may refer coffee late with 1 teaspoon of sugar at 9am from the coffee machine near his desk at a first location. The coffee machine at the first location may automatically generate a cup of such coffee at 9 am in the first location. For example, a user group such as a work-team prefers to enter a conference room having a forest background, with a light breeze at 22°C. The control system may control project the forest background (e.g., on a wall and/or on a media screen), adjust the ventilation system to have a light breeze, and adjust the HVAC system for 22°C in every conference room when this group is holding a meeting. The control system may facilitate such control by controlling the HVAC system, projector, and/or media display.

[0267] In some embodiments, the control system may adjust one or more aspects of the environment and/or target apparatus according to hierarchical preferences. When several different users (e.g., of different groups) are gathered in an enclosure, which users have conflicting preferences, the control system may adjust one or more aspects of the environment and/or target apparatus according to a pre-established hierarchy. The hierarchy may comprise jurisdictional (e.g., health and/or safety) standards, health, safety, employee rank, activity taking place in the enclosure, number of occupants in the enclosure, enclosure type, time of day, date, season, or activity in the facility, or a combination thereof.

[0268] In some embodiments, the control system considers results (e.g., scientific and/or research based results) regarding environmental conditions that affect health, safety, performance, or a combination thereof, of enclosure occupants. The control system may establish thresholds and/or preferred window-ranges for one or more environmental characteristics (or aspects) of the enclosure (e.g., of an atmosphere of the enclosure). The threshold may comprise a level of atmospheric component (e.g., VOC and/or gas), temperature, and time at a certain level. The certain level may be abnormally high, abnormally low, or average. For example, the controller may allow short instances of abnormally high VOC level, but not prolonged time with that VOC level. The control system may automatically override preference of a user if it contradicts health and/or safety thresholds. Health and/or safety thresholds may be at a higher hierarchical level relative to a user's preference. The hierarchy may utilize majority preferences. For example, if two occupants of a meeting room have one preference, and the third occupant has a conflicting preference, then the preferences of the two occupants will prevail (e.g., unless they conflict health and/or safety considerations).

[0269] Fig. 21 shows an example of a flow chart depicting operations of a control system that is

operatively coupled to one or more devices in an enclosure (e.g., a facility). In block 2100 an identify of a user is identified by a control system. The identity can be identified by one or more sensors (e.g., camera) and/or by an identification tag (e.g., by scanning or otherwise sensing by one or more sensors). In block 2101, a location of the user may optionally be tracked as the user spends time in the enclosure. The use may provide input as to any preference. The preference may be relating to a target apparatus, and/or environmental characteristics. A learning module may optionally track such preferences and provide predictions as to any future preference of the user in block 2103. Past elective preferences by the user may be recorded (e.g., in a database) and may be used as a learning set for the learning module. As the learning process progress over time and the user provides more and more inputs, the predictions of the learning module may increase in accuracy. The learning module may comprise any learning scheme (e.g., comprising artificial intelligence and/or machine learning) disclosed herein. The user may override recommendations and/or predictions made by the learning module. The user may provide manual input into the control system. In block 2102, the user input is provided (whether directly by the user or by predictions of the learning module) to the control system. In block 2104, the control system may alter (or direct alteration of) one or more devices in the facility to materialize the user preferences (e.g., input) by using the input. The control system may or may not use location of the user. The location may be a past location or a current location. For example, the user may enter a workplace by scanning a tag. Scanning of the identification tag (ID tag) can inform the control system of an identify of the user, and the location of the user at the time of scanning. The user may express a preference for a sound of a certain level that constitutes the input. The expression of preference may be by manual input (including tactile, voice, or gesture command, or a combination thereof). A past expression of preference may be registered in a database and linked to the user. The user may enter a conference room at a prescheduled time. The sound level in the conference room may be adjusted to the user preference (i) when the prescheduled meeting was scheduled to initiate and/or (ii) when one or more sensors sense presence of the user in the meeting room. The sound level in the conference room may be returned to a default level and/or adjusted to another's preference (i) when the prescheduled meeting was scheduled to end and/or (ii) when one or more sensors sense absence of the user in the meeting room.

[0270] In some embodiments, a user expresses at least one preference environmental characteristic(s) and/or target apparatus, which preference constitutes an input. The input may be by manual input (including tactile, voice, or gesture command, or a combination thereof). A past expression of preference (e.g., input) may be registered in a database and linked to the user. The user may be part of a group of users. The group of users may be any grouping disclosed herein. The preference of the user may be linked to the group to which the user belongs. The user may enter an enclosure at a prescheduled time. The environmental characteristic(s) of the enclosure may be adjusted to the user preference (i) when the user was

scheduled to enter the enclosure and/or (ii) when one or more sensors sense presence of the user in the enclosure. The environmental characteristic(s) of the enclosure may be return to a default level and/or adjusted to another's preference (i) when the scheduled presence of the user in the enclosure terminates and/or (ii) when one or more sensors sense absence of the user in the enclosure. The target apparatus may be adjusted to the user preference (i) when the user was scheduled to use the target apparatus and/or (ii) when one or more sensors sense presence of the user near the target apparatus (e.g., within a predetermined distance threshold). The target apparatus may return to default setting or be adjusted to another's preference (i) when the scheduled use of the target apparatus by the user ends and/or (ii) when one or more sensors sense absence of the user near the target apparatus (e.g., within a predetermined distance threshold).

[0271] In some examples, a target apparatus is a tintable window (e.g., an electrochromic window). In some embodiments, a dynamic state of an electrochromic window is controlled by altering a voltage signal to an electrochromic device (ECD) used to provide tinting or coloring. An electrochromic window can be manufactured, configured, or otherwise provided as an IGU. IGUs may serve as the fundamental constructs for holding electrochromic panes (also referred to as "lites") when provided for installation in a building. An IGU lite or pane may be a single substrate or a multi-substrate construct, such as a laminate of two substrates. IGUs, especially those having double- or triple-pane configurations, can provide a number of advantages over single pane configurations; for example, multi-pane configurations can provide enhanced thermal insulation, noise insulation, environmental protection and/or durability when compared with single-pane configurations. A multi-pane configuration also can provide increased protection for an ECD, for example, because the electrochromic films, as well as associated layers and conductive interconnects, can be formed on an interior surface of the multi-pane IGU and be protected by an inert gas fill in the interior volume of the IGU.

[0272] In some embodiments, a tintable window exhibits a (e.g., controllable and/or reversible) change in at least one optical property of the window, e.g., when a stimulus is applied. The stimulus can include an optical, electrical, or magnetic stimulus, or a combination thereof. For example, the stimulus can include an applied voltage. One or more tintable windows can be used to control lighting and/or glare conditions, e.g., by regulating the transmission of solar energy propagating through them. One or more tintable windows can be used to control a temperature within a building, e.g., by regulating the transmission of solar energy propagating through them. Control of the solar energy may control heat load imposed on the interior of the facility (e.g., building). The control may be manual and/or automatic. The control may be used for maintaining one or more requested (e.g., environmental) conditions, e.g., occupant comfort. The control may include reducing energy consumption of a heating, ventilation, air conditioning, or lighting systems, or a combination thereof. At least two of heating, ventilation, and air conditioning may be induced by separate systems. At least two of heating, ventilation, and air

conditioning may be induced by one system. The heating, ventilation, and air conditioning may be induced by a single system (abbreviated herein as "HVAC). In some cases, tintable windows may be responsive to (e.g., and communicatively coupled to) one or more environmental sensors and/or user control. Tintable windows may comprise (e.g., may be) electrochromic windows. The windows may be located in the range from the interior to the exterior of a structure (e.g., facility, e.g., building). However, this need not be the case. Tintable windows may operate using liquid crystal devices, suspended particle devices, microelectromechanical systems (MEMS) devices (such as micro-shutters), or any technology known now, or later developed, that is configured to control light transmission through a window. Examples of windows (e.g., with MEMS devices for tinting) are described in U.S. Patent Application Serial Number 14/443,353 filed May 15, 2015, titled "MULTI-PANE WINDOWS INCLUDING ELECTROCHROMIC DEVICES AND ELECTROMECHANICAL SYSTEMS DEVICES," that is incorporated herein by reference in its entirety. In some cases, one or more tintable windows can be located within the interior of a building, e.g., between a conference room and a hallway. In some cases, one or more tintable windows can be used in automobiles, trains, aircraft, and other vehicles, e.g., in lieu of a passive and/or non-tinting window.

[0273] In some embodiments, the tintable window comprises an electrochromic device (referred to herein as an "EC device" (abbreviated herein as ECD, or "EC"). An EC device may comprise at least one coating that includes at least one layer. The at least one layer can comprise an electrochromic material. In some embodiments, the electrochromic material exhibits a change from one optical state to another, e.g., when an electric potential is applied across the EC device. The transition of the electrochromic layer from one optical state to another optical state can be caused, e.g., by reversible, semi-reversible, or irreversible ion insertion into the electrochromic material (e.g., by way of intercalation) and a corresponding injection of charge-balancing electrons. For example, the transition of the electrochromic layer from one optical state to another optical state can be caused, e.g., by a reversible ion insertion into the electrochromic material (e.g., by way of intercalation) and a corresponding injection of charge-balancing electrons. Reversible may be for the expected lifetime of the ECD. Semi-reversible refers to a measurable (e.g., noticeable) degradation in the reversibility of the tint of the window over one or more tinting cycles. In some instances, a fraction of the ions responsible for the optical transition is irreversibly bound up in the electrochromic material (e.g., and thus the induced (altered) tint state of the window is not reversible to its original tinting state). In various EC devices, at least some (e.g., all) of the irreversibly bound ions can be used to compensate for "blind charge" in the material (e.g., ECD).

[0274] In some implementations, suitable ions include cations. The cations may include lithium ions (Li^+) and/or hydrogen ions (H^+) (i.e., protons). In some implementations, other ions can be suitable. Intercalation of the cations may be into an (e.g., metal) oxide. A change in the intercalation state of the ions (e.g. cations) into the oxide may induce a visible change in a tint

(e.g., color) of the oxide. For example, the oxide may transition from a colorless to a colored state. For example, intercalation of lithium ions into tungsten oxide (WO3-y (0 < y ≤ ~0.3)) may cause the tungsten oxide to change from a transparent state to a colored (e.g., blue) state. EC device coatings as described herein are located within the viewable portion of the tintable window such that the tinting of the EC device coating can be used to control the optical state of the tintable window.

[0275] Fig. 22 shows an example of a schematic cross-section of an electrochromic device 2200 in accordance with some embodiments. The EC device coating is attached to a substrate 2202, a transparent conductive layer (TCL) 2204, an electrochromic layer (EC) 2206 (sometimes also referred to as a cathodically coloring layer or a cathodically tinting layer), an ion conducting layer or region (IC) 2208, a counter electrode layer (CE) 2210 (sometimes also referred to as an anodically coloring layer or anodically tinting layer), and a second TCL 2214. Elements 2204, 2206, 2208, 2210, and 2214 are collectively referred to as an electrochromic stack 2220. A voltage source 2216 operable to apply an electric potential across the electrochromic stack 2220 effects the transition of the electrochromic coating from, e.g., a clear state to a tinted state. In other embodiments, the order of layers is reversed with respect to the substrate. That is, the layers are in the following order: substrate, TCL, counter electrode layer, ion conducting layer, electrochromic material layer, TCL. In various embodiments, the ion conductor region (e.g., 2208) may form from a portion of the EC layer (e.g., 2206) and/or from a portion of the CE layer (e.g., 2210). In such embodiments, the electrochromic stack (e.g., 2220) may be deposited to include cathodically coloring electrochromic material (the EC layer) in direct physical contact with an anodically coloring counter electrode material (the CE layer). The ion conductor region (sometimes referred to as an interfacial region, or as an ion conducting substantially electronically insulating layer or region) may form where the EC layer and the CE layer meet, for example through heating and/or other processing steps. Examples of electrochromic devices (e.g., including those fabricated without depositing a distinct ion conductor material) can be found in U.S. Patent Application No. 13/462,725 filed May 2, 2012, titled “ELECTROCHROMIC DEVICES,” that is incorporated herein by reference in its entirety. In some embodiments, an EC device coating may include one or more additional layers such as one or more passive layers. Passive layers can be used to improve certain optical properties, to provide moisture, to provide scratch resistance, or a combination thereof. These and/or other passive layers can serve to hermetically seal the EC stack 2220. Various layers, including transparent conducting layers (such as 2204 and 2214), can be treated with anti-reflective and/or protective layers (e.g., oxide and/or nitride layers).

[0276] In some embodiments, an IGU includes two (or more) substantially transparent substrates. For example, the IGU may include two panes of glass. At least one substrate of the IGU can include an electrochromic device disposed thereon. The one or more panes of the IGU may have a separator disposed between them. An IGU can be a hermetically sealed construct,

e.g., having an interior region that is isolated from the ambient environment. A "window assembly" may include an IGU. A "window assembly" may include a (e.g., stand-alone) laminate. A "window assembly" may include one or more electrical leads, e.g., for connecting the IGUs and/or laminates. The electrical leads may operatively couple (e.g. connect) one or more electrochromic devices to a voltage source, switches and the like, and may include a frame that supports the IGU or laminate. A window assembly may include a window controller, and/or components of a window controller (e.g., a dock).

[0277] Fig. 23 shows an example implementation of an IGU 2300 that includes a first pane 2304 having a first surface S1 and a second surface S2. In some implementations, the first surface S1 of the first pane 2304 faces an exterior environment, such as an outdoors or outside environment. The IGU 2300 also includes a second pane 2306 having a first surface S3 and a second surface S4. In some implementations, the second surface S4 of the second pane 2306 faces an interior environment, such as an inside environment of a home, building or vehicle, or a room or compartment within a home, building or vehicle.

[0278] In some embodiments, (e.g., each of the) first and/or the second panes 2304 and 2306 are transparent and/or translucent to light, e.g., in the visible spectrum. For example, (e.g., each of the) first and/or second panes 2304 and 2306 can be formed of a glass material (e.g., an architectural glass or other shatter-resistant glass material such as, for example, a silicon oxide (SO_x) -based glass material. The (e.g., each of the) first and/or second panes 2304 and 2306 may be a soda-lime glass substrate or float glass substrate. Such glass substrates can be composed of, for example, approximately 75% silica (SiO_2) as well as Na_2O, CaO, and several minor additives. However, the (e.g., each of the) first and/or the second panes 2304 and 2306 can be formed of any material having suitable optical, electrical, thermal, and mechanical properties. For example, other suitable substrates that can be used as one or both of the first and the second panes 2304 and 2306 can include other glass materials as well as plastic, semi-plastic and thermoplastic materials (for example, poly(methyl methacrylate), polystyrene, polycarbonate, allyl diglycol carbonate, SAN (styrene acrylonitrile copolymer), poly(4-methyl-1-pentene), polyester, polyamide), or mirror materials, or a combination thereof. In some embodiments, (e.g., each of the) first and/or the second panes 2304 and 2306 can be strengthened, for example, by tempering, heating, or chemically strengthening.

[0279] In Fig. 23, first and second panes 2304 and 2306 are spaced apart from one another by a spacer 2318, which is typically a frame structure, to form an interior volume 2308. In some embodiments, the interior volume is filled with Argon (Ar) or another gas, such as another noble gas (for example, krypton (Kr) or xenon (Xn)), another (non-noble) gas, or a mixture of gases (for example, air). Filling the interior volume 2308 with a gas such as Ar, Kr, or Xn can reduce conductive heat transfer through the IGU 2300. Without wishing to be bound to theory, this may be because of the low thermal conductivity of these gases as well as improve acoustic insulation, e.g., due to their increased atomic weights. In some embodiments, the interior

volume 2308 can be evacuated of air or other gas. Spacer 2318 generally determines the height "C" of the interior volume 2308 (e.g., the spacing between the first and the second panes 2304 and 2306). In Fig. 23, the thickness (and/or relative thickness) of the ECD, sealant 2320/2522 and bus bars 2326/2328 may not be to scale. These components are generally thin and are exaggerated here, e.g., for ease of illustration only. In some embodiments, the spacing "C" between the first and the second panes 2304 and 2306 is in the range of approximately 6 mm to approximately 30 mm. The width "D" of spacer 2318 can be in the range of approximately 5 mm to approximately 15 mm (although other widths are possible and may be desirable). Spacer 2318 may be a frame structure formed around all sides of the IGU 2300 (for example, top, bottom, left and right sides of the IGU 100). For example, spacer 2318 can be formed of a foam or plastic material. In some embodiments, spacer 2318 can be formed of metal or other conductive material, for example, a metal tube or channel structure having at least 3 sides, two sides for sealing to each of the substrates and one side to support and separate the lites and as a surface on which to apply a sealant, 2324. A first primary seal 2320 adheres and hermetically seals spacer 2318 and the second surface S2 of the first pane 2304. A second primary seal 2322 adheres and hermetically seals spacer 2318 and the first surface S3 of the second pane 2306. In some implementations, each of the primary seals 2320 and 2322 can be formed of an adhesive sealant such as, for example, polyisobutylene (PIB). In some implementations, IGU 2300 further includes secondary seal 2324 that hermetically seals a border around the entire IGU 2300 outside of spacer 2318. To this end, spacer 2318 can be inset from the edges of the first and the second panes 2304 and 2306 by a distance "E." The distance "E" can be in the range of approximately four (4) millimeters (mm) to approximately eight (8) mm (although other distances are possible and may be desirable). In some implementations, secondary seal 2324 can be formed of an adhesive sealant such as, for example, a polymeric material that resists water and that adds structural support to the assembly, such as silicone, polyurethane and similar structural sealants that form a water-tight seal.

[0280] In the example of Fig. 23, the ECD coating on surface S2 of first pane 2304 extends about its entire perimeter to and under spacer 2318. This configuration is functionally desirable as it protects the edge of the ECD within the primary sealant 2320 and aesthetically desirable because within the inner perimeter of spacer 2318 there is a monolithic ECD without any bus bars or scribe lines.

[0281] Configuration examples of IGUs are described in U.S. Patent No. 8,164,818, issued April 24, 2012 and titled ELECTROCHROMIC WINDOW FABRICATION METHODS (Attorney Docket No. VIEWP006), U.S. Patent Application No. 13/456,056 filed April 25, 2012 and titled ELECTROCHROMIC WINDOW FABRICATION METHODS (Attorney Docket No. VIEWP006X1), PCT Patent Application No. PCT/US2012/068817 filed December 10, 2012 and titled THIN-FILM DEVICES AND FABRICATION (Attorney Docket No. VIEWP036WO), U.S. Patent No. 9,454,053, issued September 27, 2016 and titled THIN-FILM DEVICES AND

FABRICATION (Attorney Docket No. VIEWP036US), and PCT Patent Application No. PCT/US2014/073081, filed December 13, 2014 and titled THIN-FILM DEVICES AND FABRICATION (Attorney Docket No. VIEWP036X1WO), each of which is hereby incorporated by reference in its entirety.

[0282] In the example shown in Fig. 23, an ECD 2310 is formed on the second surface S2 of the first pane 2304. The ECD 2310 includes an electrochromic ("EC") stack 2312, which itself may include one or more layers. For example, the EC stack 2312 can include an electrochromic layer, an ion-conducting layer, and a counter electrode layer. The electrochromic layer may be formed of one or more inorganic solid materials. The electrochromic layer can include or be formed of one or more of a number of electrochromic materials, including electrochemically-cathodic or electrochemically-anodic materials. EC stack 2312 may be between first and second conducting (or "conductive") layers. For example, the ECD 2310 can include a first transparent conductive oxide (TCO) layer 2314 adjacent a first surface of the EC stack 2312 and a second TCO layer 2316 adjacent a second surface of the EC stack 2312. An example of similar EC devices and smart windows can be found in U.S. Patent No. 8,764,950, titled ELECTROCHROMIC DEVICES, by Wang et al., issued July 1, 2014 and U.S. Patent No. 9,261,751, titled ELECTROCHROMIC DEVICES, by Pradhan et al., issued February 16, 2016, which is incorporated herein by reference in its entirety. In some implementations, the EC stack 2312 also can include one or more additional layers such as one or more passive layers. For example, passive layers can be used to improve certain optical properties, to provide moisture or to provide scratch resistance. These or other passive layers also can serve to hermetically seal the EC stack 2312.

[0283] In some embodiments, the selection or design of the electrochromic and counter electrode materials generally governs the possible optical transitions. During operation, in response to a voltage generated across the thickness of the EC stack (for example, between the first and the second TCO layers), the electrochromic layer transfers or exchanges ions to or from the counter electrode layer to drive the electrochromic layer to the desired optical state. To cause the EC stack to transition to a transparent state, a positive voltage may be applied across the EC stack (for example, such that the electrochromic layer is more positive than the counter electrode layer). In some embodiments, in response to the application of the positive voltage, the available ions in the stack reside primarily in the counter electrode layer. When the magnitude of the potential across the EC stack is reduced or when the polarity of the potential is reversed, ions may be transported back across the ion conducting layer to the electrochromic layer causing the electrochromic material to transition to an opaque state (or to a "more tinted," "darker" or "less transparent" state). Conversely, in some embodiments using electrochromic layers having different properties, to cause the EC stack to transition to an opaque state, a negative voltage is applied to the electrochromic layer relative to the counter electrode layer. For example, when the magnitude of the potential across the EC stack is reduced or its polarity

reversed, the ions may be transported back across the ion conducting layer to the electrochromic layer causing the electrochromic material to transition to a clear or "bleached" state (or to a "less tinted", "lighter" or "more transparent" state).

[0284] In some implementations, the transfer or exchange of ions to or from the counter electrode layer also results in an optical transition in the counter electrode layer. For example, in some implementations the electrochromic and counter electrode layers are complementary coloring layers. More specifically, in some such implementations, when or after ions are transferred into the counter electrode layer, the counter electrode layer becomes more transparent, and similarly, when or after the ions are transferred out of the electrochromic layer, the electrochromic layer becomes more transparent. Conversely, when the polarity is switched, or the potential is reduced, and the ions are transferred from the counter electrode layer into the electrochromic layer, both the counter electrode layer and the electrochromic layer become less transparent.

[0285] In some embodiments, the transition of the electrochromic layer from one optical state to another optical state is caused by reversible ion insertion into the electrochromic material (for example, by way of intercalation) and a corresponding injection of charge-balancing electrons. For example, some fraction of the ions responsible for the optical transition may be irreversibly bound up in the electrochromic material. In some embodiments, suitable ions include lithium ions (Li+) and hydrogen ions (H+) (i.e., protons). In some other implementations, other ions can be suitable. Intercalation of lithium ions, for example, into tungsten oxide (WO_{3-y} ($0 < y \leq \sim 0.3$)) causes the tungsten oxide to change from a transparent state to a blue state.

[0286] In some embodiments, a tinting transition is a transition from a transparent (or "translucent," "bleached" or "least tinted") state to an opaque (or "fully darkened" or "fully tinted") state. Another example of a tinting transition is the reverse (e.g., a transition from an opaque state to a transparent state). Other examples of tinting transitions include transitions to and from various intermediate tint states, for example, a transition from a less tinted, lighter or more transparent state to a more tinted, darker or less transparent state, and vice versa. Each of such tint states, and the tinting transitions between them, may be characterized or described in terms of percent transmission. For example, a tinting transition can be described as being from a current percent transmission (% T) to a target % T. Conversely, in some other instances, each of the tint states and the tinting transitions between them may be characterized or described in terms of percent tinting; for example, a transition from a current percent tinting to a target percent tinting.

[0287] In some embodiments, a voltage applied to the transparent electrode layers (e.g. across the EC stack) follows a control profile used to drive a transition in an optically switchable device. For example, a window controller can be used to generate and apply the control profile to drive an ECD from a first optical state (for example, a transparent state or a first intermediate state) to a second optical state (for example, a fully tinted state or a more tinted intermediate state). To

drive the ECD in the reverse direction—from a more tinted state to a less tinted state—the window controller can apply a similar but inverted profile. In some embodiments, the control profiles for tinting and lightening can be asymmetric. For example, transitioning from a first more tinted state to a second less tinted state can in some instances require more time than the reverse; that is, transitioning from the second less tinted state to the first more tinted state. In some embodiments, the reverse may be true. Transitioning from the second less tinted state to the first more tinted state can require more time. By virtue of the device architecture and materials, bleaching or lightening may not necessarily (e.g., simply) the reverse of coloring or tinting. Indeed, ECDs often behave differently for each transition due to differences in driving forces for ion intercalation and deintercalation to and from the electrochromic materials.

[0288] Fig. 24 shows an example control profile 2400 as a voltage control profile implemented by varying a voltage provided to the ECD. For example, the solid line in Fig. 24 represents an effective voltage V_{Eff} applied across the ECD over the course of a tinting transition and a subsequent maintenance period. For example, the solid line can represent the relative difference in the electrical voltages V_{App1} and V_{App2} applied to the two conducting layers of the ECD. The dotted line in Fig. 24 represents a corresponding current (I) through the device. In the illustrated example, the voltage control profile 2400 includes four stages: a ramp-to-drive stage 2402 that initiates the transition, a drive stage that continues to drive the transition, a ramp-to-hold stage, and subsequent hold stage.

[0289] In Fig. 24, the ramp-to-drive stage 2402 is characterized by the application of a voltage ramp that increases in magnitude from an initial value at time t_0 to a maximum driving value of V_{Drive} at time t_1. For example, the ramp-to-drive stage 2402 can be defined by three drive parameters known or set by the window controller: the initial voltage at t_0 (the current voltage across the ECD at the start of the transition), the magnitude of V_{Drive} (governing the ending optical state), and the time duration during which the ramp is applied (dictating the speed of the transition). The window controller may also set a target ramp rate, a maximum ramp rate or a type of ramp (for example, a linear ramp, a second degree ramp or an n^{th}-degree ramp). In some embodiments, the ramp rate can be limited to avoid damaging the ECD.

[0290] In Fig. 24, the drive stage 2404 includes application of a constant voltage V_{Drive} starting at time t_1 and ending at time t_2, at which point the ending optical state is reached (or approximately reached). The ramp-to-hold stage 2406 is characterized by the application of a voltage ramp that decreases in magnitude from the drive value V_{Drive} at time t_2 to a minimum holding value of V_{Hold} at time t_3. In some embodiments, the ramp-to-hold stage 2406 can be defined by three drive parameters known or set by the window controller: the drive voltage V_{Drive}, the holding voltage V_{Hold}, and the time duration during which the ramp is applied. The window controller may also set a ramp rate or a type of ramp (for example, a linear ramp, a second degree ramp or an n^{th}-degree ramp).

[0291] In Fig. 24, the hold stage 2408 is characterized by the application of a constant voltage

V_{Hold} starting at time t_3. The holding voltage V_{Hold} may be used to maintain the ECD at the ending optical state. As such, the duration of the application of the holding voltage V_{hold} may be concomitant with the duration of time that the ECD is to be held in the ending optical state. For example, because of non-idealities associated with the ECD, a leakage current I_{Leak} can result in the slow drainage of electrical charge from the ECD. Such a drainage of electrical charge can result in a corresponding reversal of ions across the ECD, and consequently, a slow reversal of the optical transition. The holding voltage V_{Hold} can be continuously applied to counter or prevent the leakage current. In some embodiments, the holding voltage V_{Hold} is applied periodically to "refresh" the desired optical state, or in other words, to bring the ECD back to the desired optical state.

[0292] The voltage control profile 2400 illustrated and described with reference to Fig. 24 is only one example of a voltage control profile suitable for some implementations. However, many other profiles may be desirable or suitable in such implementations or in various other implementations or applications. These other profiles also can readily be achieved using the controllers and optically switchable devices disclosed herein. For example, a current profile can be applied instead of a voltage profile. In some embodiments, a current control profile similar to that of the current density shown in Fig. 24 can be applied. In some embodiments, a control profile can have more than four stages. For example, a voltage control profile can include one or more overdrive stages. For example, the voltage ramp applied during the first stage 2402 can increase in magnitude beyond the drive voltage V_{Drive} to an overdrive voltage V_{OD}. The first stage 2402 may be followed by a ramp stage 2403 during which the applied voltage decreases from the overdrive voltage V_{OD} to the drive voltage V_{Drive}. In some embodiments, the overdrive voltage V_{OD} can be applied for a relatively short time duration before the ramp back down to the drive voltage V_{Drive}.

[0293] In some embodiments, the applied voltage or current profiles are interrupted for relatively short durations of time to provide open circuit conditions across the device. While such open circuit conditions are in effect, an actual voltage or other electrical characteristics can be measured, detected, or otherwise determined to monitor how far along an optical transition has progressed, and in some instances, to determine whether changes in the profile are desirable. Such open circuit conditions also can be provided during a hold stage to determine whether a holding voltage V_{Hold} should be applied or whether a magnitude of the holding voltage V_{Hold} should be changed. Examples related to controlling optical transitions is provided in PCT Patent Application No. PCT/US14/43514 filed June 20, 2014 and titled CONTROLLING TRANSITIONS IN OPTICALLY SWITCHABLE DEVICES, which is hereby incorporated by reference in its entirety.

[0294] In one or more aspects, one or more of the functions described herein may be implemented in hardware, digital electronic circuitry, analog electronic circuitry, computer software, firmware, including the structures disclosed in this specification and their structural

equivalents thereof, or in any combination thereof. Certain implementations of the subject matter described in this document also can be implemented as one or more controllers, computer programs, or physical structures, for example, one or more modules of computer program instructions, encoded on a computer storage media for execution by, or to control the operation of window controllers, NCs, antenna controllers, or a combination thereof. Any disclosed implementations presented as or for electrochromic windows can be more generally implemented as or for switchable optical devices (including windows, mirrors, etc.).

[0295] Various modifications to the embodiments described in this disclosure may be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other implementations without departing from the spirit or scope of this disclosure. Thus, the claims are not intended to be limited to the implementations shown herein but are to be accorded the widest scope consistent with this disclosure, the principles and the novel features disclosed herein. Additionally, a person having ordinary skill in the art will readily appreciate, the terms “upper” and “lower” are sometimes used for ease of describing the figures, and indicate relative positions corresponding to the orientation of the figure on a properly oriented page, and may not reflect the proper orientation of the devices as implemented.

[0296] Certain features that are described in this specification in the context of separate implementations also can be implemented in combination in a single implementation. Conversely, various features that are described in the context of a single implementation also can be implemented in multiple implementations separately or in any suitable sub combination. Moreover, although features may be described above as acting in certain combinations and even initially claimed as such, one or more features from a claimed combination can in some cases be excised from the combination, and the claimed combination may be directed to a sub combination or variation of a sub combination.

[0297] Similarly, while operations are depicted in the drawings in a particular order, this does not necessarily mean that the operations are required to be performed in the particular order shown or in sequential order, or that all illustrated operations be performed, to achieve desirable results. Further, the drawings may schematically depict one more example processes in the form of a flow diagram. However, other operations that are not depicted can be incorporated in the example processes that are schematically illustrated. For example, one or more additional operations can be performed before, after, simultaneously, or between any of the illustrated operations. In certain circumstances, multitasking and parallel processing may be advantageous. Moreover, the separation of various system components in the implementations described above should not be understood as requiring such separation in all implementations, and it should be understood that the described program components and systems can generally be integrated together in a single software product or packaged into multiple software products. Additionally, other implementations are within the scope of the following claims. In some cases, the actions recited in the claims can be performed in a different order and still achieve desirable

results.

[0298] While preferred embodiments of the present invention have been shown, and described herein, it will be obvious to those skilled in the art that such embodiments are provided by way of example only. It is not intended that the invention be limited by the specific examples provided within the specification. While the invention has been described with reference to the afore-mentioned specification, the descriptions and illustrations of the embodiments herein are not meant to be construed in a limiting sense. Numerous variations, changes, and substitutions will now occur to those skilled in the art without departing from the invention. Furthermore, it shall be understood that all aspects of the invention are not limited to the specific depictions, configurations, or relative proportions set forth herein which depend upon a variety of conditions and variables. It should be understood that various alternatives to the embodiments of the invention described herein might be employed in practicing the invention. It is therefore contemplated that the invention shall also cover any such alternatives, modifications, variations, or equivalents. It is intended that the following claims define the scope of the invention and that methods and structures within the scope of these claims and their equivalents be covered thereby.

CLAIMS

What is claimed is:

1. A method for sensor-based control of one or more aspects of an environment of a facility, the method comprising:

obtaining sensor data from one or more sensors of a wearable device worn by a user in the facility;

determining, based on the sensor data, a physiological condition of the user;

determining a location of the user within the facility based, at least in part, on:

one or more radio frequency (RF) signals transmitted from the wearable device, and/or

one or more RF signals received by the wearable device; and

adjusting an environmental control of the location based, at least in part, on the physiological condition of the user.

2. The method of claim 1, wherein the one or more sensors comprise a sensor configured to measure a sugar level of the user, a heart rate of the user, a step count of the user, a blood pressure of the user, a blood oxygen level of the user, a temperature of the user, a pulse of the user, or a combination thereof.

3. The method of claim 1, wherein obtaining the sensor data comprises receiving the sensor data from the wearable device and/or from a control device communicatively coupled with the wearable device.

4. The method of claim 3, wherein the control device comprises a controller of the facility, a mobile phone, laptop, or tablet.

5. The method of claim 1, wherein adjusting the environmental control of the location is further based on a user preference.

6. The method of claim 5, further comprising:

determining an identity of the user based on an association of the user with the wearable device; and

determining the user preference based on the identity of the user;

wherein adjusting the environmental control of the location is further based on the user preference.

7. The method of claim 5, wherein the user preference comprises a temperature setting, a window tint setting, a lighting setting, or a combination thereof.

8. The method of claim 7, wherein the lighting setting comprises a brightness and/or color of light.

9. The method of claim 1, wherein adjusting the environmental control of the location comprises adjusting air flow to and/or from the location; a temperature of air flowing into the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a window tint at the location; a temperature at the location; or a combination thereof.

10. The method of claim 1, wherein adjusting the environmental control of the location comprises:

determining a building system associated with the location; and

causing the building system to adjust the environmental control.

11. The method of claim 10, wherein the building system comprises a system controlling heating, ventilation, and air conditioning (HVAC) of the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a degree of window tint at the location; or a combination thereof.

12. The method of claim 10, wherein the building system comprises a device ensemble having a housing that encloses one or more devices that comprise: (i) sensors, (ii) a transceiver, (iii) a sensor and an emitter, or (iv) a combination thereof.

13. The method of claim 12, wherein the device ensemble is disposed in a fixture of the facility, or is attached to a fixture of the facility.

14. The method of claim 12, wherein the building system comprises a tintable window.

15. The method of claim 14, wherein the tintable window comprises an electrochromic window.

16. An apparatus for sensor-based control of one or more aspects of an environment of a facility, the apparatus comprising one or more processors comprising circuitry, wherein the one or more processors are configured to:

obtain, or direct obtaining of, sensor data from one or more sensors of a wearable device worn by a user in the facility;

determine, or direct determining of, a physiological condition of the user based on the sensor data;

determine, or direct determining of, a location of the user within the facility based, at least in part, on:

one or more radio frequency (RF) signals transmitted from the wearable device, and/or

one or more RF signals received by the wearable device; and

adjust, or direct adjusting of, an environmental control of the location based, at least in part, on the physiological condition of the user.

17. The apparatus of claim 16, wherein the one or more sensors comprise a sensor configured to measure a sugar level of the user, a heart rate of the user, a step count of the user, a blood pressure of the user, a blood oxygen level of the user, a temperature of the user, a pulse of the user, or a combination thereof.

18. The apparatus of claim 16, wherein, to obtain, or direct obtaining of, sensor data, the one or more processors are configured to receive the sensor data from the wearable device and/or from a control device communicatively coupled with the wearable device.

19. The apparatus of claim 18, wherein the control device comprises a controller of the facility, a mobile phone, laptop, or tablet.

20. The apparatus of claim 16, wherein the one or more processors are configured to adjust, or direct adjusting of, the environmental control of the location further based on a user preference.

21. The apparatus of claim 20, wherein the one or more processors are further configured to:

determine, or direct determining of, an identity of the user based on an association of the user with the wearable device; and

determine, or direct determining of, the user preference based on the identity of the user;

wherein the one or more processors are configured to adjust, or direct adjusting of, the environmental control of the location further based on the user preference.

22. The apparatus of claim 20, wherein the user preference comprises a temperature setting, a window tint setting, a lighting setting, or a combination thereof.

23. The apparatus of claim 22, wherein the lighting setting comprises a brightness and/or color of light.

24. The apparatus of claim 16, wherein, to adjust, or direct adjusting of, the environmental control of the location, the one or more processors are configured to adjust air flow to and/or from the location; a temperature of air flowing into the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a window tint at the location; a temperature at the location; or a combination thereof.

25. The apparatus of claim 16, wherein, to adjust, or direct adjusting of, the environmental control of the location, the one or more processors are configured to:

determine, or direct determining of, a building system associated with the location; and

cause, or direct causing of, the building system to adjust the environmental control.

26. The apparatus of claim 25, wherein the building system comprises a system controlling heating, ventilation, and air conditioning (HVAC) of the location; an oxygen level of the location;

a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a degree of window tint at the location; or a combination thereof.

27. The apparatus of claim 25, wherein the building system comprises a device ensemble having a housing that encloses one or more devices that comprise: (i) sensors, (ii) a transceiver, (iii) a sensor and an emitter, or (iv) a combination thereof.

28. The apparatus of claim 27, wherein the device ensemble is disposed in a fixture of the facility, or is attached to a fixture of the facility.

29. The apparatus of claim 27, wherein the building system comprises a tintable window.

30. The apparatus of claim 29, wherein the tintable window comprises an electrochromic window.

31. The apparatus of claim 16, wherein the apparatus comprises the wearable device; a control device communicatively coupled with the wearable device; or a computer server communicatively coupled with the wearable device, a control device, or both.

32. A non-transitory computer program product for sensor-based control of one or more aspects of an environment of a facility, which non-transitory computer program product contains instructions inscribed thereon that, when executed by one or more processors, cause the one or more processors to execute operations comprising:

obtaining sensor data from one or more sensors of a wearable device worn by a user in the facility;

determining, based on the sensor data, a physiological condition of the user;

determining a location of the user within the facility based, at least in part, on:

one or more radio frequency (RF) signals transmitted from the wearable device, and/or

one or more RF signals received by the wearable device; and

adjusting an environmental control of the location based, at least in part, on the physiological condition of the user.

33. The non-transitory computer program product of claim 32, wherein the one or more sensors comprise a sensor configured to measure a sugar level of the user, a heart rate of the user, a step count of the user, a blood pressure of the user, a blood oxygen level of the user, a temperature of the user, a pulse of the user, or a combination thereof.

34. The non-transitory computer program product of claim 32, wherein the operations comprising obtaining the sensor data include operations comprising receiving the sensor data from the wearable device and/or from a control device communicatively coupled with the wearable device.

35. The non-transitory computer program product of claim 34, wherein the control device comprises a controller of the facility, a mobile phone, laptop, or tablet.

36. The non-transitory computer program product of claim 32, wherein adjusting the environmental control of the location is further based on a user preference.

37. The non-transitory computer program product of claim 36, wherein the operations further comprise:

determining an identity of the user based on an association of the user with the wearable device; and

determining the user preference based on the identity of the user;

wherein adjusting the environmental control of the location is further based on the user preference.

38. The non-transitory computer program product of claim 36, wherein the user preference comprises a temperature setting, a window tint setting, a lighting setting, or a combination thereof.

39. The non-transitory computer program product of claim 38, wherein the lighting setting comprises a brightness and/or color of light.

40. The non-transitory computer program product of claim 32, wherein the operations comprising adjusting the environmental control of the location include operations comprising adjusting air flow to and/or from the location; a temperature of air flowing into the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a window tint at the location; a temperature at the location; or a combination thereof.

41. The non-transitory computer program product of claim 32, wherein the operations comprising adjusting the environmental control of the location include operations comprising:

determining a building system associated with the location; and

causing the building system to adjust the environmental control.

42. The non-transitory computer program product of claim 41, wherein the building system comprises a system controlling heating, ventilation, and air conditioning (HVAC) of the location; an oxygen level of the location; a carbon dioxide (CO2) level of the location; an amount of lighting at the location; a color of lighting at the location; a degree of window tint at the location; or a combination thereof.

43. The non-transitory computer program product of claim 41, wherein the building system comprises a device ensemble having a housing that encloses one or more devices that comprise: (i) sensors, (ii) a transceiver, (iii) a sensor and an emitter, or (iv) a combination thereof.

44. The non-transitory computer program product of claim 43, wherein the device ensemble is disposed in a fixture of the facility, or is attached to a fixture of the facility.

45. The non-transitory computer program product of claim 43, wherein the building system comprises a tintable window.

46. The non-transitory computer program product of claim 45, wherein the tintable window comprises an electrochromic window.

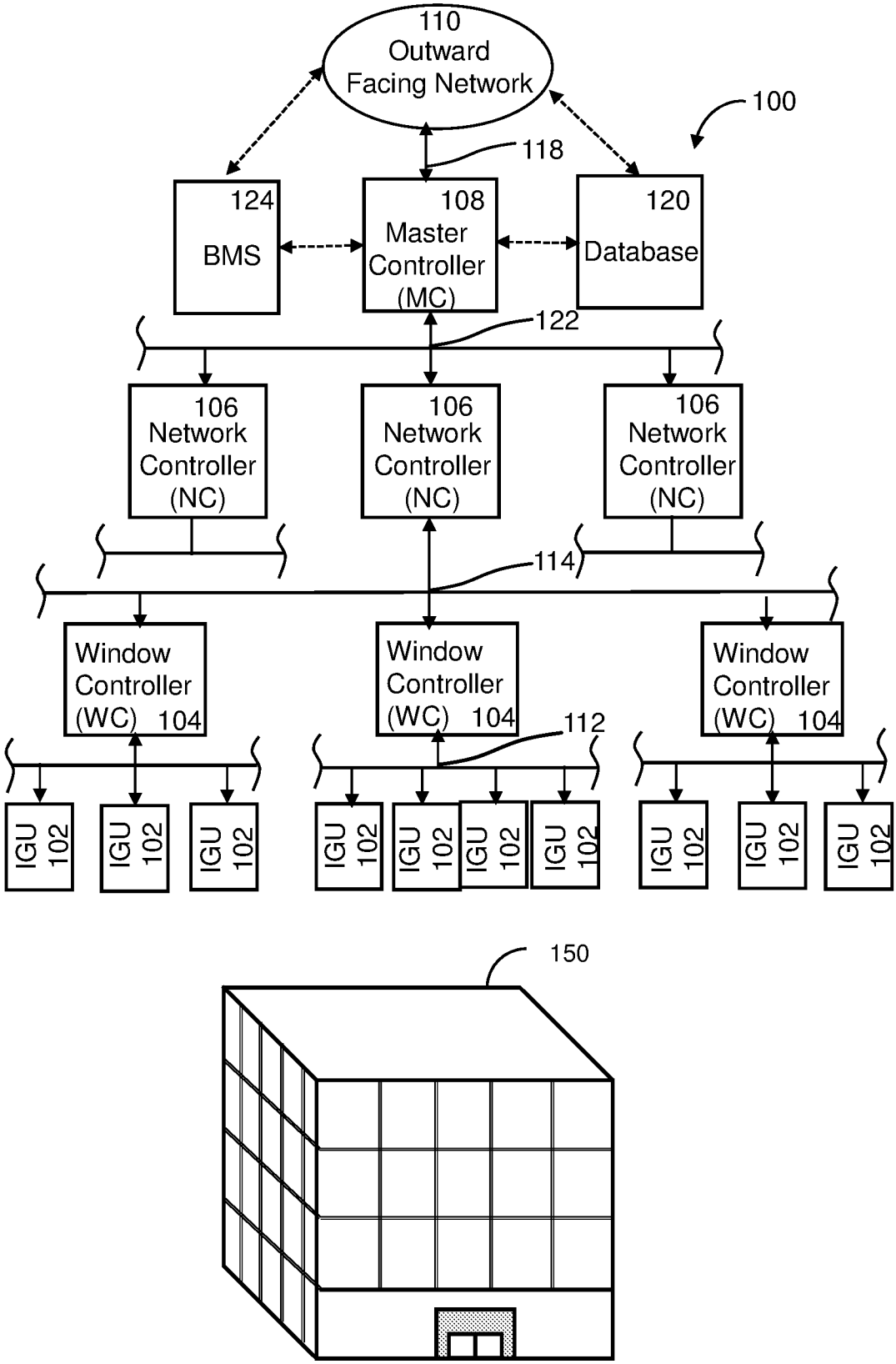

110
Outward
Facing Network
100
118
124
BMS
108
Master
Controller
(MC)
120
Database
122
106
Network
Controller
(NC)
106
Network
Controller
(NC)
106
Network
Controller
(NC)
114
Window
Controller
(WC) 104
Window
Controller
(WC) 104
Window
Controller
(WC) 104
112
IGU
102
IGU
102
IGU
102
IGU
102
IGU
102
IGU
102
IGU
102
IGU
102
IGU
102
150

Figure 1

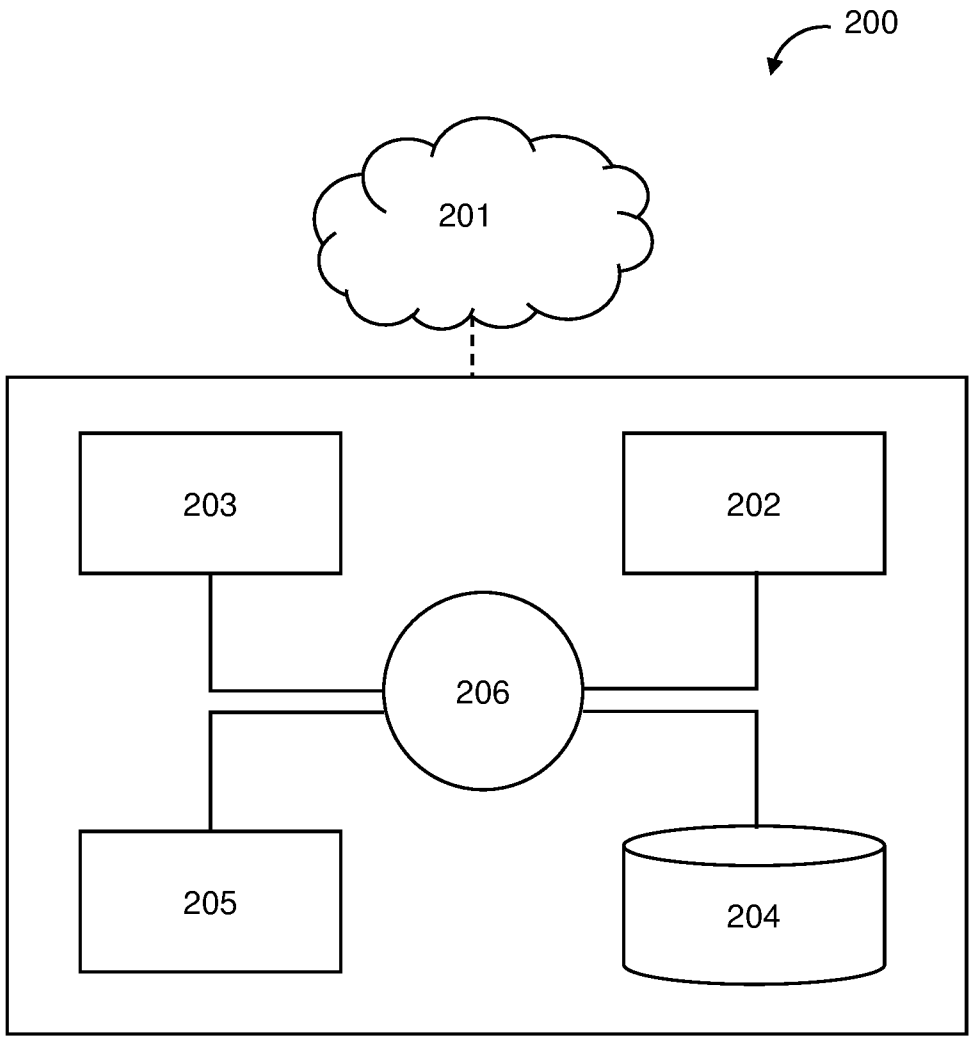


Figure 2

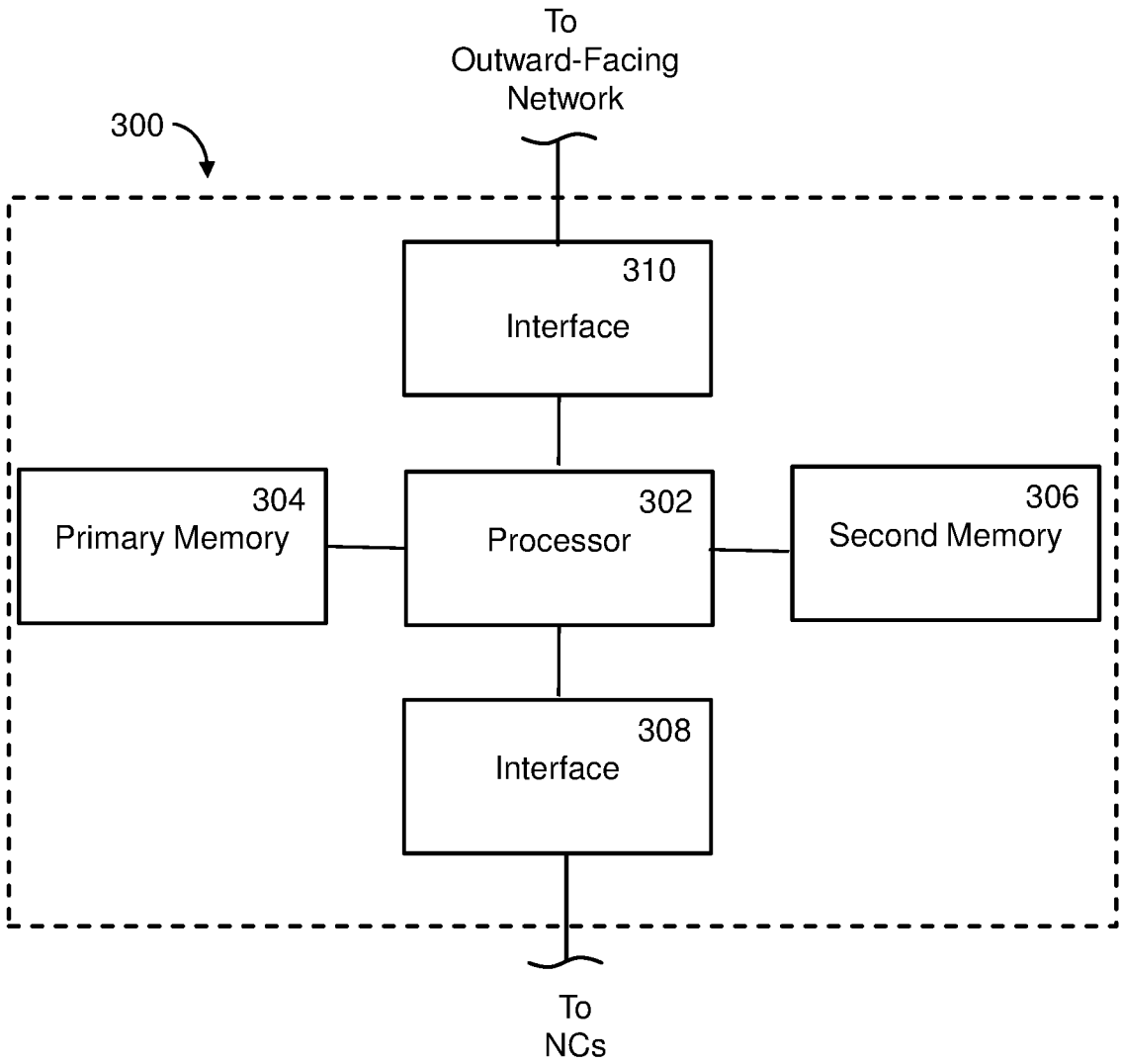

To
Outward-Facing
Network
300
310
Interface
304
Primary Memory
302
Processor
306
Second Memory
308
Interface
To
NCs

Figure 3

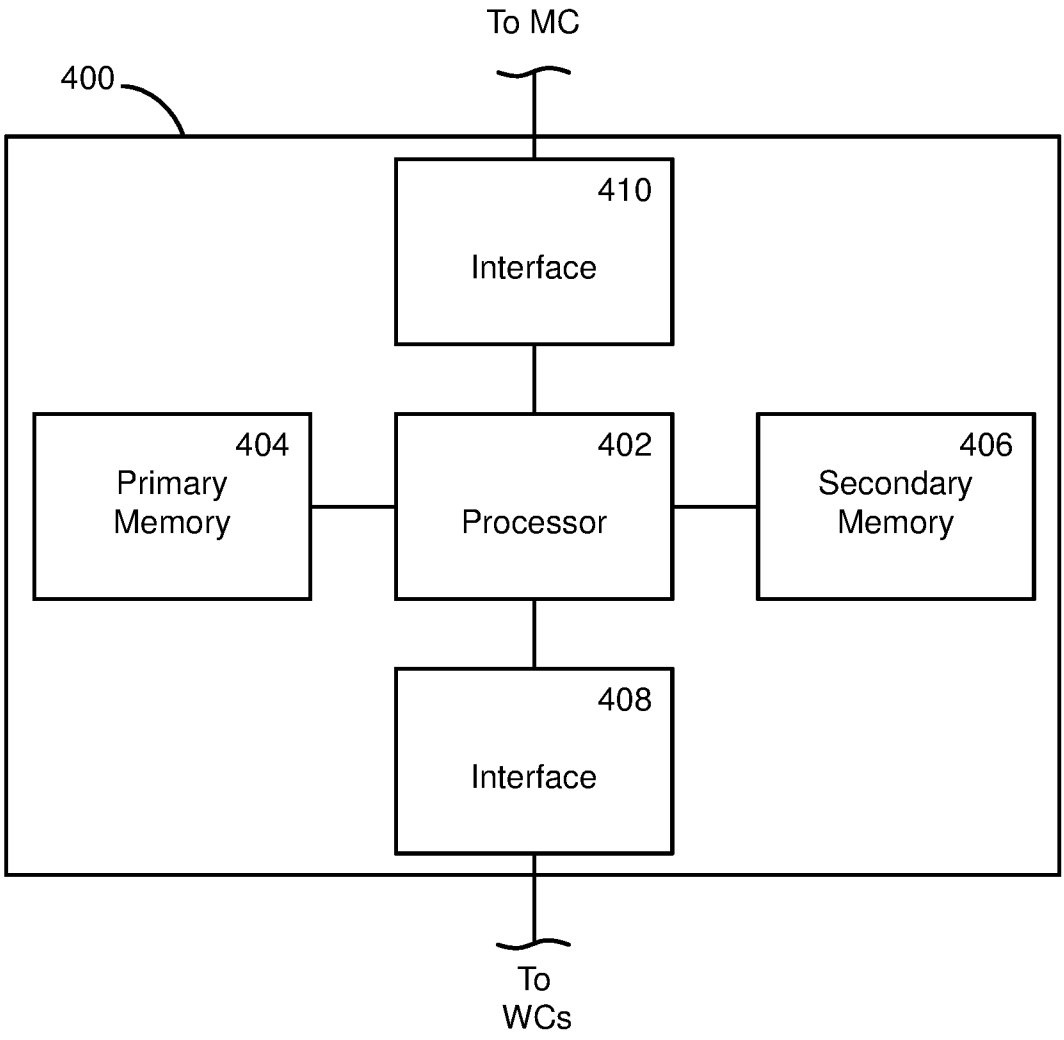

To MC
400
410
Interface
404
Primary
Memory
402
Processor
406
Secondary
Memory
408
Interface
To
WCs

Figure 4

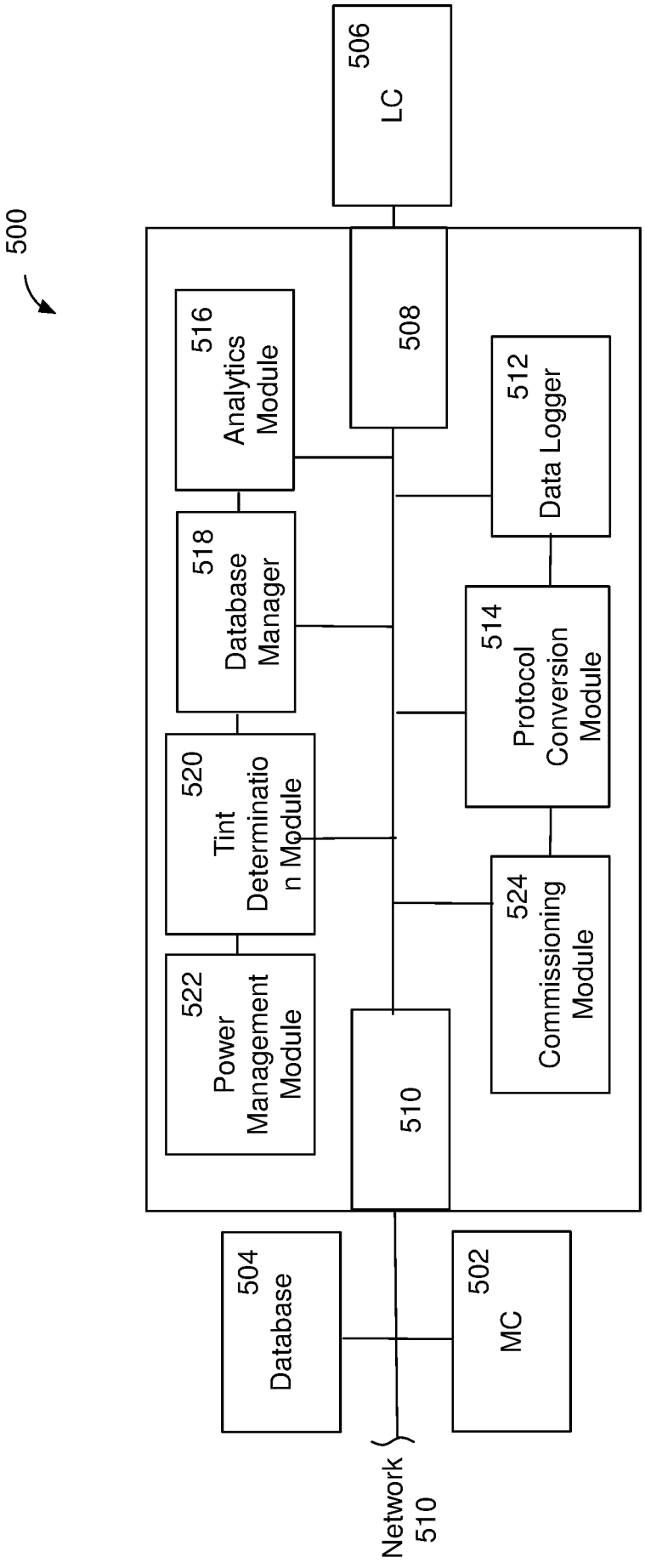

500
506
LC
508
516
Analytics
Module
512
Data Logger
518
Database
Manager
514
Protocol
Conversion
Module
520
Tint
Determinatio
n Module
524
Commissioning
Module
522
Power
Management
Module
510
504
Database
502
MC
Network
510

Figure 5

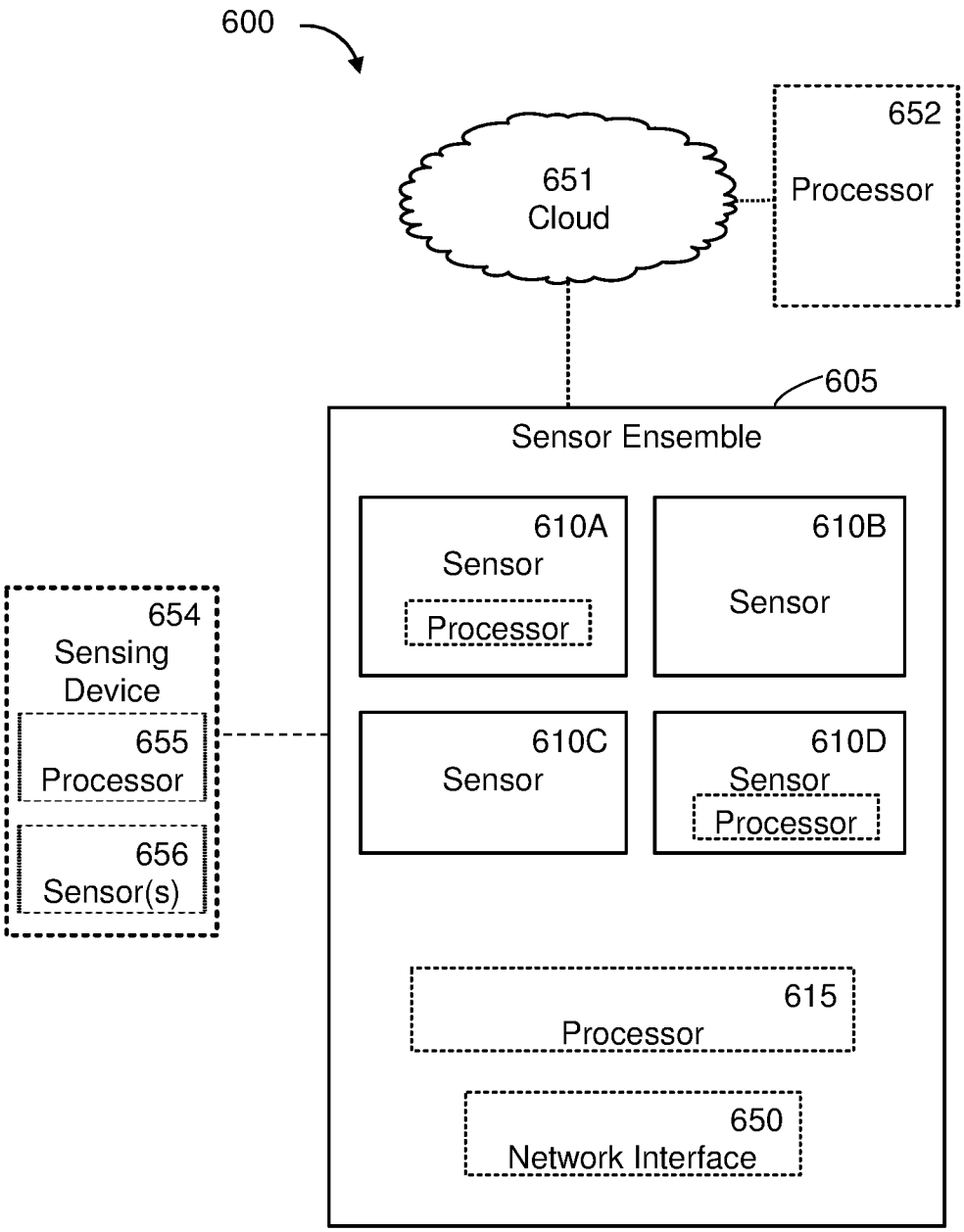

600
652
Processor
651
Cloud
605
Sensor Ensemble
610A
Sensor
Processor
610B
Sensor
654
Sensing
Device
655
Processor
610C
Sensor
610D
Sensor
Processor
656
Sensor(s)
615
Processor
650
Network Interface

Figure 6

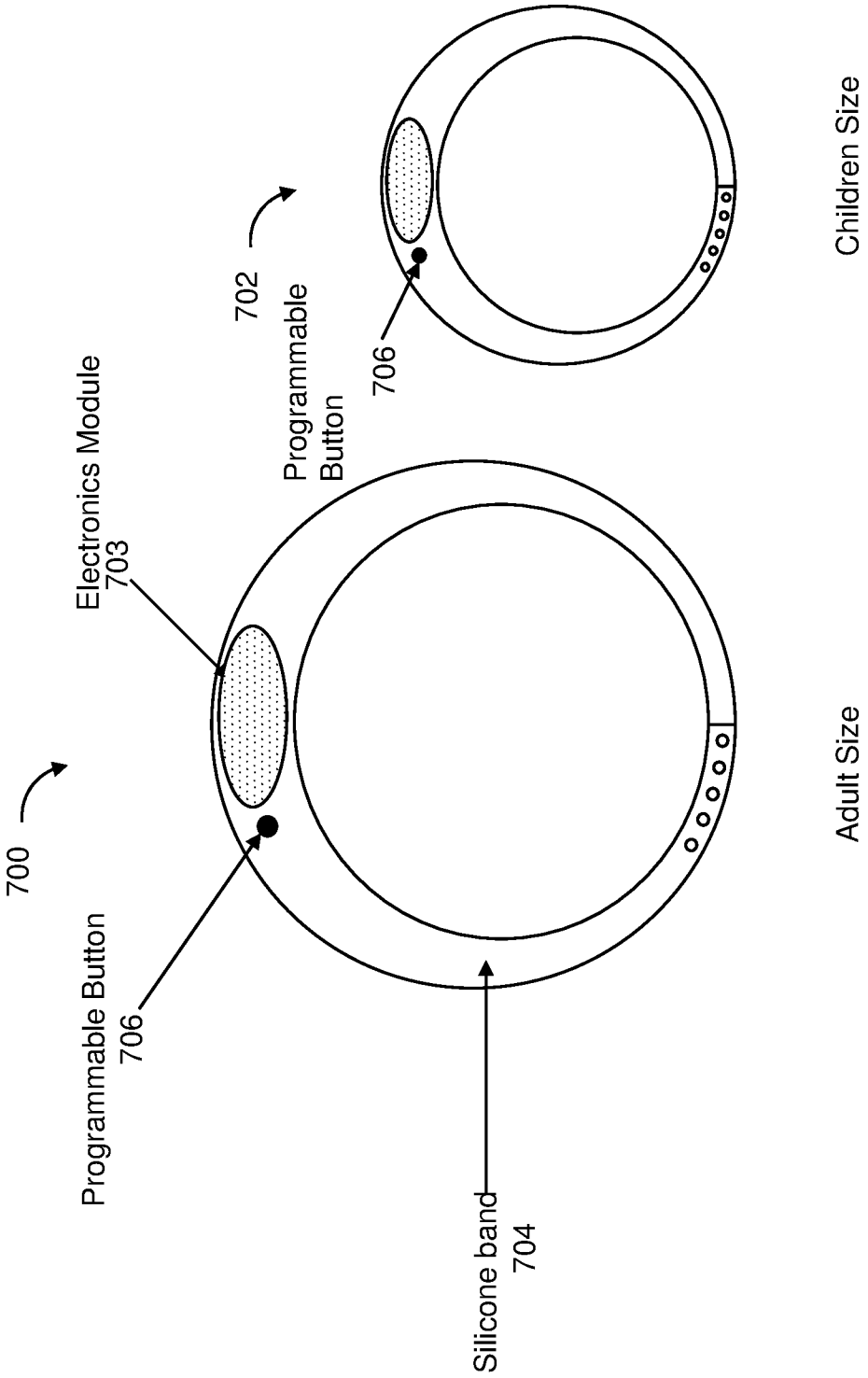

700
Programmable Button
706
Electronics Module
703
Silicone band
704
Adult Size
702
Programmable Button
706
Children Size

FIGURE 7

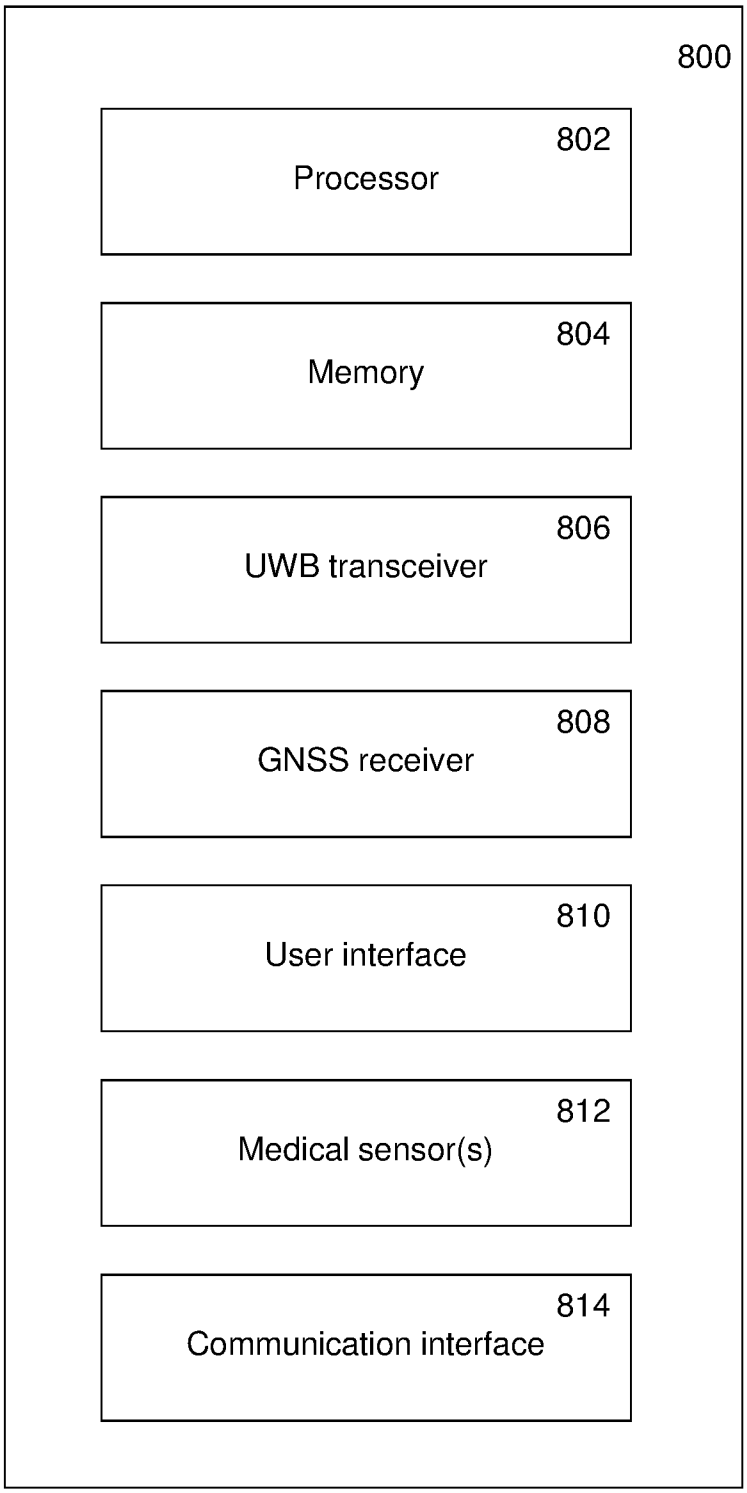

800
802
Processor
804
Memory
806
UWB transceiver
808
GNSS receiver
810
User interface
812
Medical sensor(s)
814
Communication interface

Figure 8

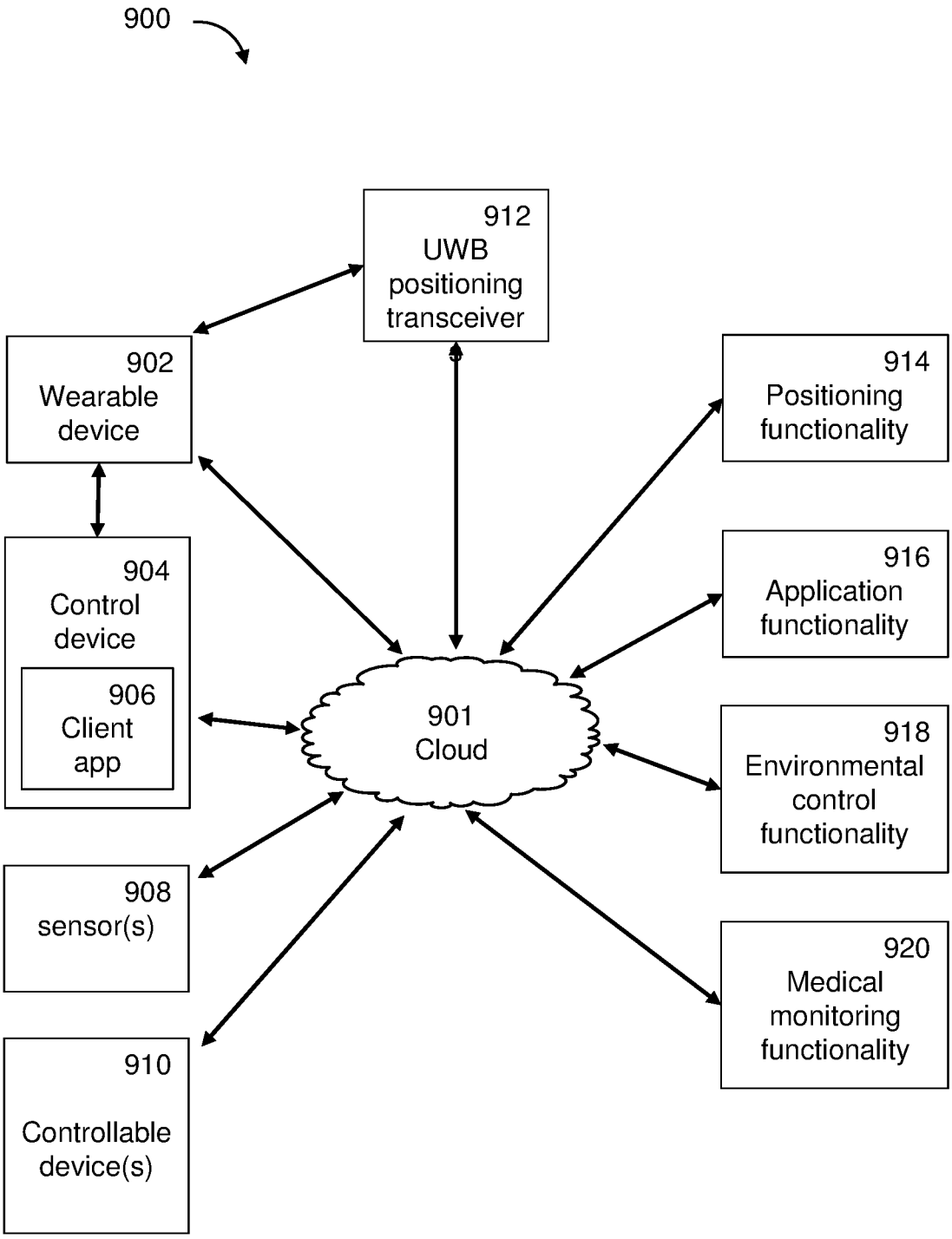

900
912
UWB
positioning
transceiver
902
Wearable
device
914
Positioning
functionality
904
Control
device
906
Client
app
916
Application
functionality
901
Cloud
918
Environmental
control
functionality
908
sensor(s)
920
Medical
monitoring
functionality
910
Controllable
device(s)

Figure 9

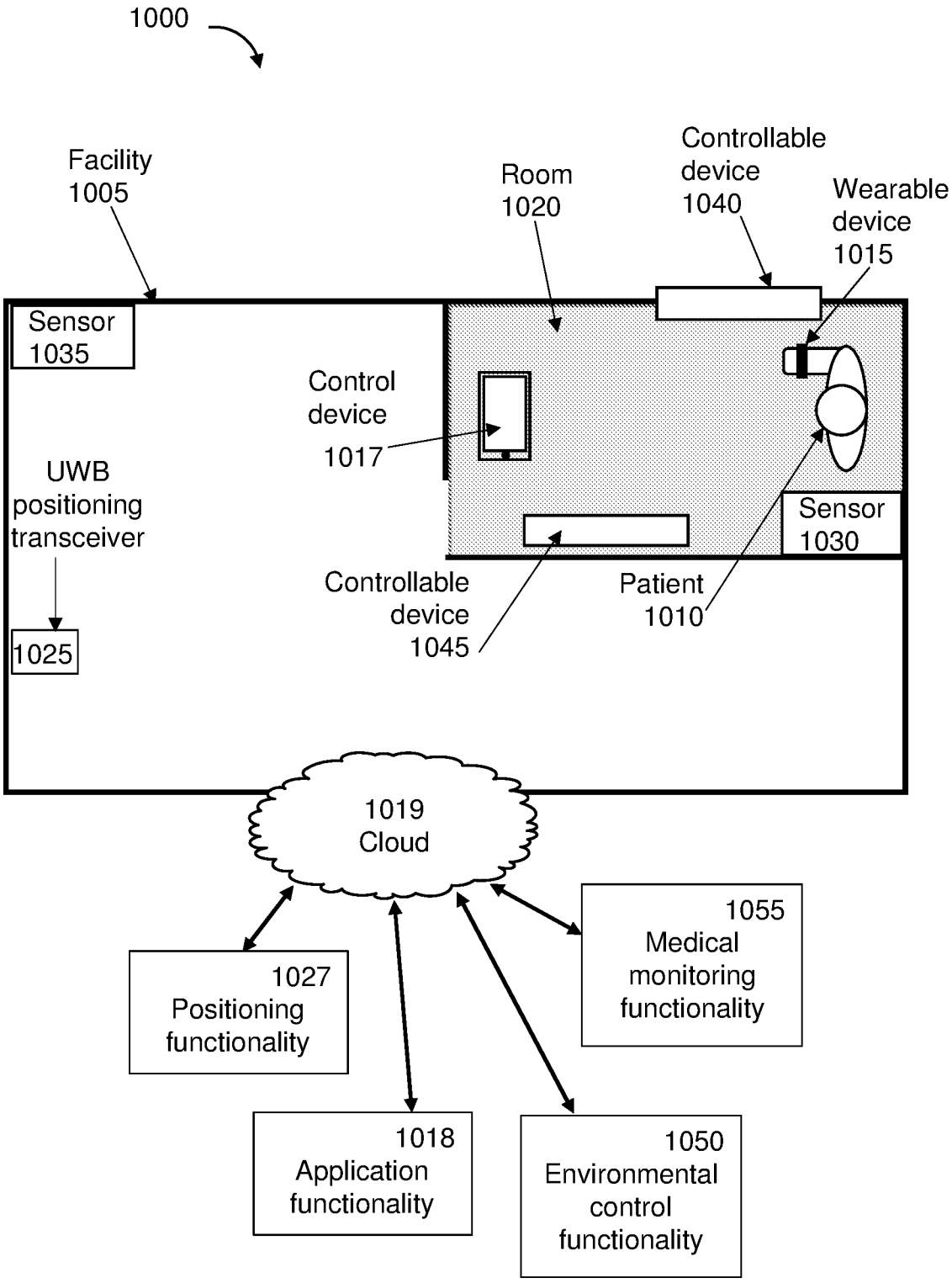

1000
Facility
1005
Room
1020
Controllable
device
1040
Wearable
device
1015
Sensor
1035
Control
device
1017
UWB
positioning
transceiver
1025
Sensor
1030
Controllable
device
1045
Patient
1010
1019
Cloud
1027
Positioning
functionality
1055
Medical
monitoring
functionality
1018
Application
functionality
1050
Environmental
control
functionality

Figure 10

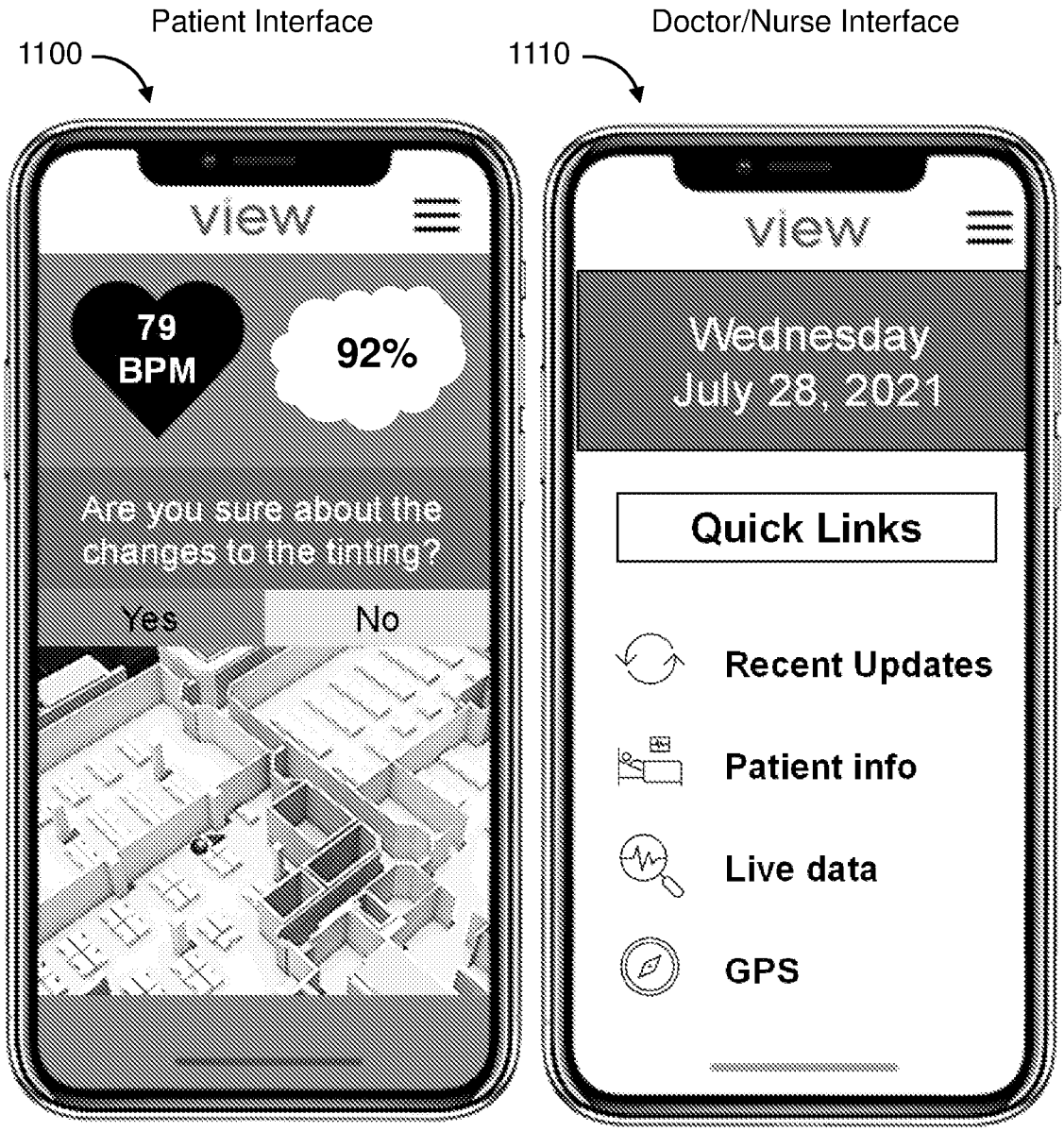

Patient Interface
1100
Doctor/Nurse Interface
1110
view
79 BPM
92%
Are you sure about the changes to the tinting?
Yes
No
view
Wednesday
July 28, 2021
Quick Links
Recent Updates
Patient info
Live data
GPS

FIGURE 11

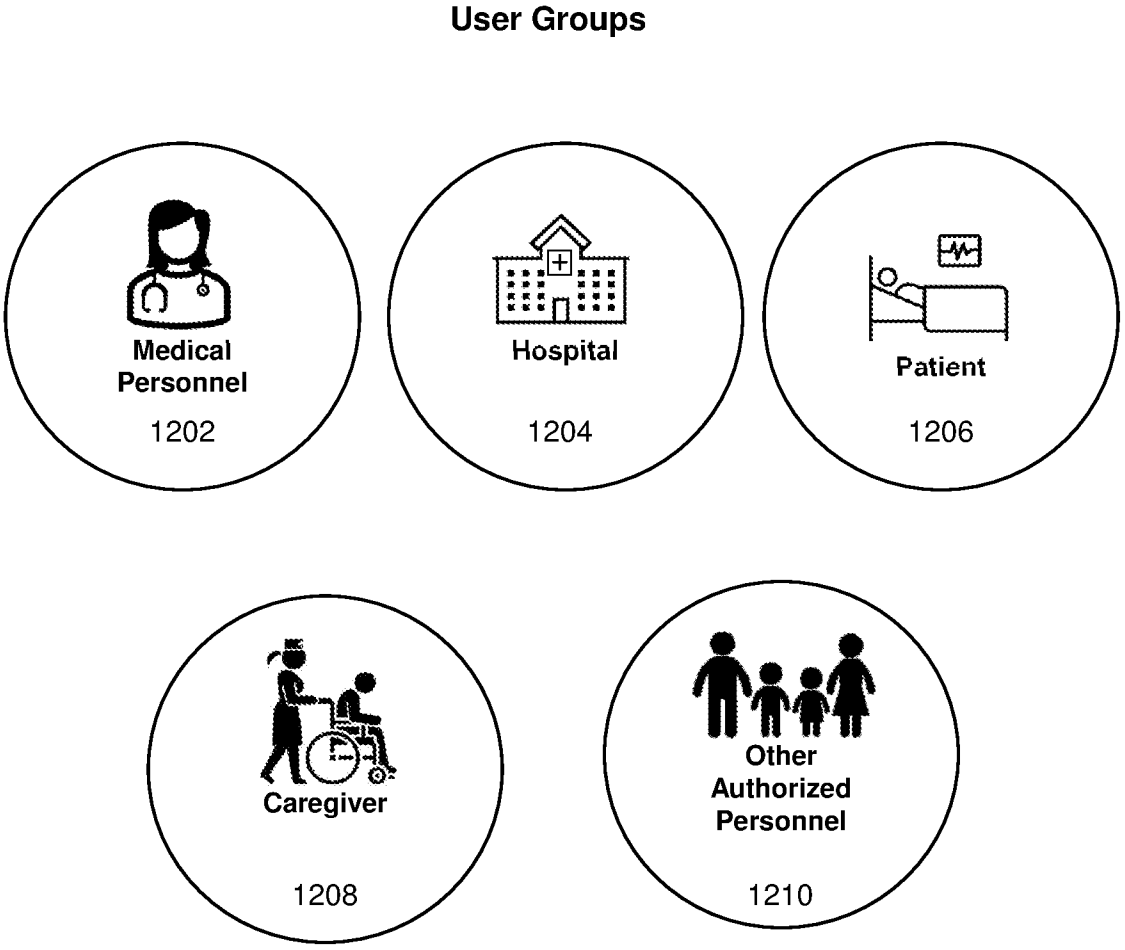

User Groups
Medical Personnel
1202
Hospital
1204
Patient
1206
Caregiver
1208
Other Authorized Personnel
1210

FIGURE 12

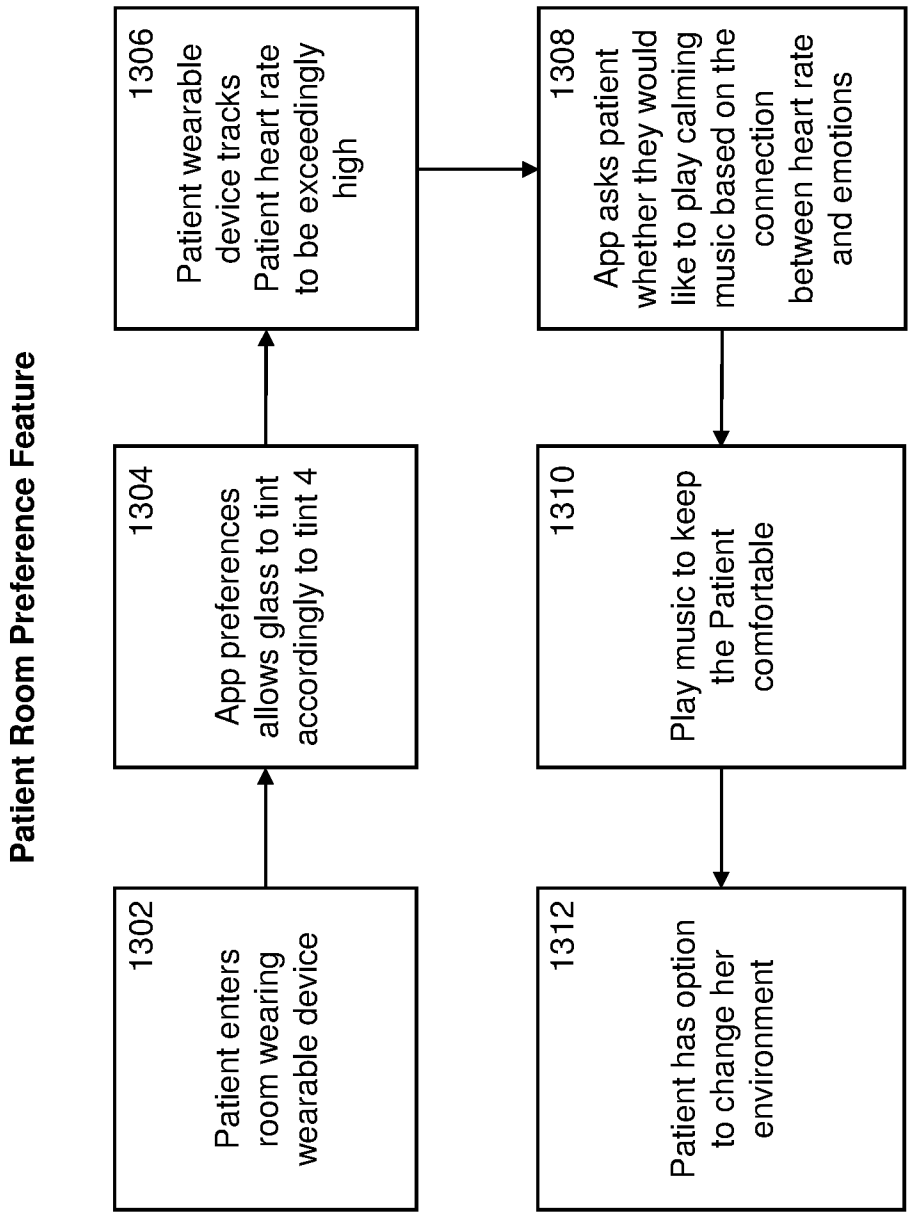

Patient Room Preference Feature
1302
Patient enters room wearing wearable device
1304
App preferences allows glass to tint accordingly to tint 4
1306
Patient wearable device tracks Patient heart rate to be exceedingly high
1308
App asks patient whether they would like to play calming music based on the connection between heart rate and emotions
1310
Play music to keep the Patient comfortable
1312
Patient has option to change her environment

FIGURE 13

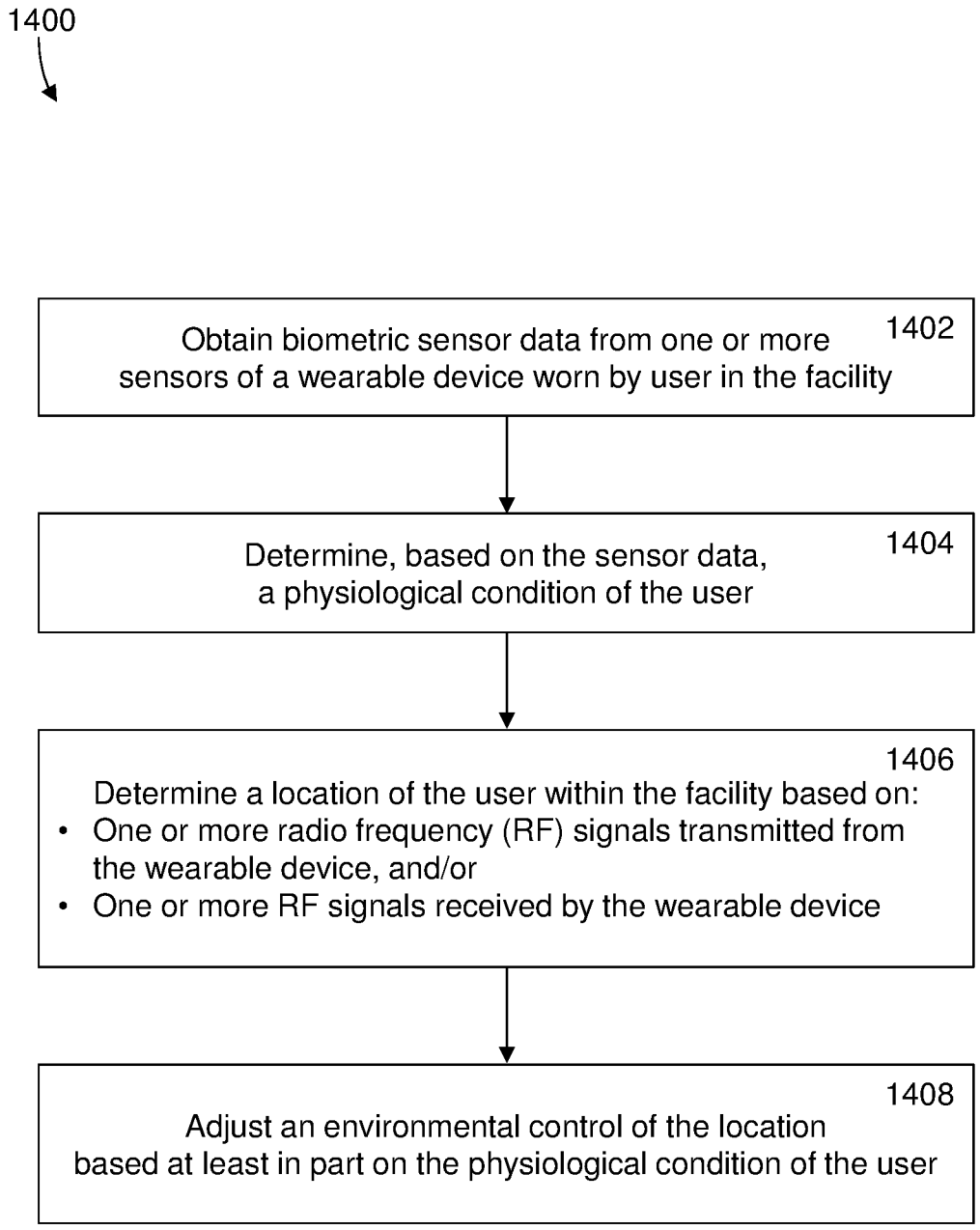

1400
Obtain biometric sensor data from one or more sensors of a wearable device worn by user in the facility
1402
Determine, based on the sensor data, a physiological condition of the user
1404
1406
Determine a location of the user within the facility based on:
• One or more radio frequency (RF) signals transmitted from the wearable device, and/or
• One or more RF signals received by the wearable device
1408
Adjust an environmental control of the location based at least in part on the physiological condition of the user

Figure 14

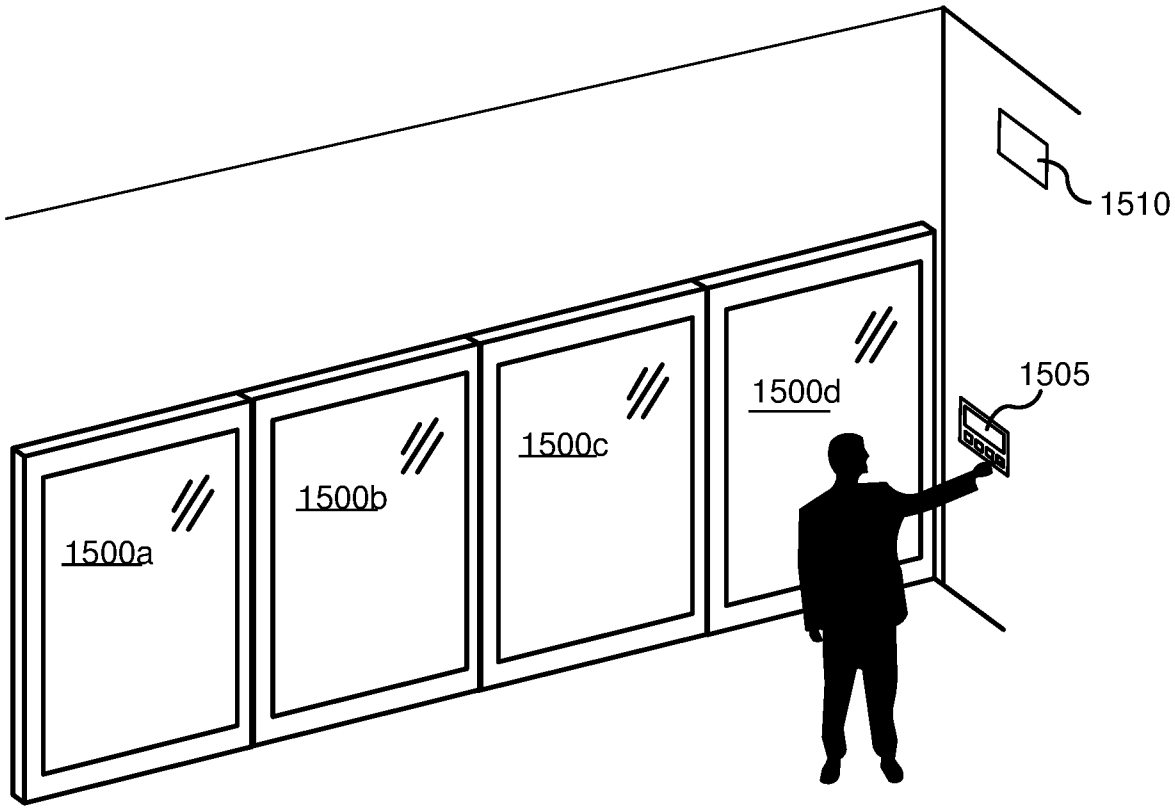


Figure 15A

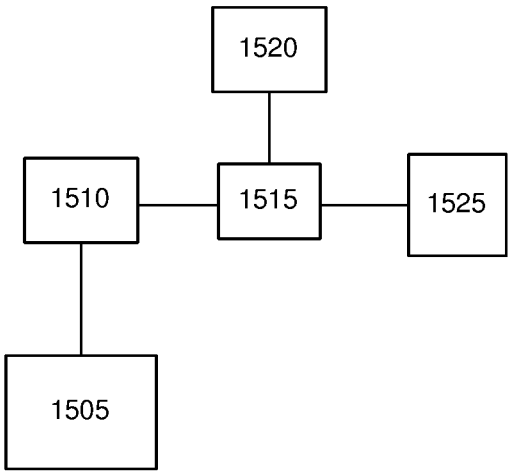


Figure 15B

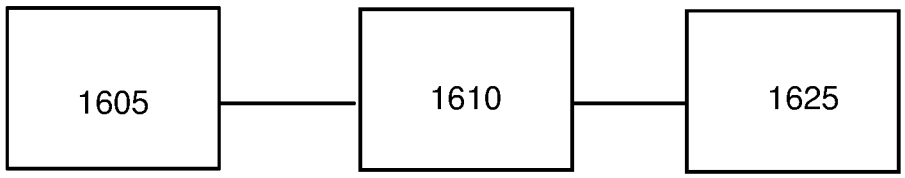


Figure 16A

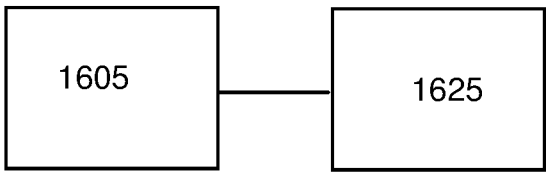


Figure 16B

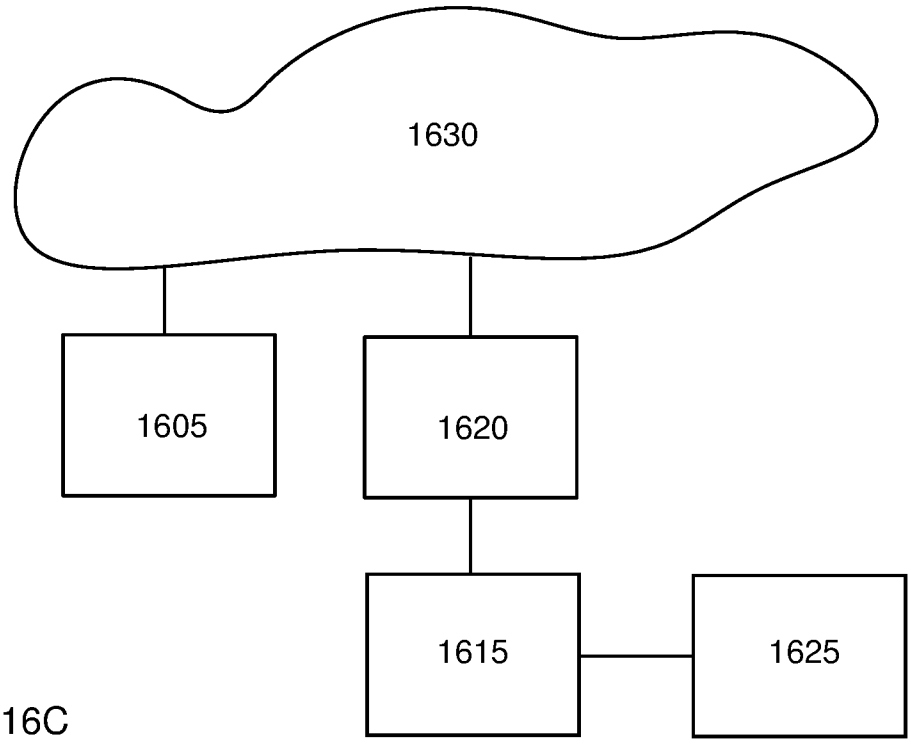
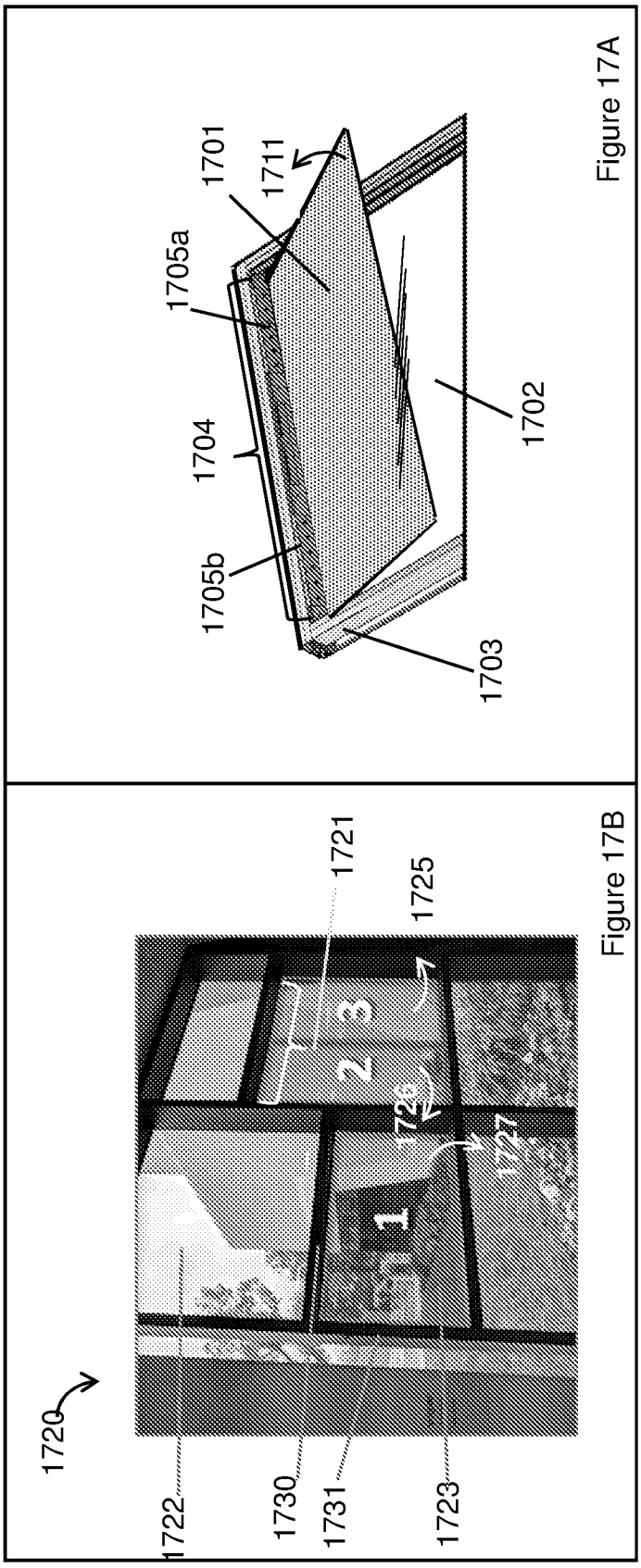


Figure 16C


1701
1711
1705a
1704
1705b
1702
1703
Figure 17A
1721
1725
1720
1722
1730
1731
1723
Figure 17B

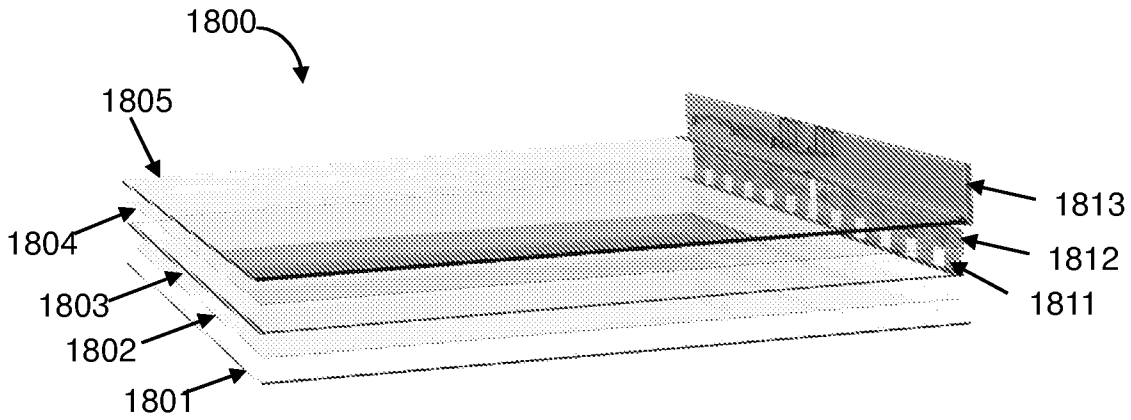


Figure 18

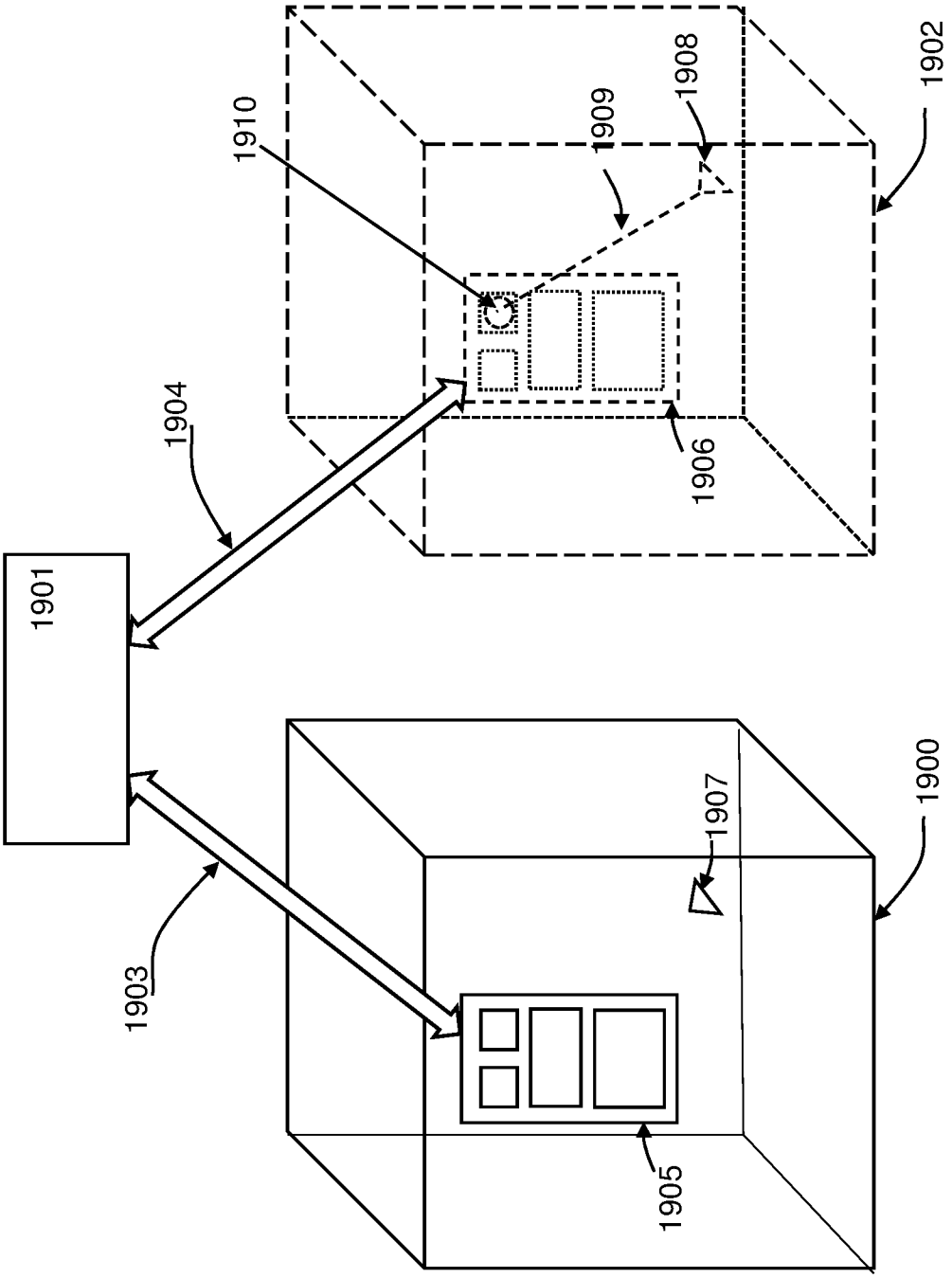


Figure 19

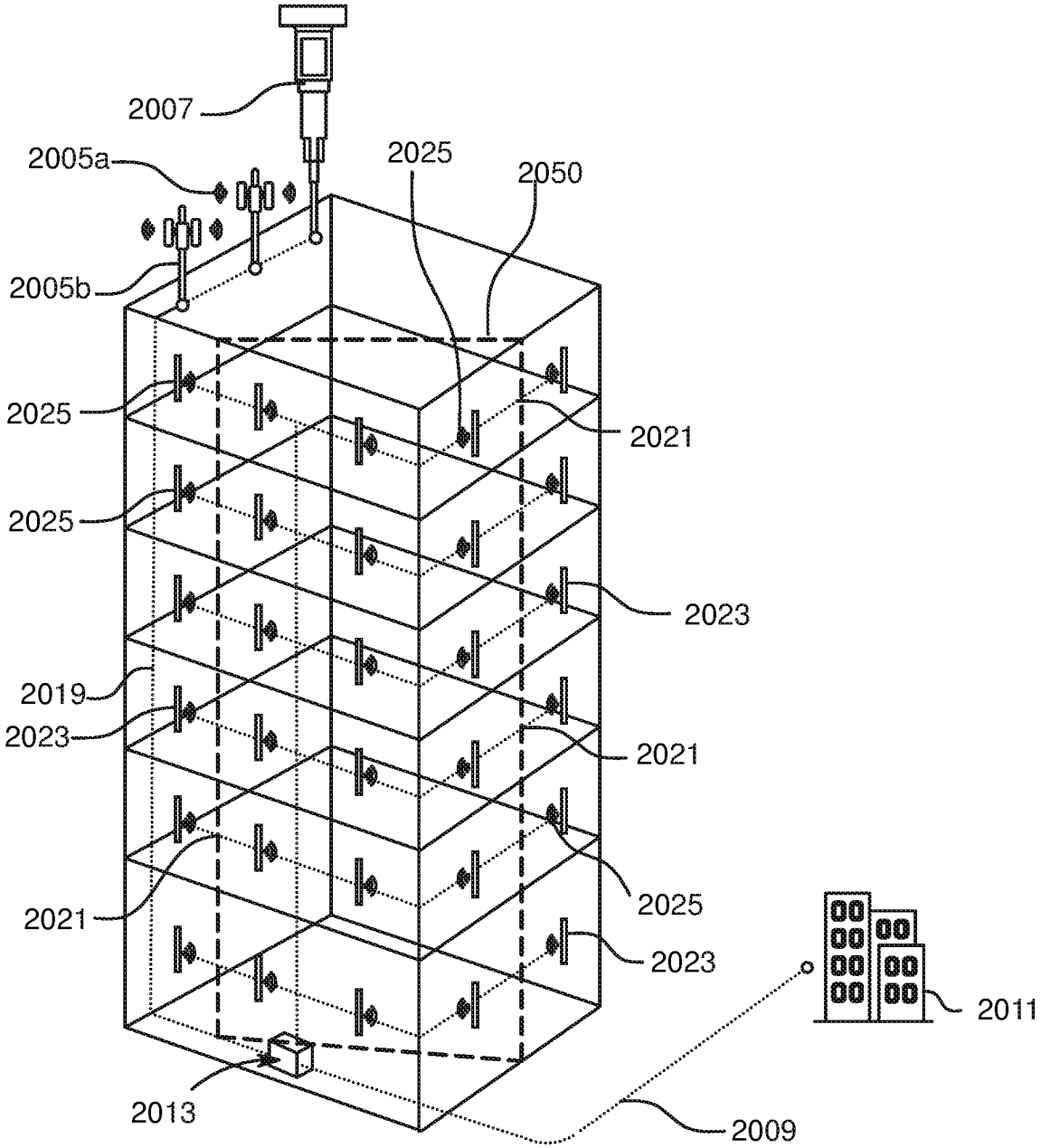

2007
2005a
2025
2050
2005b
2025
2021
2025
2023
2019
2023
2021
2021
2025
2023
2011
2013
2009

Figure 20

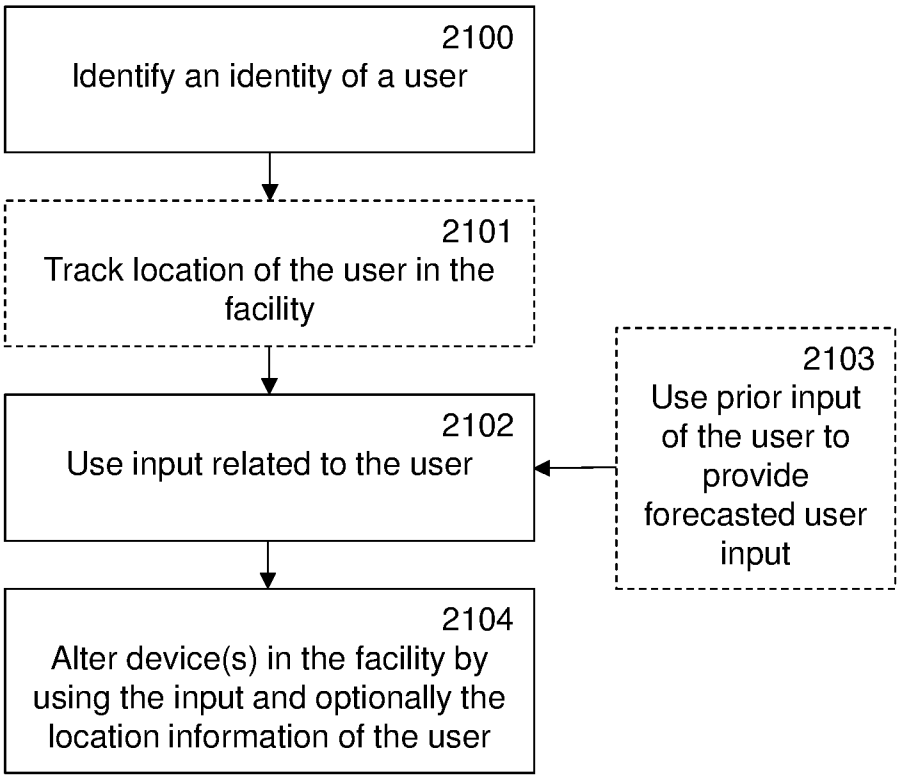

2100
Identify an identity of a user
2101
Track location of the user in the facility
2102
Use input related to the user
2103
Use prior input of the user to provide forecasted user input
2104
Alter device(s) in the facility by using the input and optionally the location information of the user

Figure 21

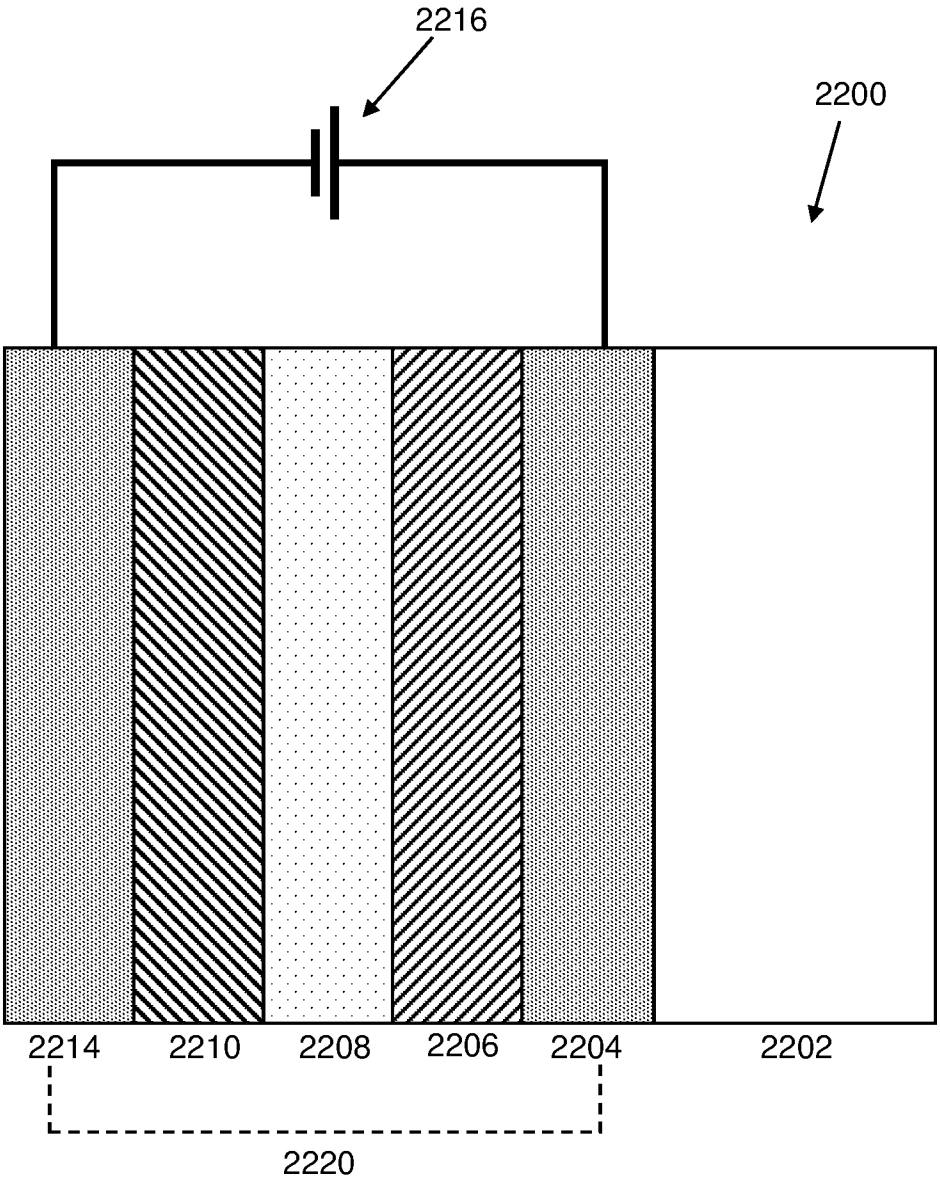


Figure 22

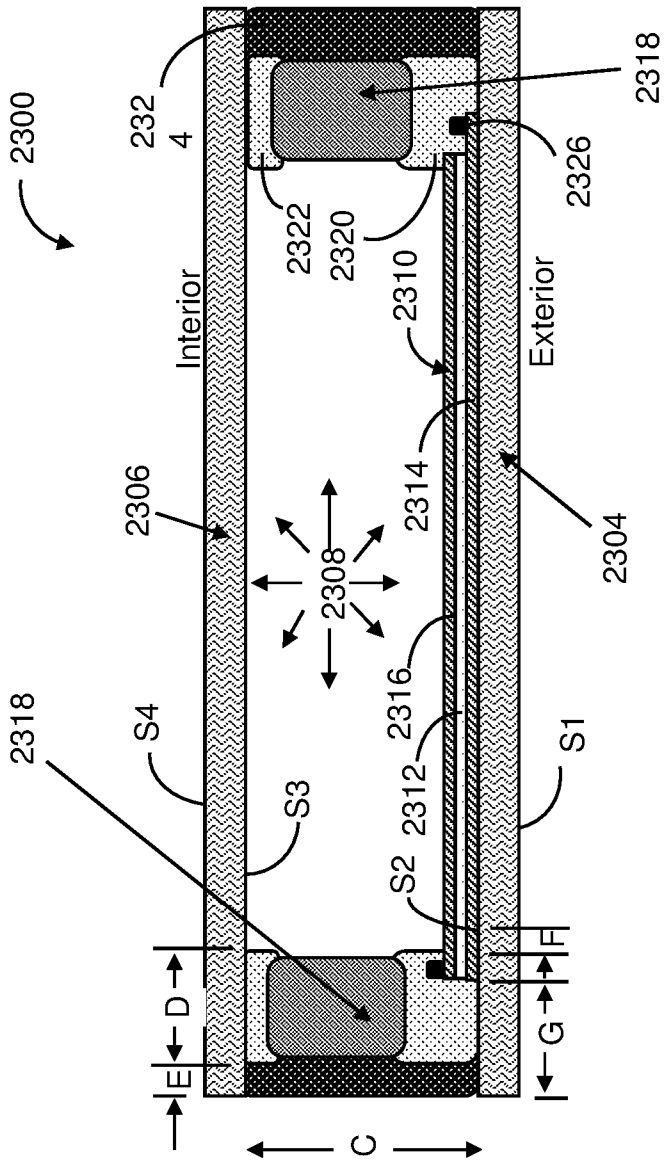

2300
2324
2318
2326
2322
2320
2310
Interior
Exterior
2306
2314
2304
2308
2316
2318
S4
S1
S3
2312
S2
F
D
G
E
C

Figure 23

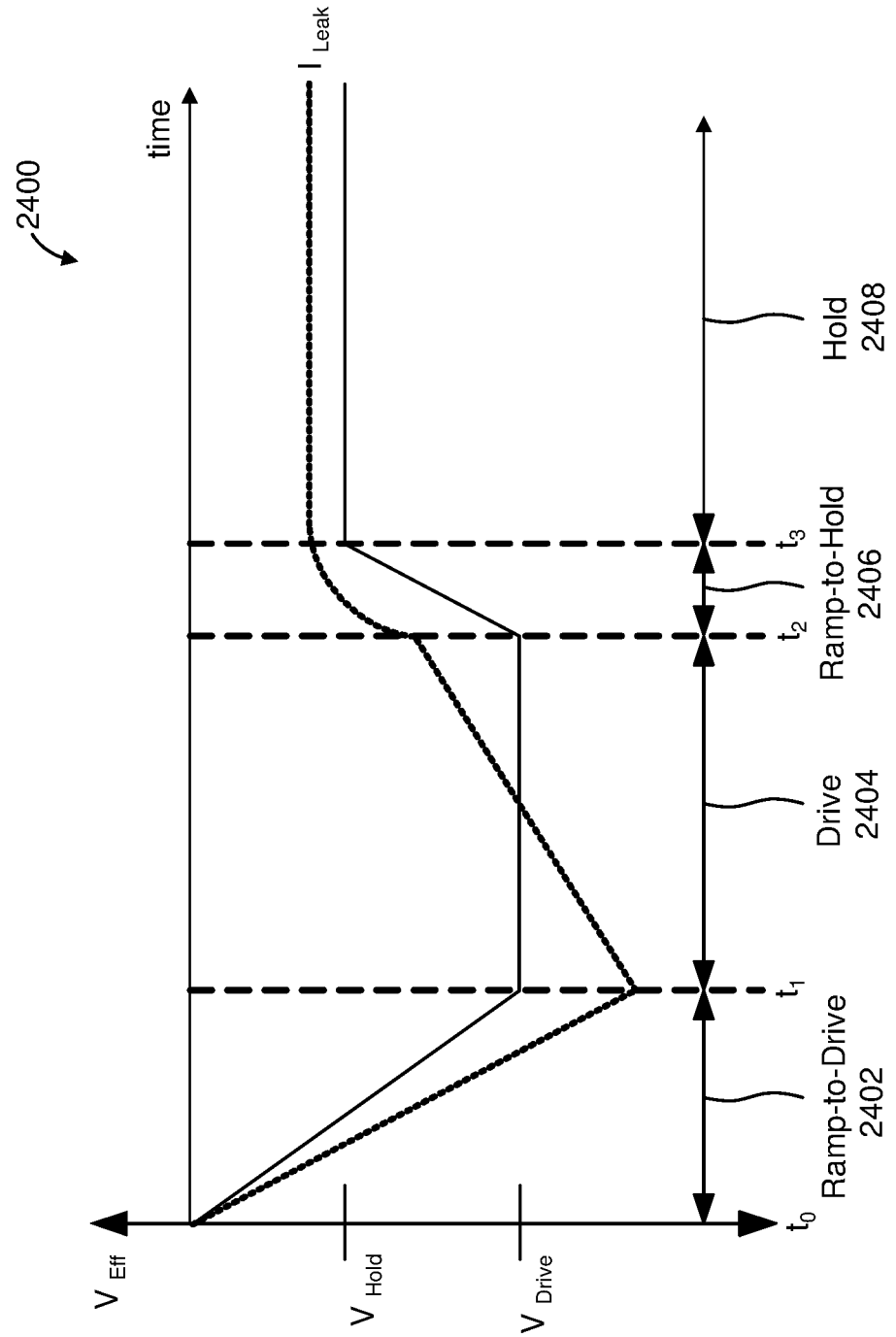

2400
time
I Leak
V Eff
V Hold
V Drive
t0
t1
t2
t3
Ramp-to-Drive
2402
Drive
2404
Ramp-to-Hold
2406
Hold
2408

Figure 24

INTERNATIONAL SEARCH REPORT

International application No.
PCT/US2022/016838

A. CLASSIFICATION OF SUBJECT MATTER

G10L 15/22(2006.01)i; **G06F 21/32**(2013.01)i; **G06F 3/16**(2006.01)i; **E06B 9/24**(2006.01)i; **G10L 15/26**(2006.01)i; **G06F 3/04886**(2022.01)i; **E06B 3/67**(2006.01)i; **G02F 1/163**(2006.01)i

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

G10L 15/22(2006.01); G01K 13/00(2006.01); G02F 1/163(2006.01); G05B 15/02(2006.01); G05D 23/19(2006.01); G05D 27/00(2006.01); G06F 1/16(2006.01); G06F 13/00(2006.01); G06F 3/00(2006.01); G06F 3/01(2006.01)

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Korean utility models and applications for utility models
Japanese utility models and applications for utility models

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

eKOMPASS(KIPO internal) & Keywords: sensor, physiological condition, wearable, location, environmental control

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 2019-0101878 A1 (HEARTMILES, LLC) 04 April 2019 (2019-04-04) claims 24-25, 28; and figures 2-5	1-46
Y	US 2017-0010670 A1 (SONY CORPORATION et al.) 12 January 2017 (2017-01-12) paragraphs [0033], [0056]; claims 1-7; and figures 1-2, 5-9	1-46
Y	WO 2018-222140 A1 (NATIONAL UNIVERSITY OF SINGAPORE) 06 December 2018 (2018-12-06) claims 1-11; and figures 2-7	5-15,20-31,36-46
A	KR 10-2016-0004644 A (NEOINPLUS CO., LTD.) 13 January 2016 (2016-01-13) claims 1-5; and figures 1-8b	1-46
A	US 2018-0188628 A1 (VIEW, INC.) 05 July 2018 (2018-07-05) paragraphs [0076], [0101]-[0106]; claims 1-10; and figures 4-12	1-46

☐ 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
"D" document cited by the applicant in the international application
"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	Date of mailing of the international search report
07 June 2022	**08 June 2022**

Name and mailing address of the ISA/KR	Authorized officer
Korean Intellectual Property Office **189 Cheongsa-ro, Seo-gu, Daejeon** **35208, Republic of Korea**	**YANG, JEONG ROK**
Facsimile No. **+82-42-481-8578**	Telephone No. **+82-42-481-5709**

INTERNATIONAL SEARCH REPORT
Information on patent family members

International application No.
PCT/US2022/016838

Patent document cited in search report	Publication date (day/month/year)	Patent family member(s)	Publication date (day/month/year)
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		US 10678201 B2	09 June 2020
		US 2017-0031334 A1	02 February 2017
		WO 2015-157670 A1	15 October 2015
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		CN 107193382 A	22 September 2017
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		EP 3092631 A1	16 November 2016
		EP 3110606 A1	04 January 2017
		JP 2017-513536 A	01 June 2017
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		JP 6660300 B2	11 March 2020
		KR 10-1939889 B1	17 January 2019
		KR 10-1946130 B1	11 June 2019
		KR 10-2204265 B1	15 January 2021
		US 2017-0010665 A1	12 January 2017
		US 2017-0010666 A1	12 January 2017
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		WO 2015-127143 A1	27 August 2015
WO 2018-222140 A1	06 December 2018	SG 11201909980 A	28 November 2019
KR 10-2016-0004644 A	13 January 2016	None	
US 2018-0188628 A1	05 July 2018	CN 106462023 A	22 February 2017
		CN 112615135 A	06 April 2021
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		US 9348192 B2	24 May 2016
		US 9664976 B2	30 May 2017
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		US 9690162 B2	27 June 2017
		US 9703167 B2	11 July 2017
		US 9728920 B2	08 August 2017