

METHOD AND SYSTEM FOR FACILITY MANAGEMENT FOR IDENTIFYING ACTIONABLE EVENT IN RELATION TO A BUILDING

TECHNICAL FIELD

5 [0001] The present invention generally relates to a method and a system for facility management for identifying an actionable event in relation to a building.

BACKGROUND

10 [0002] Ensuring security, facility maintenance, maintaining comfortable space in a building are essential operations for added value to real estate. For example, monitoring/questioning suspicious persons by security guard, cleaning high touch surfaces by cleaning staff, and maintaining comfortable air quality (e.g., carbon dioxide (CO₂) level, temperature level, humidity level, and so on) by a building officer. However, manual patrolling and routine checks by human resource may lead to actionable events being not identified or overlooked (e.g.,
15 missed incident detection) and higher labor cost for patrolling. Accordingly, an automated system for facility management is desired.

[0003] For example, Japanese patent no. 4943079 discloses a sensor information conversion system for converting sensor data received from sensors into information to be provided for a user. The system comprises a sensor data conversion means for converting sensor
20 data received from a sensor into state information showing a state adapted to an object measured by the sensor, and a state information conversion means for converting the state information into information showing a predetermined event expected from the state information. Accordingly, the system may define relationships of (a)sensor-(b)object-(c)meaning and (c)meaning-(d)incident by referring to a predefined relationship table. An incident may then be
25 detected based on the obtained sensor data and these relationships defined. In an example, (a)sensor data is retrieved by a vibration sensor and (b)the sensor is installed on a door, and (c)meaning is added to "switch status of door open/close each time vibration is detected". Finally (d)incident is detected based on a definition "if door is left open/close for a long time, it means there is no activity for long time". Accordingly, the system is able to understand that
30 an abnormal event or situation may have occurred based on the sensor data obtained. However, there are a number of problems associated with such a conventional system and two problems will be explained below.

[0004] Firstly, as incidents are detected by referring only sensor observation values, the above-mentioned conventional system is not able to handle more complex incident detection. For example, suppose that air quality sensors detect high CO₂ level in room A based on sensor observation value. If the purpose of a room is for meeting usage, air ventilation of the room may be desired before someone uses the room. On the other hand, if the purpose of the room is not for meeting usage (e.g., a computer server room), the priority for air ventilation may be low. Therefore, merely detecting high CO₂ level in the room does not necessarily mean that air ventilation is desired or is a priority. Accordingly, the above-mentioned conventional system suffers from deficiencies in facility management (e.g., ineffective or non-optimal facility management).

[0005] Secondly, the above-mentioned conventional system suffers from high development cost of sensor analysis to detect each incident respectively, since program development for each use case is required. For example, if a user wants to check whether the CO₂ level is maintained above a threshold consistently for 10 minutes, program development to monitor CO₂ level in real-time and check if the monitored value is above the threshold for 10 minutes is required. Accordingly, in the above-mentioned conventional system, program development for each respective use case is required, resulting in high development cost in sensor analytics to realize facility management.

[0006] A need therefore exists to provide a method and a system for facility management for identifying an actionable event in relation to a building, that seek to overcome, or at least ameliorate, one or more problems associated with conventional methods and systems for facility management, and in particular, enhancing or improving efficiency and effectiveness in facility management, such as an automated system for facility management with enhanced efficiency and effectiveness. It is against this background that the present invention has been developed.

SUMMARY

[0007] According to a first aspect of the present invention, there is provided a method of facility management for identifying an actionable event in relation to a building using at least one processor, the method comprising:

obtaining a plurality of sensor data from a plurality of sensors, respectively, wherein each sensor of the plurality of sensors is associated with a building asset of a plurality of building assets of the building, each building asset of the plurality of building assets has a

corresponding digital representation in a building information database, and for said each building asset, the corresponding digital representation of the building asset has one or more attribute parameters, a location parameter and one or more sensor observation parameters associated therewith, the one or more attribute parameters indicating one or more attributes assigned to the building asset, the location parameter indicating a location of the building asset and the one or more sensor observation parameters indicating one or more sensor observation values obtained based on one or more sensor data from one or more sensors associated with the building asset of the plurality of sensors; and

identifying an actionable event based on the one or more attribute parameters, the location parameter and the one or more sensor observation parameters associated with that of one or more building assets of the plurality of building assets.

[0008] According to a second aspect of the present invention, there is provided a system for facility management for identifying an actionable event in relation to a building, the system comprising:

at least one memory; and

at least one processor communicatively coupled to the at least one memory and configured to:

obtain a plurality of sensor data from a plurality of sensors, respectively, wherein each sensor of the plurality of sensors is associated with a building asset of a plurality of building assets of the building, each building asset of the plurality of building assets has a corresponding digital representation in a building information database, and for said each building asset, the corresponding digital representation of the building asset has one or more attribute parameters, a location parameter and one or more sensor observation parameters associated therewith, the one or more attribute parameters indicating one or more attributes assigned to the building asset, the location parameter indicating a location of the building asset and the one or more sensor observation parameters indicating one or more sensor observation values obtained based on one or more sensor data from one or more sensors associated with the building asset of the plurality of sensors; and

identify an actionable event based on the one or more attribute parameters, the location parameter and the one or more sensor observation parameters associated with that of one or more building assets of the plurality of building assets.

[0009] According to a third aspect of the present invention, there is provided a computer program product, embodied in one or more non-transitory computer-readable storage mediums,

comprising instructions executable by at least one processor to perform the method of facility management for identifying an actionable event in relation to a building according to the above-mentioned first aspect of the present invention.

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BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Embodiments of the present invention will be better understood and readily apparent to one of ordinary skill in the art from the following written description, by way of example only, and in conjunction with the drawings, in which:

FIG. 1 depicts a schematic flow diagram of a method of facility management for identifying an actionable event in relation to a building using at least one processor, according to various embodiments of the present invention;

FIG. 2 depicts a schematic block diagram of a system for facility management for identifying an actionable event in relation to a building, according to various embodiments of the present invention;

FIG. 3 depicts a schematic block diagram of an exemplary computer system which may be used to realize or implement the system for facility management, according to various embodiments of the present invention;

FIG. 4 depicts a schematic drawing of an overview of an example system for facility management for identifying an actionable event in relation to a building, according to various example embodiments of the present invention;

FIG. 5 illustrates a schematic drawing of an example building comprising a plurality of building assets, with two example building assets (Room A and Concierge B) being monitored, according to various example embodiments of the present invention;

FIG. 6 shows a table (Table 1) with two example combined conditions for monitoring by the system, according to various example embodiments of the present invention;

FIG. 7 illustrates a schematic drawing of the example building comprising a plurality of building assets, with two example building assets (Room A and Corridor C) being monitored, according to various example embodiments of the present invention;

FIG. 8 shows an example GUI of a GUI-based analytics generator, according to various example embodiments of the present invention;

FIG. 9 depicts a schematic flow diagram of an overview of a method of facility management, according to various example embodiments of the present invention;

FIG. 10 shows a table (Table 2) corresponding to an example monitoring database, according to various example embodiments of the present invention;

FIG. 11 shows a table (Table 3) corresponding to an example monitoring condition database, according to various example embodiments of the present invention;

5 FIG. 12 depicts a schematic flow diagram of combined metric monitoring, according to various example embodiments of the present invention.

FIG. 13 depicts a schematic flow diagram of monitoring condition creation, according to various example embodiments of the present invention;

10 FIG. 14 depicts another example of monitoring condition creation, according to various example embodiments of the present invention;

FIGs. 15A to 15F illustrate various example time-based operators, along with their usage, according to various example embodiments of the present invention; and

FIGs. 16A and 16B illustrate two example spatial-based operators, along with their usage, according to various example embodiments of the present invention.

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DETAILED DESCRIPTION

[0011] Various embodiments of the present invention provide a method and a system for facility management for identifying an actionable event in relation to a building. For example, the actionable event may refer to any event that may require or be desirable for an action or task to be performed in relation to the building in response to sensor data from one or more sensors, such as but not limited to, an incident or an unusual, unexpected or undesired condition or observation in relation to one or more building assets of the building based on the sensor data. Accordingly, it will be appreciated by a person skilled in the art that the present invention is not limited to any particular or specific actionable event in relation to a building.

20 [0012] For example, as described in the background, manual patrolling and routine checks by human resource may lead to actionable events being not identified or overlooked (e.g., missed incident detection) and higher labor cost for patrolling. Therefore, an automated system for facility management is desired. However, as explained in the background, conventional systems for facility management has been found to be inefficient and ineffective. Accordingly, various embodiments of the present invention provide a method and a system for facility management for identifying an actionable event in relation to a building, that seek to overcome, or at least ameliorate, one or more problems associated with conventional methods and systems for facility management, and in particular, enhancing or improving efficiency and effectiveness

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in facility management, such as an automated system for facility management with enhanced efficiency and effectiveness.

[0013] FIG. 1 depicts a schematic flow diagram of a method 100 of facility management for identifying an actionable event in relation to a building using at least one processor, according to various embodiments of the present invention. The method 100 comprises obtaining (at 102) a plurality of sensor data from a plurality of sensors, respectively, wherein each sensor of the plurality of sensors is associated with a building asset of a plurality of building assets of the building, each building asset of the plurality of building assets has a corresponding digital representation in a building information database, and for said each building asset, the corresponding digital representation of the building asset has one or more attribute parameters, a location parameter and one or more sensor observation parameters associated therewith. In this regard, the one or more attribute parameters indicate one or more attributes assigned to the building asset, the location parameter indicates a location of the building asset and the one or more sensor observation parameters indicate one or more sensor observation values obtained based on one or more sensor data from one or more sensors associated with the building asset of the plurality of sensors. The method 100 further comprises identifying (at 106) an actionable event based on the one or more attribute parameters, the location parameter and the one or more sensor observation parameters associated with that of one or more building assets of the plurality of building assets.

[0014] Accordingly, the method 100 of facility management has advantageously been found to enhance or improve efficiency and effectiveness in facility management. In particular, by identifying the actionable event based on attribute parameters and location parameters associated with one or more building assets in addition to sensor observation parameters, facility management can be better performed or optimized based on situation and context awareness (e.g., purpose or function of building asset(s) and presence of staff) and physical properties (e.g., location of building asset(s)) associated with the building, thereby resulting in enhanced efficiency and effectiveness. These advantages or technical effects, and/or other advantages or technical effects, will become more apparent to a person skilled in the art as the method 100 of facility management, as well as the corresponding system for facility management, is described in more detail according to various embodiments and example embodiments of the present invention.

[0015] In various embodiments, the above-mentioned one or more building assets are multiple building assets. For example, in relation to the above-mentioned identifying (at 106)

the actionable event, in the case of two building assets (e.g., a first building asset and a second building asset), the above-mentioned identifying (at 106) the actionable event is based on the one or more attribute parameters, the location parameter and the one or more sensor observation parameters associated with the first building asset and the one or more attribute parameters, the location parameter and the one or more sensor observation parameters associated with the second building asset of the plurality of building assets. In this regard, the method 100 of facility management can be further optimized based on situation and context awareness and physical properties (e.g., relative distance between building assets) associated with the building, thereby further enhancing efficiency and effectiveness. As an illustrative example, when high CO₂ level in a first building asset (e.g., a room) is detected, if a building staff is at a second building asset (e.g., a concierge or corridor) nearby (or sufficiently close to) the first building asset (e.g., based on the relative distance between the first and second building assets), for example, the building staff can be dispatched to open a window in the first building asset for air ventilation. On the other hand, if no building staff is nearby, an air conditioner in the building asset can be turned on for air ventilation instead of dispatching a building staff. Therefore, facility management can be better performed or further optimized based on situation and context awareness and physical properties associated with the building, thereby further enhancing efficiency and effectiveness.

[0016] In various embodiments, the above-mentioned identifying (at 106) the actionable event is further based on a predetermined actionable event condition associated with the one or more building assets.

[0017] In various embodiments, the above-mentioned identifying (at 106) the actionable event based on the predetermined actionable event condition comprises, for each of the one or more building assets: determining whether the one or more sensor observation parameters associated with the building asset satisfy corresponding one or more predetermined sensor observation conditions associated with the building asset included in the predetermined actionable event condition; determining whether the one or more attribute parameters associated with the building asset satisfy corresponding one or more predetermined attribute conditions associated with the building asset included in the predetermined actionable event condition; and determining whether the location parameter associated with the building asset satisfy a corresponding location condition associated with the building asset included in the predetermined actionable event condition.

[0018] In various embodiments, the actionable event is identified if the predetermined actionable event condition is determined to be satisfied. In this regard, the method 100 further

comprises triggering a predetermined task associated with the predetermined actionable event condition for the actionable event identified.

[0019] In various embodiments, the predetermined task associated with the predetermined actionable event condition is determined to be satisfied if at least: the one or more predetermined sensor observation conditions associated with that of the one or more building assets included in the predetermined actionable event condition are determined to be satisfied; the one or more predetermined attribute conditions associated with that of the one or more building assets included in the predetermined actionable event condition are determined to be satisfied; and the location condition associated with that of the one or more building assets included in the predetermined actionable event condition is determined to be satisfied.

[0020] In various embodiments, the above-mentioned one or more building assets are multiple building assets. In this regard, the above-mentioned identifying (at 106) the actionable event based on the predetermined actionable event condition further comprises determining whether the location parameters associated with the multiple building assets satisfy a relative location condition associated with the multiple building assets based on a predetermined reference distance or range of distance between the multiple building assets. For example, in the case of two building assets, the relative location condition may be based on a predetermined reference distance or range of distance between the two building assets. For example, the relative location condition associated with first and second building assets is determined to be satisfied if a distance between the location of the first building asset indicated by the location parameter associated with the first building asset and the location of the second building asset indicated by the location parameter associated with the second building asset is less than the predetermined reference distance or within the predetermined range of distance.

[0021] In various embodiments, in the case of the above-mentioned one or more building assets being multiple building assets, the predetermined task associated with the predetermined actionable event condition comprises tasking one or more individuals detected based on one or more sensor data obtained from one or more sensors associated with a first building asset of the multiple building assets to attend to the actionable event at a second building asset of the multiple building assets in relation to one or more sensor observation parameters associated with the second building asset.

[0022] In various embodiments, the predetermined actionable event condition is included in an actionable event condition database. In this regard, the method 100 further comprises

adding a new actionable event condition in the actionable event condition database via an actionable event condition generation user interface.

[0023] In various embodiments, the above-mentioned adding the new actionable event condition comprises: receiving, via the actionable event condition generation user interface, one or more building asset identity inputs, each building asset identity input designating a corresponding building asset of the plurality of building assets for which the new actionable event condition is associated with. Furthermore, for each of the one or more building asset identity inputs, the above-mentioned adding the new actionable event condition comprises: receiving, via the actionable event condition generation user interface, one or more sensor observation type inputs designating one or more sensor observation parameters associated with the designated building asset for which the new actionable event condition is associated with; receiving, via the actionable event condition generation user interface, one or more function operator inputs designating one or more functions for subjecting the designated one or more sensor observation parameters to; and receiving, via the actionable event condition generation user interface, one or more reference value inputs designating one or more reference values based on which one or more results of the one or more functions are compared respectively for determining an outcome on whether the new actionable event condition with respect to the designated building asset is satisfied.

[0024] In various embodiments, the above-mentioned one or more building asset identity inputs are multiple building asset identity inputs designating multiple building assets for which the new actionable event condition is associated with. In this regard, the above-mentioned adding the new actionable event condition further comprises: receiving, via the actionable event condition generation user interface, an integration operator type input designating an integration operator for integrating the outcomes on whether the new actionable event condition with respect to the multiple designated building assets are satisfied. For example, the integration operator may be an “and” operator, and in such a case, the new actionable event condition is satisfied only if all of the outcomes with respect to the multiple designated building assets are determined to be satisfied. As another example, if the integration operator is an “or” operator, the new actionable event condition is satisfied if any of the outcomes with respect to the multiple designated building assets is determined to be satisfied.

[0025] In various embodiments, the one or more building asset identity inputs are selected from a predefined set of building asset identities corresponding to building assets of the building available for a user to select. In various embodiments, the one or more sensor observation type

inputs are selected from a predefined set of sensor observation types available for the user to select for the designated building asset. In various embodiments, the one or more function operator inputs are selected from a predefined set of functions available for the user to select. In various embodiments, the integration operator type input is selected from a predefined set of integration operators available for the user to select.

[0026] In various embodiments, the method 100 further comprises updating, for each building asset of the plurality of building assets, the one or more sensor observation parameters associated with the corresponding digital representation of the building asset with the one or more sensor observation values based on the one or more sensor data obtained from the one or more sensors associated with the building asset.

[0027] In various embodiments, the predefined set of functions comprises a set of time-based functions and a set of spatial-based functions. In various embodiments, the set of time-based functions comprises one or more of an average function, a maximum function, a minimum function, a maximum range function, a cumulative sum function, a differential cumulative sum function, a differential absolute cumulative sum function, a count number of occurrences above or below a threshold function and a value difference between time instances function. In various embodiments, the set of spatial-based functions comprises one or more of an average function, a summation function, a maximum function, a minimum function, a maximum range function and a value difference between locations function.

[0028] In various embodiments, for each building asset of the plurality of building assets, the one or more attribute parameters associated with the corresponding digital representation of the building asset indicates a current purpose or function of the building asset or a status of the building asset.

[0029] In various embodiments, for each building asset of the plurality of building assets, the building asset is a room, an area or a building equipment.

[0030] In various embodiments, each sensor of the plurality of sensors is an imaging sensor, a distance sensor, an Internet of Things (IoT) sensor, an inertial measurement unit (IMU) sensor or a feed sensor. For example, the feed sensor may be configured to receive feeds from a feed source, such as feeds from a website or API (e.g., weather forecast, news, and so on).

[0031] In various embodiments, the building information database is a digital twin database for the building, and for each building asset of the plurality of building assets, the corresponding digital representation of the building asset is a corresponding digital twin object in the digital twin database.

[0032] FIG. 2 depicts a schematic block diagram of a system 200 for facility management for identifying an actionable event in relation to a building, according to various embodiments of the present invention, corresponding to the method 100 of facility management for identifying an actionable event as described hereinbefore with reference to FIG. 1 according to various embodiments of the present invention. The system 200 comprises: at least one memory 202; and at least one processor 204 communicatively coupled to the at least one memory 202 and configured to: obtain a plurality of sensor data from a plurality of sensors, respectively, wherein each sensor of the plurality of sensors is associated with a building asset of a plurality of building assets of the building, each building asset of the plurality of building assets has a corresponding digital representation in a building information database, and for said each building asset, the corresponding digital representation of the building asset has one or more attribute parameters, a location parameter and one or more sensor observation parameters associated therewith, the one or more attribute parameters indicating one or more attributes assigned to the building asset, the location parameter indicating a location of the building asset and the one or more sensor observation parameters indicating one or more sensor observation values obtained based on one or more sensor data from one or more sensors associated with the building asset of the plurality of sensors; and identify an actionable event based on the one or more attribute parameters, the location parameter and the one or more sensor observation parameters associated with that of one or more building assets of the plurality of building assets.

[0033] It will be appreciated by a person skilled in the art that the at least one processor 204 may be configured to perform various functions or operations through set(s) of instructions (e.g., software modules) executable by the at least one processor 204 to perform various functions or operations. Accordingly, as shown in FIG. 2, the system 200 may comprise a sensor data obtaining module (or a sensor data obtaining circuit) 206 configured to perform the above-mentioned obtain a plurality of sensor data from a plurality of sensors, respectively; and an actionable event identifying module (or an actionable event identifying circuit) 210 configured to perform the above-mentioned identify an actionable event.

[0034] It will be appreciated by a person skilled in the art that the above-mentioned modules are not necessarily separate modules, and two or more modules may be realized by or implemented as one functional module (e.g., a circuit or a software program) as desired or as appropriate without deviating from the scope of the present invention. For example, the sensor data obtaining module 206 and the actionable event identifying module 210 may be realized (e.g., compiled together) as one executable software program (e.g., software application or

simply referred to as an “app”), which for example may be stored in the at least one memory 202 and executable by the at least one processor 204 to perform various functions/operations as described herein according to various embodiments of the present invention.

5 [0035] In various embodiments, the system 200 for facility management corresponds to the method 100 of facility management as described hereinbefore with reference to FIG. 1 according to various embodiments, therefore, various functions or operations configured to be performed by the least one processor 204 may correspond to various steps or operations of the method 100 of facility management as described hereinbefore according to various
10 embodiments, and thus need not be repeated with respect to the system 200 for facility management for clarity and conciseness. In other words, various embodiments described herein in context of the methods are analogously valid for the corresponding systems, and vice versa.

[0036] For example, in various embodiments, the at least one memory 202 may have stored therein the sensor data obtaining module 206 and/or the actionable event identifying module 210, which respectively correspond to various steps (or operations or functions) of the method
15 100 of facility management as described herein according to various embodiments, which are executable by the at least one processor 204 to perform the corresponding functions or operations as described herein.

[0037] A computing system, a controller, a microcontroller or any other system providing a processing capability may be provided according to various embodiments in the present
20 disclosure. Such a system may be taken to include one or more processors and one or more computer-readable storage mediums. For example, the system 200 for facility management described hereinbefore may include at least one processor (or controller) 204 and at least one computer-readable storage medium (or memory) 202 which are for example used in various processing carried out therein as described herein. A memory or computer-readable storage
25 medium used in various embodiments may be a volatile memory, for example a DRAM (Dynamic Random Access Memory) or a non-volatile memory, for example a PROM (Programmable Read Only Memory), an EPROM (Erasable PROM), EEPROM (Electrically Erasable PROM), or a flash memory, e.g., a floating gate memory, a charge trapping memory, an MRAM (Magnetoresistive Random Access Memory) or a PCRAM (Phase Change Random
30 Access Memory).

[0038] In various embodiments, a “circuit” may be understood as any kind of a logic implementing entity, which may be special purpose circuitry or a processor executing software stored in a memory, firmware, or any combination thereof. Thus, in an embodiment, a “circuit”

may be a hard-wired logic circuit or a programmable logic circuit such as a programmable processor, e.g., a microprocessor (e.g., a Complex Instruction Set Computer (CISC) processor or a Reduced Instruction Set Computer (RISC) processor). A “circuit” may also be a processor executing software, e.g., any kind of computer program, e.g., a computer program using a virtual machine code, e.g., Java. Any other kind of implementation of the respective functions may also be understood as a “circuit” in accordance with various embodiments. Similarly, a “module” may be a portion of a system according to various embodiments and may encompass a “circuit” as described above, or may be understood to be any kind of a logic-implementing entity.

10 **[0039]** Some portions of the present disclosure are explicitly or implicitly presented in terms of algorithms and functional or symbolic representations of operations on data within a computer memory. These algorithmic descriptions and functional or symbolic representations are the means used by those skilled in the data processing arts to convey most effectively the substance of their work to others skilled in the art. An algorithm is here, and generally, 15 conceived to be a self-consistent sequence of steps leading to a desired result. The steps are those requiring physical manipulations of physical quantities, such as electrical, magnetic or optical signals capable of being stored, transferred, combined, compared, and otherwise manipulated.

[0040] Unless specifically stated otherwise, and as apparent from the following, it will be appreciated that throughout the present specification, description or discussions utilizing terms 20 such as “obtaining”, “updating”, “identifying”, “determining”, “triggering”, “tasking”, “adding”, “receiving” or the like, refer to the actions and processes of a computer system, or similar electronic device, that manipulates and transforms data represented as physical quantities within the computer system into other data similarly represented as physical quantities within the computer system or other information storage, transmission or display 25 devices.

[0041] The present specification also discloses a system (e.g., which may also be embodied as a device or an apparatus), such as the system 200 for facility management, for performing various operations/functions of various methods described herein. Such a system may be 30 specially constructed for the required purposes, or may comprise a general purpose computer or other device selectively activated or reconfigured by a computer program stored in the computer. The algorithms presented herein are not inherently related to any particular computer or other apparatus. Various general-purpose machines may be used with computer programs in

accordance with the teachings herein. Alternatively, the construction of more specialized apparatus to perform various method steps may be appropriate.

[0042] In addition, the present specification also at least implicitly discloses a computer program or software/functional module, in that it would be apparent to the person skilled in the art that individual steps of various methods described herein may be put into effect by computer code. The computer program is not intended to be limited to any particular programming language and implementation thereof. It will be appreciated that a variety of programming languages and coding thereof may be used to implement the teachings of the disclosure contained herein. Moreover, the computer program is not intended to be limited to any particular control flow. There are many other variants of the computer program, which can use different control flows without departing from the scope of the invention. It will be appreciated by a person skilled in the art that various modules described herein (e.g., the sensor data obtaining module 206 and/or the actionable event identifying module 210) may be software module(s) realized by computer program(s) or set(s) of instructions executable by a computer processor to perform the required functions, or may be hardware module(s) being functional hardware unit(s) designed to perform the required functions. It will also be appreciated that a combination of hardware and software modules may be implemented.

[0043] Furthermore, one or more of the steps of a computer program/module or method described herein may be performed in parallel rather than sequentially. Such a computer program may be stored on any computer readable medium. The computer readable medium may include storage devices such as magnetic or optical disks, memory chips, or other storage devices suitable for interfacing with a general purpose computer. The computer program when loaded and executed on such a general-purpose computer effectively results in an apparatus that implements the steps of the methods described herein.

[0044] In various embodiments, there is provided a computer program product, embodied in one or more computer-readable storage mediums (non-transitory computer-readable storage medium(s)), comprising instructions (e.g., the sensor data obtaining module 206 and/or the actionable event identifying module 210) executable by one or more computer processors to perform the method 100 of facility management, as described herein with reference to FIG. 1 according to various embodiments. Accordingly, various computer programs or modules described herein may be stored in a computer program product receivable by a system therein, such as the system 200 for facility management as shown in FIG. 2, for execution by at least one processor 204 of the system 200 to perform various functions.

[0045] Software or functional modules described herein may also be implemented as hardware modules. More particularly, in the hardware sense, a module is a functional hardware unit designed for use with other components or modules. For example, a module may be implemented using discrete electronic components, or it can form a portion of an entire electronic circuit such as an Application Specific Integrated Circuit (ASIC). Numerous other possibilities exist. Those skilled in the art will appreciate that the software or functional module(s) described herein can also be implemented as a combination of hardware and software modules.

[0046] In various embodiments, the system 200 for facility management may be realized by any computer system (e.g., desktop or portable computer system) including at least one processor and at least one memory, such as an example computer system 300 as schematically shown in FIG. 3 as an example only and without limitation. Various methods/steps or functional modules may be implemented as software, such as a computer program being executed within the computer system 300, and instructing the computer system 300 (in particular, one or more processors therein) to conduct various functions or operations as described herein according to various embodiments. The computer system 300 may comprise a system unit 302, input devices such as a keyboard and/or a touchscreen 304 and a mouse 306, and a plurality of output devices such as a display 308. The system unit 302 may be connected to a computer network 312 via a suitable transceiver device 314, to enable access to e.g., the Internet or other network systems such as Local Area Network (LAN) or Wide Area Network (WAN). The system unit 302 may include a processor 318 for executing various instructions, a Random Access Memory (RAM) 320 and a Read Only Memory (ROM) 322. The system unit 302 may further include a number of Input/Output (I/O) interfaces, for example I/O interface 324 to the display device 308 and I/O interface 326 to the keyboard 304. The components of the system unit 302 typically communicate via an interconnected bus 328 and in a manner known to the person skilled in the art.

[0047] It will be appreciated by a person skilled in the art that the terminology used herein is for the purpose of describing various embodiments only and is not intended to be limiting of the present invention. As used herein, the singular forms "a", "an" and "the" are intended to include the plural forms as well, unless the context clearly indicates otherwise. It will be further understood that the terms "comprises" and/or "comprising," when used in this specification, specify the presence of stated features, integers, steps, operations, elements, and/or components,

but do not preclude the presence or addition of one or more other features, integers, steps, operations, elements, components, and/or groups thereof.

[0048] Any reference to an element or a feature herein using a designation such as “first”, “second” and so forth does not limit the quantity or order of such elements or features, unless
5 stated or the context requires otherwise. For example, such designations may be used herein as a convenient way of distinguishing between two or more elements or instances of an element. Thus, a reference to first and second elements does not necessarily mean that only two elements can be employed, or that the first element must precede the second element. In addition, a phrase referring to “at least one of” a list of items refers to any single item therein or any combination
10 of two or more items therein.

[0049] In order that the present invention may be readily understood and put into practical effect, various example embodiments of the present invention will be described hereinafter by way of examples only and not limitations. It will be appreciated by a person skilled in the art that the present invention may, however, be embodied in various different forms or
15 configurations and should not be construed as limited to the example embodiments set forth hereinafter. Rather, these example embodiments are provided so that this disclosure will be thorough and complete, and will fully convey the scope of the present invention to those skilled in the art.

[0050] FIG. 4 depicts a schematic drawing of an overview of an example system 400 for
20 facility management for identifying an actionable event in relation to a building, according to various example embodiments of the present invention. For example, the system 400 may be an incident management system. In various example embodiments, the example system 400 may be configured to monitor selected target building assets of a building, such as certain target areas, for detecting abnormal condition or situation by using a plurality of sensors 402, such as
25 imaging sensors (e.g., cameras such as closed-circuit television (CCTV)), a distance sensor (e.g., LiDAR), Internet of Things (IoT) sensors, feed sensors, and so on. For example, IoT sensors may be any sensors capable of sensing physical properties, such as but not limited to, air quality sensor, pressure sensor, thermal sensor, beacon sensor, and so on. Feed sensors may be configured to receive feeds from a feed source, such as feeds from a website or API (e.g.,
30 weather forecast, news, and so on). In various example embodiments, incident detection modules 406 may be provided to continuously obtain sensor data (e.g., sensor observation values) from the sensors 402. For example, if an observation value received by an incident detection module 406 meets a pre-defined condition, it is determined that a corresponding

condition or situation is abnormal. In various example embodiments, an incident management module 410 may be configured to define and manage rules of relationship between types of incident and what kind of dispatch (e.g., an action or a task) is required to handle such an incident. For example, the dispatch may refer to the assignment of a staff to handle the incident such as by generating and sending a notification to the staff's mobile to inform the staff of the situation and the assigned task. As another example, the dispatch may refer to executing one or more building control functions, such as but not limited to, air conditioner control function, lift control function, lighting control function, and so on.

[0051] By way of an example only and without limitation, an example of room air quality monitoring and dispatching staff to handle an event (e.g., incident) detected will now be described according to various example embodiments of the present invention. First, air quality sensors may be provided to monitor CO₂ level at a room. The incident detection module 406 may be configured to obtain the sensor data (CO₂ level) at the room and when the CO₂ level is determined to exceed a pre-defined threshold, an incident at the room is identified. In response, the incident management module 410 may be configured to trigger a predetermined task associated with the incident identified, such as staff dispatching for air ventilation. In this regard, based on sensor data from one or more sensors associated with other room(s) or area(s), a staff capable of handling the incident and is sufficiently close to the target room (i.e., the above-mentioned room where the incident occurred) may be detected. The incident management module 410 may then, as the predetermined task, send a notification to the staff to attend to the incident at the target room. After receiving the notification, for example, the staff may then proceed to the target room to open a window for ventilation so as to reduce the CO₂ level at the target room.

[0052] Accordingly, the system 400 for facility management advantageously addresses a number of problems associated with conventional systems, such as the conventional system described in the background. For example, regarding the conventional system described in the background, as incidents are identified and handled by referring only to sensor observation values, it is not possible to handle more complex incident that requires consideration of the attributes of building assets and relative location relationships of the building assets.

[0053] In contrast, the system 400 for facility management does not only take into account sensor observations, but also attributes and locations associated with the building assets, thus advantageously enabling the system 400 to identify and handle more complex events (e.g., incidents) in relation to the building. According to various example embodiments, the system

400 may include a building information database comprising digital representations corresponding to building assets of the building. In various example embodiments, the building information database may be a digital twin (DT) database including a digital twin of the building, including building assets thereof, which is a digital representation (e.g., virtual replica) of the building. For example, a building asset may be a room, an area or a building equipment and a digital twin of a building asset is a digital representation (e.g., virtual replica), and may be referred to as a digital twin object (or DT object) in the DT database. In various example embodiments, the DT database comprises DT objects corresponding to building assets (e.g., monitored building assets) in a physical space (e.g., a room, an area or a building equipment). Each DT object manages and has associated therewith one or more attributes (one or more attribute parameters) and a location (location parameter) of the corresponding building asset. In addition, for each DT object, one or more sensor observation parameters (indicating sensor observation values) are linked to (associated with) the corresponding DT object and sensor observation values may be continuously or periodically updated into the corresponding DT object. With such a configuration, the system 400 is able to refer to attributes and locations (attribute and location parameters) of DT objects as well as sensor observation values (sensor observation parameters) thereof, and monitor combined sensor observation conditions. Based on the attribute parameters, the location parameters and the sensor observation parameters associated with the DT objects of corresponding building assets, the system 400 may be configured to identify an actionable event (e.g., an incident) based on a predetermined actionable event condition (e.g., a combined condition) and trigger a predetermined task associated with the predetermined actionable event condition to handle or resolve the actionable event when the predetermined actionable event condition is satisfied.

[0054] By way of an example for illustration purpose only, FIG. 5 illustrates a schematic drawing of an example building comprising a plurality of building assets, including a first building asset (Room A) and a second building asset (Concierge B) being monitored, according to various example embodiments of the present invention. An example method of facility management for identifying an actionable event will now be described according to various example embodiments of the present invention.

[0055] As described above, the digital twin model has, for each monitored building asset, a corresponding DT object. In the example shown in FIG. 5, there are two building assets being monitored, namely, Room A and Concierge B. Each DT object has associated therewith one or more attribute parameters (indicating one or more attributes assigned to the corresponding

building asset) and a location parameter (indicating a location of the corresponding building asset) as well as one or more sensor observation parameters (updated with one or more sensor observation values based on one or more sensor data obtained from one or more sensors, which may also be referred to as annotated sensor observation values). In various example

5 embodiments, an attribute assigned to a building asset indicates a current purpose or function of the building asset or a status of the building asset. In the example shown in FIG. 5, Room A has an attribute of “Purpose” being “For meeting”, and a location of (X, Y) = (25 m, 10 m). Concierge B has an attribute of “Schedule” being “Free time”, and a location (X, Y) = (25 m, 30 m)”

10 **[0056]** In the example shown in FIG. 5, an air quality sensor is physically installed in Room A, and the sensor observation parameter updated with sensor observation value from the air quality sensor is linked to the corresponding DT object of Room A in the DT database. The air quality sensor continuously or periodically updates the observed CO₂ level into the corresponding sensor observation parameter associated with the DT object of Room A. In

15 addition, a LiDAR sensor is installed at Concierge B, and the LiDAR sensor may be configured to continuously or periodically count the number of staff at Concierge B and update the observation value into the corresponding sensor observation parameter associated with the DT object of Concierge B.

20 **[0057]** The system 400 may then be configured to monitor a combined condition which are given not only by the sensor observation parameters of the DT objects but also the attributes and locations of the DT objects of Room A and Concierge B. By way of an example only and without limitation, FIG. 6 shows a table (Table 1) with two example combined conditions (each corresponding to the above-mentioned predetermined actionable event condition) for monitoring by the system 400. As can be seen in a first example (Example 1) shown in Table

25 1, the system 400 may be configured to monitor a combined condition which includes:

- CO₂ level in Room A exceeds a predetermined threshold: obtained from the sensor observation parameter of the DT object corresponding to Room A, which is updated based on sensor observation value (sensor data) from the air quality sensor in Room A; and
- 30 • Purpose of Room A is currently “Meeting”: obtained from the attribute parameter of the DT object corresponding to Room A.

In the first example, when the above-mentioned two conditions are satisfied, air ventilation in Room A may be determined to be required. In this case, for example, a control signal may be sent to turn on an air conditioner in Room A.

[0058] As can be seen in a second example (Example 2) shown in Table 1, the system 400 may be configured to monitor a combined condition which includes:

- CO₂ level in Room A exceeds a predetermined threshold: obtained from the sensor observation parameter of the DT object corresponding to Room A, which is updated based on sensor observation value (sensor data) from the air quality sensor in Room A;
- A staff is in Concierge B: obtained from the sensor observation parameter of the DT object corresponding to Concierge B, which is updated based on sensor observation value (sensor data) from the LiDAR sensor in Concierge B;
- Schedule of Room A is currently “Free time”: obtained from the attribute parameter of the DT object corresponding to Room A; and
- whether distance between Room A and Concierge B is less than 20 m: obtained from location parameters of the DT objects corresponding to Room A and Concierge B.

In the second example, when all of the above-mentioned conditions are satisfied, air ventilation in Room A may be determined to be required. In this case, for example, a closest staff to Room A may be notified by the system 400 and dispatched to open a window in Room A for air ventilation.

[0059] Accordingly, when all of the predetermined conditions are satisfied (i.e., a combined condition is satisfied), an actionable event is identified and a corresponding predetermined task may be triggered. For example, both the above first and second examples indicate that CO₂ level in Room A exceeds a predetermined threshold. However, according to various example embodiments, as illustrated in the above first and second examples, how to attend or handle to the actionable event identified is optimized based on situation and context awareness and physical properties associated with the building, and more particularly, based on attribute and location parameters of monitored objects.

[0060] Accordingly, based on attribute and location parameters in addition to sensor observation parameters, automated system 400 for facility management with enhanced efficiency and effectiveness is achieved according to various example embodiments of the present invention, such as being able to handle more complex events. For example, from the examples shown in FIG. 5 discussed above, how the actionable event is handled or resolved is advantageously optimized based on a state or status of a surrounding environment.

[0061] For example, the conventional system described in the background also suffers from high development cost of sensor analysis to detect each incident respectively, since specific program development for each use case is required. In contrast, the system 400 for facility management is advantageously configured to provide an actionable event condition generation user interface (which may also be referred to as a graphical user interface (GUI)-based analytics generator), according to various example embodiments of the present invention, such that new actionable event conditions (e.g., new combined conditions) can be generated for monitoring building assets without program development.

[0062] According to various example embodiments, pre-defined calculation or computation operators may be selected through a GUI and apply the selected computation operators to sensor observation values (including past time series) for advantageously realizing any analysis method without program development (i.e., without requiring coding by a person). In various example embodiments, the operators comprise time-based operators, spatial-based (or space) operators and integration operators.

[0063] By way of an example for illustration purpose only, FIG. 7 illustrates a schematic drawing of an example building comprising a plurality of building assets, including a first building asset (Room A) and a second building asset (Corridor C) being monitored, according to various example embodiments of the present invention. An example method of generating a new actionable event condition using the GUI-based analytics generator will now be described according to various example embodiments of the present invention.

[0064] For example, suppose that a user wants to create a condition or an analysis for whether CO₂ level in Room A is constantly above a predetermined threshold for 10 minutes. In order to realize this analysis without specific program development (i.e., without requiring coding by a person), by using the GUI-based analytics generator, as an example, a user may select a time-based operator “Minimum” and apply this selected operator to a time series of sensor observation values (CO₂ level) past history from the air quality sensor every 10 minutes. As another example, if a user wants to check whether a staff is anywhere in Corridor C, by using the GUI-based analytics generator, the user may select a spatial-based operator “Sum” to sensor observation values (people count) from all the beacon sensors in Corridor C.

[0065] FIG. 8 shows an example GUI of the GUI-based analytics generator, according to various example embodiments of the present invention. As shown in FIG. 8, an example method of generating a new actionable event condition using the GUI-based analytics generator may include the following steps:

1. A user may click on a target building asset (or target DT object) for which the new actionable event condition is to be associated with. For example, as shown in FIG. 8, Room A shown in the GUI may be clicked.

2. Select one or more sensor observation types (e.g., based on all available sensors associated with the target building asset) designating one or more sensor observation parameters associated with the target building for which the new actionable event condition is to be associated. For example, as shown in FIG. 8, Room A has four sensor observation types based on all available sensors associated with the target building asset, namely, CO₂ level, Temperature, Humidity, and Light brightness. For example, the user may select CO₂ level as the selected sensor observation type.

3. Select a function operator type designating a function for subjecting the sensor observation values of the selected sensor observation type to. For example, there may be provided a time-based operator category and a spatial-based operator category. In this example, the user may select the time-based operator category.

4. From the time-based operator category, select a time-based operator to apply to the sensor observation values of the selected sensor observation type. For example, the user may select the time-based operator “Min” (a minimum function).

5. Select a time duration for the selected time-based operator. For example, the user may select 10 minutes.

6. Set a threshold for the selected sensor observation type. For example, a user may set a threshold of 100 for the CO₂ level.

7. After performing the above steps 1 to 6, the new actionable event condition created may be added to an actionable event condition database (e.g., an actionable event conditions list).

[0066] As will be described later below according to various example embodiments of the present invention, additional target DT objects may be added for which the new actionable event condition is to be associated with, thereby forming a combined condition. Each additional target DT object may be added in the manner as described above in steps 1 to 6.

[0067] Accordingly, data processing for event (e.g., incident) management can be reduced to a few calculation patterns such as calculation operator against time series, spatial area, such as time averages, spatial totals, and so on. If a certain number of patterns are covered and predefined, arbitrary analysis may be carried out without program development, and so on. For example, a set of time-based functions may be provided comprising one or more of an average

function (e.g., an average of sensor observation values over a time period), a maximum function (e.g., a maximum sensor observation value over a time period), a minimum function (e.g., a minimum sensor observation value over a time period), a maximum range function, a cumulative summation function, a differential cumulative summation function, a differential absolute cumulative summation function, a count number of occurrences above or below a threshold function and a value difference between time instances function. For example, the set of spatial-based functions comprises one or more of an average function (e.g., an average of sensor observation values at multiple locations), a cumulative summation function, a maximum function (e.g., a maximum sensor observation value amongst multiple locations), a minimum function (e.g., a minimum sensor observation value amongst multiple locations), a maximum range function and a value difference between locations function. It will be appreciated by a person skilled in the art that the time-based functions and the spatial-based functions mentioned above are merely examples. Therefore, the time-based functions and the spatial-based functions available for a user to select or apply are not limited to such examples and may include other time-based functions and/or other spatial-based functions as desired or as appropriate.

[0068] Accordingly, the system 400 for facility management according to various example embodiments is advantageously able to handle more complicated events (e.g., incidents) by utilizing attributes and locations of target building assets. Furthermore, in various example embodiments, the system 400 is able to reduce development cost of event detection by providing a GUI-based analytics generator for enabling a user to generate a new actionable event condition for monitoring, without specific program development.

[0069] Accordingly, the method and system for facility management according to various example embodiments of the present invention have one or more of the following features:

- Sensor observation values are linked to DT objects of corresponding monitored building assets in a DT database. Actionable events (e.g., incidents) are identified and the situation may be visualized by managing the linked sensor observation values.
- Monitoring conditions (actionable event conditions) are evaluated with reference to the attributes and locations of DT objects of corresponding monitored building assets in the DT database, as well as the relative locations of two or more objects.
- New monitoring conditions can be generated by applying time-based (or temporal), spatial and integration operators to the sensor observation value.

[0070] For better understanding, the method and system for facility management according to various example embodiments of the present invention will now be further described according to various example embodiments.

5 [0071] FIG. 9 depicts a schematic flow diagram of an overview of the method 500 of facility management according to various example embodiments (e.g., corresponding to the method 100 of facility management as described hereinbefore according to FIG. 1).

Sensor data acquisition S001

10 [0072] Obtain sensor observation values (e.g., sensor levels, human positions, and so on) from multiple sensors. For example, in Example 2 of Table 1 shown in FIG. 6 and the example building shown in FIG. 5, obtain CO₂ level from the air quality sensor in Room A and people count from the LiDAR sensor in Concierge B.

Sensor data annotation S002

15 [0073] Continuously or periodically update sensor observation parameters associated with the corresponding digital representations (e.g., monitored objects) of the monitored building assets (e.g., room, area, building equipment, and so on) with sensor observation values from sensors associated with the monitored building assets in a monitoring database (e.g., corresponding to the building information database as described hereinbefore according to various embodiments, such as a DT database) D001. FIG. 10 shows a table (Table 2) 20 corresponding to an example monitoring database. For example, in Example 2 of Table 1 shown in FIG. 6 and the example building shown in FIG. 5, CO₂ value in Room A of 100 ppm and people count in Concierge B of 1 person may be updated into the monitoring database D001.

[0074] As shown in Table 2, for each monitored object, the attribute and location of the 25 monitored object, as well as one or more annotated sensor observation values, may be stored in the monitoring database D001. In various example embodiments, the attribute and location of a monitored object may be updated from external sources or systems. For example, an attribute of Concierge B for "Schedule" may be updated through an external meeting schedule system via system integration, from a current status of "Free time" to another status of "Serving 30 customers". Therefore, in various example embodiments, the monitoring database does not merely function to record data but also as an interface for integrating external systems.

Combined metric monitoring S003

[0075] Input the annotated sensor observation value and the attribute and location of the monitored object from the monitoring database, and a monitoring condition (e.g., corresponding to the actionable event condition as described hereinbefore according to various embodiments) from a monitoring condition database D002. Calculate combined metrics to be monitored based on these inputs.

[0076] FIG. 11 shows a table (Table 3) corresponding to an example monitoring condition database (e.g., corresponding to the actionable event condition database as described hereinbefore according to various embodiments), according to various example embodiments of the present invention. In various example embodiments, each monitoring condition is associated with one or more monitored objects and includes predetermined sensor observation condition(s), predetermined attribute condition(s) and location condition(s). By way of examples only and without limitations, three example monitoring conditions in the monitoring condition database D002 are shown in FIG. 11.

[0077] The first example monitoring condition evaluates whether the CO₂ level in Room A is above a predetermined sensor observation condition of greater than 90 ppm and the usage is for meeting purpose. If the first example monitoring condition is satisfied (e.g., meaning low priority for air ventilation), a predetermined task associated therewith is triggered to handle the event identified, such as showing an alert on a floor map in a monitoring system.

[0078] The second example monitoring condition is a combined condition which evaluates whether the following individual conditions are satisfied at the same time:

- Room A: the CO₂ level in Room A is above a predetermined sensor observation condition of greater than 90 ppm and the usage is for meeting purpose; and
- Concierge B: People count equals to 0 (i.e., no staff present).

If the second example monitoring condition is satisfied, a predetermined task associated therewith is triggered to handle the event, such as sending a control signal to an air conditioner in Room A to turn it on.

[0079] The third example monitoring condition is also a combined condition which evaluates whether the following individual conditions are satisfied at the same time:

- Room A: the CO₂ level in Room A is above a predetermined sensor observation condition of greater than 90 ppm and the usage is for meeting purpose;
- Concierge B: People count is more than or equal to 1 (staff present) and Schedule is currently free time; and

- Relative location between Room A and Concierge B: Distance between Room A and Concierge B is less than 30 m.

If the third example monitoring condition is satisfied, a predetermined task associated therewith is triggered to handle the event, such as sending a notification to a staff at Concierge B to attend to the event identified at Room A to open a window for air ventilation.

[0080] FIG. 12 depicts a schematic flow diagram of combined metric monitoring S003 according to various example embodiments.

[0081] At S3001, obtain the annotated sensor observation value (or updated sensor observation value) linked to the monitored object from the monitoring database D001. For example, in Example 2 of Table 1 shown in FIG. 6 and the example building shown in FIG. 5, CO₂ level in Room A of 100 ppm (sensor observation parameter associated with Room A) and people count at Concierge B of 1 person (sensor observation parameter associated with Concierge B) stored at the monitoring database D001 may be obtained (e.g., referenced).

[0082] At S3002, obtain attribute of the monitored object from the monitoring database D001. For example, in the above-mentioned Example 2, purpose of Room A being “Meeting” (attribute parameter associated with Room A) and schedule of Concierge B being “Free time” (attribute parameter associated with Concierge B) may be obtained (e.g., referenced).

[0083] At S3003, obtain location of the monitored object from the monitoring database D001. For example, in the above-mentioned Example 2, Room A having a location of (X, Y) = (25 m, 10m) at level 3 and Concierge B having a location of (20m, 30m) at level 3 may be obtained (e.g., referenced).

[0084] At S3004, for each monitored object of a plurality of monitored objects, repeat steps S3001 to S3003.

[0085] At S3005, determine the combined metric with respect to a predetermined monitoring condition. For example, the combined metric may be determined based on the following:

- Compare annotated sensor observation values from the monitoring database D001 and the corresponding sensor observation conditions in the predetermined monitoring condition from the monitoring condition database D002;
- Compare attributes of monitored objects from the monitoring database D001 and the corresponding attribute conditions in the predetermined monitoring condition from the monitoring condition database D002;
- Compare locations of monitored objects from the monitoring database D001 and the

corresponding location condition(s) in the predetermined monitoring condition from the monitoring condition database D002 (e.g., relative distance(s) between monitored objects); and

- Integration conditions (e.g., operator AND or OR)) defined by monitoring condition database D001 for the above conditions.

[0086] By way of an example only and without limitation, referring to the above-mentioned Example 2 and combined condition no. 3 in Table 3 in FIG. 11, the combined metric may be determined with respect to combined condition no. 3 as follows:

- Annotated sensor observation associated with Room A: CO₂ level in room A “100 ppm” vs. condition “> 90 ppm”, condition is satisfied;
- Annotated sensor observation associated with Concierge B: People count at Concierge B “1 person” vs. Condition “>=” 1 person, condition is satisfied;
- Attribute: Purpose of usage of Room A “Meeting” vs. Condition “== Meeting”, condition is satisfied;
- Attribute associated with Concierge B: Schedule of Concierge B “Free time” vs. Condition “== Free time”, condition is satisfied;
- Relative location: Between Room A “(25m,10m)” and Concierge B “(30m, 10m)”, Distance = “5m” vs. Condition “< 30m”, condition is satisfied; and
- “AND” integration of all above conditions, condition is satisfied.

Accordingly, the combined condition no. 3 is satisfied and the corresponding predetermined task associated with the combined condition no. 3 may be triggered.

Event (e.g., Incident) Identification S004

[0087] If the combined metric determined matches the combined condition at step S003, the corresponding predetermined dispatch or task associated with the event identified may be obtained from the monitoring condition database D002. The dispatch information or predetermined task includes information for handling or addressing the event identified. For example, if combined condition no. 3 in Table 3 shown in FIG. 11 is satisfied, the corresponding dispatch or task “Dispatch staff to the object location” is triggered.

Event handling S005

[0088] The event (e.g., incident) identified may then be handled based on the dispatch or task information obtained at step S004. For example, as described hereinbefore, if combined

condition no. 3 in Table 3 shown in FIG. 11 is satisfied, a notification may be generated and sent to a detected staff's mobile to assign the task to the staff (e.g., a closest staff). In other examples, a building equipment (e.g., air conditioner, lighting device and so on) may be control based on a control signal, such as via an API.

5 **[0089]** In various example embodiments, the monitoring database D001 may be a digital twin (DT) database. A digital twin model is a digital representation (e.g., virtual copy) of a physical space, according to various example embodiments of the present invention, includes the following components:

- 10 • DT objects corresponding to monitored building assets, respectively, in the physical space (e.g., a room, an area, a building equipment, and so on)
- For each DT object, one or more attribute parameters, one or more sensor observation parameters and a location parameter (e.g., 2D or 3D location) associated with the DT object. The DT object may also have associated therewith various physical properties such as a size or dimension of the DT object.
- 15 • Adjacency relationships between 2 or more DT objects (e.g., relative location, adjacent information, routes between them).

[0090] In various example embodiments, in relation to step S002 in FIG. 9, the sensor observation values are continuously or periodically updated into the corresponding DT objects in the DT database. For example, for the example building shown in FIG. 5, the CO₂ level is
20 linked to the corresponding DT object of Room A and the people count is linked to the corresponding DT object of Concierge B.

[0091] In various example embodiments, in relation to step S003 in FIG. 9, the annotated sensor observations, attributes and locations are obtained from the DT objects in the DT database. As a result, for example, the distance between objects can be calculated more
25 accurately. In this regard, by using the DT model, the distance between objects can be determined based on the actual route between the objects based on various information available in the DT model, such as adjacent information, obstacles, movement from floor to floor, and so on. The 3D size of the physical space also can be managed easily. In contrast, without using a DT model, the distance between objects may simply be determined based on a
30 straight line between the objects, which may not be an accurate representation of the actual route between the objects.

[0092] In various embodiments, in relation to step S005 in FIG. 9, when sending a notification to a staff or user, route information may be provided for enabling route navigation

to the target building asset to be visualized on their mobile app or dashboard screen. This can enable the staff to proceed to the target building asset without difficulty.

Monitoring condition creation S006

5 [0093] In various example embodiments, an actionable event condition generation user interface (e.g., GUI-based analytics generator) is provided for facilitating a user to add new actionable event conditions (which may also be referred to as monitoring conditions) to the actionable event condition database (e.g., monitoring condition database D002) for monitoring building assets. In various example embodiments, a new monitoring condition may be created
10 by selecting and applying calculation or computation operators (e.g., time, space, integration) to be applied to sensor observation values using a GUI with DT visualization.

[0094] FIG. 13 depicts a schematic flow diagram of the monitoring condition creation S006 according to various example embodiments of the present invention. The example GUI shown in FIG. 13 is that of FIG. 8 as described hereinbefore. By way of an example only and without
15 limitation, as shown in FIG. 8, a user may add an analytic for checking whether the CO₂ level in Room A is continuously above a threshold for past 10 minutes. For example, this analytic can be considered as whether the minimum value of the time series for past 10 minutes is above the threshold.

[0095] FIG. 14 depicts another example of generating a new monitoring condition according to various example embodiments of the present invention. In this example, as shown
20 in FIG. 14, a user may add an analytic for checking whether at least 1 person is at Corridor C. For example, this analytic can be implemented by first calculate the sum of all people counts from all beacon sensors which are installed at Corridor C, and then checking whether the total people count is more than 1.

25 [0096] For better understanding, the monitoring condition creation S006 will now be further described according to various example embodiments, with reference to the examples shown in FIGs. 8 and 14.

[0097] At S6001, select a DT object to be added to a new monitoring condition (e.g., corresponding to the one or more building asset identity inputs as described hereinbefore
30 according to various embodiments). For example, as shown in FIG. 8, Room A shown in the GUI may be clicked. As another example, as shown in FIG. 14, search DT object with keyword "People count".

[0098] At S6002, select a sensor observation type associated with the selected DT object (e.g., corresponding to the one or more sensor observation type inputs as described hereinbefore according to various embodiments). For example, as shown in FIG. 8, select “CO2 level”. As another example, as shown in FIG. 14, select “People count 1 to 5” for five sensors.

5 **[0099]** At S6003, select a spatial-based (or space) operator which is calculation for spatial data and registered in the spatial-based operator list (e.g., corresponding to the one or more function operator inputs as described hereinbefore according to various embodiments). For example, as shown in FIG. 14, select spatial-based operator “Sum” to calculate total value of annotated sensor observation of “People count 1 to 5”

10 **[00100]** At S6004, select a time-based operator and a duration from a predefined list (e.g., corresponding to the one or more function operator inputs as described hereinbefore according to various embodiments). The time-based operator is calculation for time series data and registered in time-based operator list. For example, as shown in FIG. 8, select “Min” (a minimum function) which extracts a minimum value from the time series data for a target time period. Next, select a target time period of “10 min”.

[00101] Prior to S6005, execute steps S6001 to S6004 for each additional DT object desired to be added into the combined condition.

[00102] At S6005, select an integration operator (e.g., corresponding to the integration operator type input as described hereinbefore according to various embodiments). For example, in FIG. 14, for the two conditions created for the two DT objects selected, select integration operator “AND” to combine these two conditions.

[00103] At S6006, register the new combined condition generated into the monitoring condition database D002.

25 **[00104]** Accordingly, data processing for event (e.g., incident) management can be reduced to a few calculation patterns such as calculation operator against time series, spatial area, such as time averages, spatial totals, and so on. If a certain number of patterns are covered and predefined, arbitrary analysis may be carried out without program development, and so on.

[00105] By way of examples only and without limitations, FIGs. 15A to 15F illustrate various example time-based operators, along with their usage, according to various example embodiments of the present invention. FIGs. 16A and 16B illustrate two example spatial-based operators, along with their usage, according to various example embodiments of the present invention. The time-based operators or functions and the spatial-based operators or functions may involve calculation based on one or more of maximum, minimum, cumulative sum, count

of values above or below a threshold, difference of values between a certain time frame and next time frame or a certain location point and next location point, range, absolute, and recursive combinations of these operators. As explained hereinbefore, it will be appreciated by a person skilled in the art that the time-based functions and the spatial-based functions mentioned above are merely examples. Therefore, the time-based functions and the spatial-based functions available for a user to select or apply are not limited to such examples and may include other time-based functions and/or other spatial-based functions as desired or as appropriate.

[00106] For example, FIG. 15A illustrates example average, maximum and minimum functions. For example, in relation to the example maximum function, if the CO₂ level has exceeded the predetermined threshold at least once, ventilation may be determined to be required. For example, in relation to the example minimum function, if the CO₂ level has continuously exceeded the predetermined threshold, ventilation may be determined to be required. For example, FIG. 15B illustrates example low (minus) differential summation (e.g., decreasing) and high differential cumulative summation (e.g., increasing) functions. For example, in relation to the example high differential cumulative summation function, if humidity in a room is increasing over a time period (e.g., not maintained at a certain level), it may be determined that an air conditioner in the room is to be inspected. For example, FIG. 15C illustrates example low differential absolute cumulative summation (e.g., no major change) and high differential absolute cumulative summation functions (e.g., large fluctuation). For example, in relation to the example high differential absolute cumulative summation function, if a room brightness has high fluctuation (e.g., caused by light blinking), it may be determined that a lighting bulb in the room is to be inspected. For example, FIG. 15D illustrates an example range function. For example, if the temperature in a room is not within a certain range, it may be determined that an air conditioner in the room is to be inspected. For example, FIG. 15E illustrates an example count number of occurrences above a threshold function. For example, if high count number of occurrences above the threshold is determined in relation to a building equipment, it may be determined that maintenance is required. For example, FIG. 15F illustrates an example cumulative summation function. For example, if the cumulative count of people in a room over a time period is above a predetermined threshold, it may be determined that the room requires cleaning.

[00107] For example, FIG. 16A illustrates example average, maximum and minimum functions in the case of air quality sensors in a room. For example, in relation to the example maximum or minimum function, it may be applied to determine whether air quality is poor at

one or more particular locations in the room. For example, in relation to the example average function, it may be applied to determine whether the temperature is high throughout the room. For example, FIG. 16B illustrates example summation function in the case of beacon sensors in a corridor. For example, the example summation function may be applied to determine the
5 number of staff in the corridor.

[00108] Various example embodiments note that there are increasing examples of city-level digital twin applications led by local authorities and others (e.g., Virtual Singapore, Plateau). In this regard, the use of digital twins in buildings is expected to increase (e.g., construction developers creating digital twin at the time of construction). Accordingly, when considering
10 building security and facility management, various example embodiments advantageously utilise the digital twins of building that may already exist, and provide an interface between facility management systems and the digital twins.

[00109] While embodiments of the invention have been particularly shown and described with reference to specific embodiments, it should be understood by those skilled in the art that
15 various changes in form and detail may be made therein without departing from the scope of the invention as defined by the appended claims. The scope of the invention is thus indicated by the appended claims and all changes which come within the meaning and range of equivalency of the claims are therefore intended to be embraced.

CLAIMS

What is claimed is:

- 5 1. A method of facility management for identifying an actionable event in relation to a building using at least one processor, the method comprising:

obtaining a plurality of sensor data from a plurality of sensors, respectively, wherein each sensor of the plurality of sensors is associated with a building asset of a plurality of building assets of the building, each building asset of the plurality of building assets has a
10 corresponding digital representation in a building information database, and for said each building asset, the corresponding digital representation of the building asset has one or more attribute parameters, a location parameter and one or more sensor observation parameters associated therewith, the one or more attribute parameters indicating one or more attributes assigned to the building asset, the location parameter indicating a location of the building asset
15 and the one or more sensor observation parameters indicating one or more sensor observation values obtained based on one or more sensor data from one or more sensors associated with the building asset of the plurality of sensors; and

identifying an actionable event based on the one or more attribute parameters, the location parameter and the one or more sensor observation parameters associated with that of
20 one or more building assets of the plurality of building assets.

2. The method according to claim 1, wherein said identifying the actionable event is further based on a predetermined actionable event condition associated with the one or more building
assets.

25

3. The method according to claim 2, wherein said identifying the actionable event based on the predetermined actionable event condition comprises, for each of the one or more building assets:

determining whether the one or more sensor observation parameters associated with the
30 building asset satisfy corresponding one or more predetermined sensor observation conditions associated with the building asset included in the predetermined actionable event condition;

determining whether the one or more attribute parameters associated with the building asset satisfy corresponding one or more predetermined attribute conditions associated with the building asset included in the predetermined actionable event condition; and

5 determining whether the location parameter associated with the building asset satisfy a corresponding location condition associated with the building asset included in the predetermined actionable event condition.

4. The method according to claim 3, wherein
the actionable event is identified if the predetermined actionable event condition is
10 determined to be satisfied, and

the method further comprises triggering a predetermined task associated with the predetermined actionable event condition for the actionable event identified.

5. The method according to claim 4, wherein the predetermined task associated with the
15 predetermined actionable event condition is determined to be satisfied if at least:

the one or more predetermined sensor observation conditions associated with that of the one or more building assets included in the predetermined actionable event condition are determined to be satisfied;

20 the one or more predetermined attribute conditions associated with that of the one or more building assets included in the predetermined actionable event condition are determined to be satisfied; and

the location condition associated with that of the one or more building assets included in the predetermined actionable event condition is determined to be satisfied.

25 6. The method according to any one of claims 3 to 5, wherein
the one or more building assets are multiple building assets, and
said identifying the actionable event based on the predetermined actionable event condition further comprises determining whether the location parameters associated with said multiple building assets satisfy a relative location condition associated with said multiple
30 building assets based on a predetermined reference distance or range of distance between said multiple building assets.

7. The method according to claim 6, wherein

the predetermined task associated with the predetermined actionable event condition comprises tasking one or more individuals detected based on one or more sensor data obtained from one or more sensors associated with a first building asset of said multiple building assets to attend to the actionable event at a second building asset of said multiple building assets in relation to one or more sensor observation parameters associated with the second building asset.

8. The method according to any one of claims 2 to 7,
wherein the predetermined actionable event condition is included in an actionable event condition database, and
10 the method further comprises adding a new actionable event condition in the actionable event condition database via an actionable event condition generation user interface.

9. The method according to claim 8, wherein said adding the new actionable event condition comprises:

15 receiving, via the actionable event condition generation user interface, one or more building asset identity inputs, each building asset identity input designating a corresponding building asset of the plurality of building assets for which the new actionable event condition is associated with; and

for each of the one or more building asset identity inputs,
20 receiving, via the actionable event condition generation user interface, one or more sensor observation type inputs designating one or more sensor observation parameters associated with the designated building asset for which the new actionable event condition is associated with;

receiving, via the actionable event condition generation user interface, one or
25 more function operator inputs designating one or more functions for subjecting the designated one or more sensor observation parameters to; and

receiving, via the actionable event condition generation user interface, one or
more reference value inputs designating one or more reference values based on which one or more results of the one or more functions are compared respectively for determining an outcome
30 on whether the new actionable event condition with respect to the designated building asset is satisfied.

10. The method according to claim 9, wherein

the one or more building asset identity inputs are multiple building asset identity inputs designating multiple building assets for which the new actionable event condition is associated with, and

said adding the new actionable event condition further comprises:

5 receiving, via the actionable event condition generation user interface, an integration operator type input designating an integration operator for integrating the outcomes on whether the new actionable event condition with respect to said multiple designated building assets are satisfied.

10 11. The method according to claim 9 or 10, wherein

the one or more building asset identity inputs are selected from a predefined set of building asset identities corresponding to building assets of the building available for a user to select,

15 the one or more sensor observation type inputs are selected from a predefined set of sensor observation types available for the user to select for the designated building asset,

the one or more function operator inputs are selected from a predefined set of functions available for the user to select, and

the integration operator type input is selected from a predefined set of integration operators available for the user to select.

20

12. The method according to claim 11, further comprising updating, for each building asset of the plurality of building assets, the one or more sensor observation parameters associated with the corresponding digital representation of the building asset with the one or more sensor observation values based on the one or more sensor data obtained from the one or more sensors associated with the building asset, wherein

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the predefined set of functions comprises a set of time-based functions and a set of spatial-based functions,

30 the set of time-based functions comprises one or more of an average function, a maximum function, a minimum function, a maximum range function, a cumulative sum function, a differential cumulative sum function, a differential absolute cumulative sum function, a count number of occurrences above or below a threshold function and a value difference between time instances function, and

the set of spatial-based functions comprises one or more of an average function, a summation function, a maximum function, a minimum function, a maximum range function and a value difference between locations function.

5 13. The method according to any one of claims 1 to 12, wherein for each building asset of the plurality of building assets, the one or more attribute parameters associated with the corresponding digital representation of the building asset indicates a current purpose or function of the building asset or a status of the building asset.

10 14. The method according to any one of claims 1 to 13, wherein for each building asset of the plurality of building assets, the building asset is a room, an area or a building equipment, and wherein each sensor of the plurality of sensors is an imaging sensor, a distance sensor, an Internet of Things (IoT) sensor, an inertial measurement unit (IMU) sensor or a feed sensor.

15 15. The method according to any one of claims 1 to 14, wherein
the building information database is a digital twin database for the building, and
for each building asset of the plurality of building assets, the corresponding digital
representation of the building asset is a corresponding digital twin object in the digital twin
database.

20

16. A system for facility management for identifying an actionable event in relation to a building, the system comprising:

at least one memory; and

25 at least one processor communicatively coupled to the at least one memory and
configured to:

30 obtain a plurality of sensor data from a plurality of sensors, respectively, wherein each
sensor of the plurality of sensors is associated with a building asset of a plurality of building
assets of the building, each building asset of the plurality of building assets has a corresponding
digital representation in a building information database, and for said each building asset, the
corresponding digital representation of the building asset has one or more attribute parameters,
a location parameter and one or more sensor observation parameters associated therewith, the
one or more attribute parameters indicating one or more attributes assigned to the building asset,
the location parameter indicating a location of the building asset and the one or more sensor

observation parameters indicating one or more sensor observation values obtained based on one or more sensor data from one or more sensors associated with the building asset of the plurality of sensors; and

5 identify an actionable event based on the one or more attribute parameters, the location parameter and the one or more sensor observation parameters associated with that of one or more building assets of the plurality of building assets.

10 17. The system according to claim 16, wherein said identify the actionable event is further based on a predetermined actionable event condition associated with the one or more building assets.

18. The system according to claim 17, wherein said identify the actionable event based on the predetermined actionable event condition comprises, for each of the one or more building assets:

15 determining whether the one or more sensor observation parameters associated with the building asset satisfy corresponding one or more predetermined sensor observation conditions associated with the building asset included in the predetermined actionable event condition;

determining whether the one or more attribute parameters associated with the building asset satisfy corresponding one or more predetermined attribute conditions associated with the building asset included in the predetermined actionable event condition; and

20 determining whether the location parameter associated with the building asset satisfy a corresponding location condition associated with the building asset included in the predetermined actionable event condition.

25 19. The system according to claim 18, wherein the actionable event is identified if the predetermined actionable event condition is determined to be satisfied, and

the at least one processor is further configured to trigger a predetermined task associated with the predetermined actionable event condition for the actionable event identified.

30

20. The system according to claim 19, wherein the predetermined task associated with the predetermined actionable event condition is determined to be satisfied if at least:

the one or more predetermined sensor observation conditions associated with that of the one or more building assets included in the predetermined actionable event condition are determined to be satisfied;

5 the one or more predetermined attribute conditions associated with that of the one or more building assets included in the predetermined actionable event condition are determined to be satisfied; and

the location condition associated with that of the one or more building assets included in the predetermined actionable event condition is determined to be satisfied.

10 21. The system according to any one of claims 18 to 20, wherein
the one or more building assets are multiple building assets, and
said identify the actionable event based on the predetermined actionable event condition
further comprises determining whether the location parameters associated with said multiple
building assets satisfy a relative location condition associated with said multiple building assets
15 based on a predetermined reference distance or range of distance between said multiple building
assets.

22. The system according to claim 21, wherein
the predetermined task associated with the predetermined actionable event condition
20 comprises tasking one or more individuals detected based on one or more sensor data obtained
from one or more sensors associated with a first building asset of said multiple building assets
to attend to the actionable event at a second building asset of said multiple building assets in
relation to one or more sensor observation parameters associated with the second building asset.

25 23. The system according to any one of claims 17 to 22,
wherein the predetermined actionable event condition is included in an actionable event
condition database, and
the at least one processor is further configured to add a new actionable event condition
in the actionable event condition database via an actionable event condition generation user
30 interface.

24. The system according to claim 23, wherein said add the new actionable event condition
comprises:

receiving, via the actionable event condition generation user interface, one or more building asset identity inputs, each building asset identity input designating a corresponding building asset of the plurality of building assets for which the new actionable event condition is associated with; and

5 for each of the one or more building asset identity inputs,

 receiving, via the actionable event condition generation user interface, one or more sensor observation type inputs designating one or more sensor observation parameters associated with the designated building asset for which the new actionable event condition is associated with;

10 receiving, via the actionable event condition generation user interface, one or more function operator inputs designating one or more functions for subjecting the designated one or more sensor observation parameters to; and

 receiving, via the actionable event condition generation user interface, one or more reference value inputs designating one or more reference values based on which one or more results of the one or more functions are compared respectively for determining an outcome on whether the new actionable event condition with respect to the designated building asset is satisfied.

25 The system according to claim 24, wherein

20 the one or more building asset identity inputs are multiple building asset identity inputs designating multiple building assets for which the new actionable event condition is associated with, and

 said add the new actionable event condition further comprises:

 receiving, via the actionable event condition generation user interface, an integration operator type input designating an integration operator for integrating the outcomes on whether the new actionable event condition with respect to said multiple designated building assets are satisfied.

26 The system according to claim 24 or 25, wherein

30 the one or more building asset identity inputs are selected from a predefined set of building asset identities corresponding to building assets of the building available for a user to select,

the one or more sensor observation type inputs are selected from a predefined set of sensor observation types available for the user to select for the designated building asset,

the one or more function operator inputs are selected from a predefined set of functions available for the user to select, and

- 5 the integration operator type input is selected from a predefined set of integration operators available for the user to select.

27. The system according to claim 26, wherein

- 10 the at least one processor is further configured to update, for each building asset of the plurality of building assets, the one or more sensor observation parameters associated with the corresponding digital representation of the building asset with the one or more sensor observation values based on the one or more sensor data obtained from the one or more sensors associated with the building asset,

- 15 the predefined set of functions comprises a set of time-based functions and a set of spatial-based functions,

- 20 the set of time-based functions comprises one or more of an average function, a maximum function, a minimum function, a maximum range function, a cumulative sum function, a differential cumulative sum function, a differential absolute cumulative sum function, a count number of occurrences above or below a threshold function and a value difference between time instances function, and

the set of spatial-based functions comprises one or more of an average function, a summation function, a maximum function, a minimum function, a maximum range function and a value difference between locations function.

- 25 28. The system according to any one of claims 16 to 27, wherein for each building asset of the plurality of building assets, the one or more attribute parameters associated with the corresponding digital representation of the building asset indicates a current purpose or function of the building asset or a status of the building asset.

- 30 29. The system according to any one of claims 16 to 28, wherein

the building information database is a digital twin database for the building, and

for each building asset of the plurality of building assets, the corresponding digital representation of the building asset is a corresponding digital twin object in the digital twin database.