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(54) **Title:** AUTODETECTION OF CHANGES IN A BUILDING BASED ON OCCUPANCY SENSOR SIGNALS

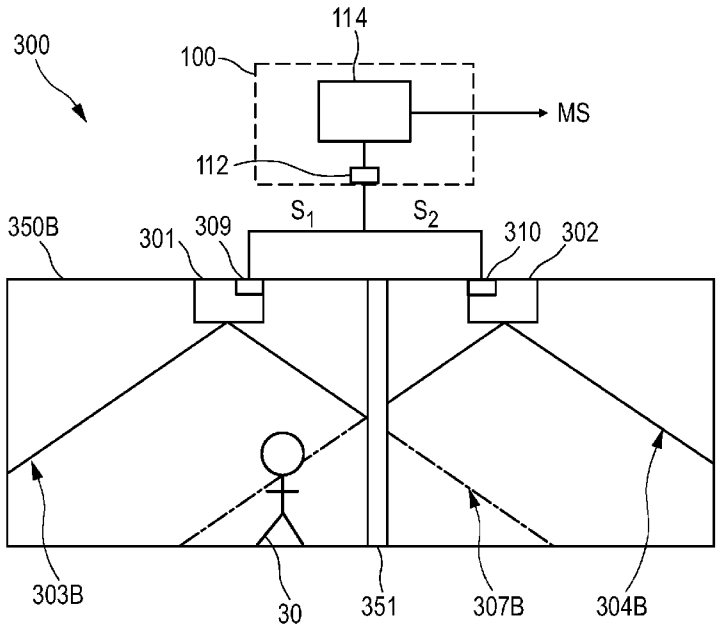


FIG. 4

(57) **Abstract:** The invention is directed to an occupancy evaluation unit that comprises an input interface for receiving current occupancy sensor signals from a plurality of occupancy sensors. The occupancy sensor signals are indicative of whether or not a human is currently present within a respective field of view of the given occupancy sensor. A processing unit is configured to determine a reference correlation, which is indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the occupancy sensors. Comparison with a current correlation, which is indicative of a current amount of the correlation measure between the occupancy sensor signals of the at least one pair of occupancy sensors, triggers provision of a field-of-view modification signal upon determining that the current correlation differs from the reference correlation by more than a predetermined threshold amount.

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AUTODETECTION OF CHANGES IN A BUILDING BASED ON OCCUPANCY SENSOR SIGNALS

FIELD OF THE INVENTION

The present invention is directed to an occupancy evaluation unit, to an occupancy evaluation arrangement, to a method for operating an occupancy evaluation unit, to a method for operating an occupancy evaluation arrangement and to a computer program.

BACKGROUND OF THE INVENTION

US 2018/0121572 A1 describes a system for managing workspace layouts in a building. The system comprises a plurality of sensors, which determine changes in a current layout of a workspace with regard to a previous layout of the workspace. At least one of the sensors is associated with a corresponding workspace. The current layout is determined based on signals received from selected ones of the sensors. The plurality of sensors is further configured to provide an indication when a change in the layout has been determined.

SUMMARY OF THE INVENTION

It would be desirable to provide an alternative for detecting a layout modification in a building.

According to a first aspect of the present invention, an occupancy evaluation unit is disclosed. The occupancy evaluation unit comprises an input interface for receiving current occupancy sensor signals from a plurality of external occupancy sensors, wherein a respective one of the occupancy sensor signals is indicative of whether or not a human is currently present within a respective field of view of the given occupancy sensor. The occupancy evaluation unit further comprises a processing unit. The processing unit is configured to determine a reference correlation and a current correlation and to provide a field-of-view modification signal upon determining that the current correlation differs from the reference correlation by more than a predetermined threshold amount. The reference correlation is indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the external occupancy sensors and the current correlation is indicative of a current amount of the correlation measure between the occupancy sensor signals of the at least one pair of external occupancy sensors.

The invention is based on the recognition that it is not necessary to evaluate motion sensor signals to determine a layout modification. Instead, occupancy sensors can be used to derive information on layout modifications in a building. In particular, the invention recognizes that a layout change can affect the field of view of an occupancy sensor. As a consequence, for illustration, a layout modification such as an addition or removal of an internal wall can result in different occupancy sensor signals of a given occupancy sensor even under identical occupancy conditions, e.g., an identical number of people sitting at identical positions, due to a modification of the field of view of the given occupancy sensor by the added or removed internal wall. The invention further recognizes that a single sensor is not a reliable source of information for such layout modifications. Based on this recognition, the invention makes use of the observation that an evaluation of a correlation measure of the occupancy sensor signals of suitable pairs of occupancy sensors can provide a reliable source of information of layout modifications. Therefore, the processing unit of the occupancy evaluation unit of the present inventions is operable to determine a reference correlation, which is indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the external occupancy sensors. Furthermore, the processing unit is configured to determine a current correlation which is indicative of a current amount of the correlation measure between the occupancy sensor signals of the at least one pair of external occupancy sensors.

Thus, according to the present invention, a modification in the field of view of an occupancy sensor is detected by means of a significant change in the current correlation with respect to the reference correlation between the occupancy sensor signals of a given pair. Based on this correlation measure, the field-of-view modification is determined in a reliable manner. The processing unit therefore provides a field-of-view modification signal upon determining that the current correlation differs from the reference correlation by more than a predetermined threshold amount. This field-of-view modification signal can be applied to detect indications of a layout modification in a building. Therefore, occupancy sensors, which in many application cases are provided in a lighting system for lighting control in a building, can at the same time be used for providing layout modification information to a building management system, thus contributing to avoiding complexity of a sensor infrastructure in the building.

As an illustrative example, the field-of-view modification signal will be provided upon determining that the reference correlation has a significantly smaller amount than the current correlation after a side wall or a cabinet has been removed from the fields of

view of a given pair of occupancy sensors. As a further illustrative example, the field-of-view modification signal will indicate that a field-of-view limiting object has been added within the field of view of an occupancy sensor if the current correlation is found to have a smaller amount than the reference correlation.

The occupancy evaluation unit is suited to be employed in an environment of an installed sensor infrastructure of occupancy sensors and thus forms a particularly cost-effective means of adding layout monitoring functionality to such pre-existing sensor infrastructures. The occupancy sensors of such a sensor infrastructure are therefore considered as being external to the occupancy evaluation unit of the first aspect of the present invention.

In the following, embodiments of the occupancy evaluation unit will be described.

As is per se known in the art, a correlation measure is indicative of a statistical association between two signals. The present invention determines a reference correlation as an indication of an expected statistical association between occupancy sensor signals of at least one pair of the external occupancy sensors, whereas a current correlation is determined as an indication of a statistical association between current occupancy sensor signals of the at least one pair of external occupancy sensors. In the following, different embodiments making use of different ways of determining the correlation measure will be discussed.

The processing unit of the occupancy evaluation unit is in one embodiment configured to receive floorplan data and field-of-view data. The floorplan data are indicative of a floorplan defining a physical layout of an interior space of a building. The field-of-view data are indicative of a position of the respective occupancy sensors and a respective spatial extension of a field of view of the respective occupancy sensors with reference to the floorplan. The processing unit is configured to determine, using the floorplan data, and using the field-of-view data, the reference correlation for at least one pair of the external occupancy sensors. In a variant of this embodiment field-of-view data and floorplan data form parts of a building information model (BIM). As is per se known, a building information model forms a digital representation of physical and functional features of a building and is used for managing physical infrastructures, e.g., the layout of the interior space of a building, and its functional infrastructures, e.g., for distributing water, electricity or gas within a building. Thus, the reference correlation is in this exemplary embodiment determined by a calculation based on geometrical information regarding the position and extension of the fields of view of the occupancy sensors and regarding the layout, using a common geometrical reference

system for instance provided by the building information model. This embodiment therefore does not require occupancy sensor signals from the given pair for determining their reference correlation.

Different variants of this embodiment make use of different ways for determining the reference correlation based on the floorplan data and the field-of-view data. In some variants, the processing unit of the occupancy evaluation unit is configured to determine a distance between a first external occupancy sensor and a second external occupancy sensor, and to determine the reference correlation for the pair formed by the first and second external occupancy sensor only if the determined distance is smaller than a predefined threshold distance. For determination of a distance between the external occupancy sensors the respective field-of-view data are used. Suitably, the distance is determined between all possible pairs of external occupancy sensors.

The threshold distance is dependent on spatial extension of the fields of view of the respective external occupancy sensor. For instance, the processing unit is configured to exclude those possible pairs of the external occupancy sensors from the determination of the reference correlation which have fields of view without possible overlap. This way, the determination of the reference correlation is avoided for pairs of externals occupancy sensors which are known from existing floorplan and field-of-view data to have no correlation whatsoever. Examples of such uncorrelated occupancy sensors are sensors in different floors of a building or sensors in different wings of a building.

In a variant of these embodiments the processing unit is configured to associate a smaller field of view of a given occupancy sensor with a smaller threshold distance for the given external occupancy sensor, and a larger field of view with a larger threshold distance for the given external occupancy sensor.

In an alternative embodiment, no floorplan data and no field-of-view data is required. Instead, the processing unit is configured to determine, using previous occupancy sensor signals of the external occupancy sensors, the reference correlation for at least one pair of the external occupancy sensors. This embodiment thus relies on the sensing history of the occupancy sensors to detect an existing correlation between sensor pairs that is used as a reference correlation during further operation.

A sensor signal history can be provided for instance by an external data base of a building management system. The determination of the reference correlation in the context of this embodiment therefore does not require that the occupancy evaluation unit itself stores a history of sensor signals before being able to determine the reference

correlation. However, in a variant, the occupancy evaluation unit does have such storage means allowing to store a sensor signal history and determine the reference correlation based on this information.

In a further embodiment that combines both previously described approaches, the processing unit is configured to determine, using the floorplan data, and using the field-of-view data, and using the previous occupancy sensor signals of the external occupancy sensors, the reference correlation for at least one pair of the external occupancy sensors. This embodiment is useful for avoiding possible inaccuracies in a determination of the reference correlation using only the floorplan data and the field-of-view data. For example, in the case of outdated floorplan data, the previous occupancy sensor signals can provide additional information reflecting the most recent floorplan, thus avoiding "false alarm" by a field-of-view modification signal generated in operation of the occupancy evaluation unit.

Generally, a given occupancy sensor has a spatial resolution that corresponds to an extension of its field of view. In other words, the given occupancy sensor alone is typically not capable of providing information on the location of detected occupancy with a high spatial resolution that allows to distinguish occupancy information between different locations within its field of view. A pair of occupancy sensors, however, may provide a higher spatial resolution of occupancy information, for instance because the occupancy sensors may have overlapping fields of view. The accumulated fields of view of a given sensor pair in such an exemplary sensor arrangement thus may have up to three different distinguishable regions: an overlap region covered by both fields of view, a first non-overlap region covered by the field of view of only a first one of the pair of occupancy sensors, and a second non-overlap regions covered by the field of view of only a second one of the pair of occupancy sensors. The correlation measure will exhibit a higher amount in the overlap region than in the non-overlapping region, and the non-overlapping regions can be distinguished by additionally evaluating which of the individual occupancy sensor signal shows occupancy and which shows non-occupancy.

For that reason, the correlation between the sensor signals of a given sensor pair may differ depending on a given location in the region covered by their accumulated fields of view. In this situation, the determination of the reference correlation using the floorplan data and the field-of-view data can be further improved, if the processing unit is configured

- to determine, using the floorplan data and the field-of-view data, for a given one of the pairs of external occupancy sensors, a plurality of local reference correlations,

which each are indicative of an expected amount of the correlation measure between the occupancy sensor signals of the given pair of external occupancy sensors for a respective fraction of an accumulated spatial extension formed by a combination of the fields of view of the given pair of occupancy sensors; and

- to determine the reference correlation for the given pair of external occupancy sensors by determining an average of the plurality of determined local reference correlations for the given pair.

In this embodiment, the reference correlation is first determined with a higher spatial resolution than that allowed by the individual fields of view of the occupancy sensors, additionally using the information provided by the floorplan data. Such floorplan data may for instance provide layout data defining a layout and furnishing data defining a previously recorded furnishing of an interior building space. Then, an average of the local reference correlations is determined. This allows achieving a higher reliability in the significance of detecting that the threshold amount has been exceeded, and thus in the generation of the field-of-view modification signal.

In different variants of this embodiment, the average is determined in different ways, which may be based on conditions of a given application case. In a very simple variant, the average is the arithmetic mean value of the local reference correlations. In another variant, different weights are assigned to different local reference correlations, using additional information on expected or previously determined occupancy in the different fractions of the accumulated field of view. For example, a first fraction known to exhibit regular occupancy can be assigned a higher weight than a second fraction known to exhibit only rare occupancy.

While the previously described embodiment made of the floorplan data and of the field-of-view data for determining the reference correlation, this is not a necessary requirement. In another embodiment, which does not require the use of this data for determining the reference correlation, the occupancy evaluation unit is configured to be operated in one of an initialization mode and a regular operation mode at a given point time. The initialization mode serves for determining and selecting those pairs of occupancy sensors, which have a significant correlation. In particular, the processing unit is configured to determine, in the initialization mode and during an initialization time span, a plurality of samples of the current correlation for all possible pairs of the external occupancy sensors. As previously mentioned, the current correlation of a given pair of the external occupancy sensors is indicative of a current amount of the correlation measure between the occupancy

sensor signals of the given pair. Furthermore, still in the initialization mode, the processing unit is configured to determine an average amount of the current correlations of all the possible pairs of the external occupancy sensors.

Further, still in the initialization mode, the processing unit is configured to determine the reference correlation only for those selected pairs of the external occupancy sensors, for which the respective average amount of the current correlation exceeds a threshold amount. This way, the processing unit achieves a determination of those pairs of external occupancy sensors, which have a correlation with significance for occupancy evaluation and thus for determination of a layout modification.

To accelerate the occupancy evaluation, the processing unit of such embodiment is preferably configured to determine, in a regular operation mode, the current correlation only for the selected pairs of external occupancy sensors. However, it is also possible to even further reduce the number of used pairs to further increase efficiency of evaluation, for instance if only a certain region of a layout is to be evaluated for possible layout changes.

In a particularly advantageous variant the processing unit is configured, instead of performing live measurements for obtaining the samples in the initialization mode of occupancy sensor signals for determining the current correlation, to determine the average amounts of the current correlations using previously measured occupancy sensor signals of all possible pairs of the external occupancy sensors. Such data may for instance be accessed by the processing unit in an occupancy database that stores such previously recorded occupancy sensor signals.

Different correlation measures can be used in different embodiments of the occupancy evaluation unit. As mentioned, any correlation measure is indicative of a statistical association between two signals. Some correlation measures additionally consider the time dependence of the signals. For instance, a cross-correlation is a measure of similarity of two series of signal samples as a function of the time displacement of one series relative to the other. In the context of occupancy evaluation, the use of a cross-correlation as the correlation measure may be useful in order to take into account the movement of people in the interior of the building. This will result in occupancy sensor signals which exhibit mutual correlation in “time-shifted manner”. Thus, even if a pair of given occupancy sensors does not exhibit a correlation at a given single point in time, for instance due to lacking overlap in their fields of view, the cross-correlation between the sensor signals may still be significant for providing information on layout modification. As a simple example, a newly built interior

wall may block a walking path previously used within an office space such that some occupancy sensors that previously followed other occupancy sensors in their detection pattern, will lose that correlation due to the newly built wall.

In one embodiment making use of a cross-correlation as the correlation measure, the processing unit is configured to determine reference occupancy sensor signals of the external occupancy sensors as a function of time at a plurality of sampling points of a predetermined model time window that comprises an occurrence of at least one predetermined model event and to determine the reference correlation by determining a reference cross correlation between the reference occupancy sensor signals as a function of time in the predetermined model time window and by determining a reference cross correlation amount from the determined reference cross correlation. As a simple example, a model event may be formed by a person walking from one room of an office space to the neighboring room.

The processing unit is in such an embodiment preferably further configured to determine the occupancy sensor signals of the external occupancy sensors as a function of time at a plurality of sampling points of a predetermined measurement time window. Furthermore, the processing unit is configured to determine the current correlation by determining a current cross correlation between the occupancy sensor signals as a function of time in the predetermined measurement time window and by determining a current cross-correlation amount from the determined current cross correlation. Thus, the processing unit of this embodiment provides the field-of-view modification signal upon determining that the current correlation in the form of the cross-correlation differs from the reference correlation in the form of the reference cross correlation by more than a predetermined threshold amount.

This way, a movement of a human, which is detected by a plurality of the external occupancy sensors at different times, can be used by the occupancy evaluation unit in the context of the monitoring for possible field-of-view modifications. The determined reference cross correlation and the determined current cross correlation allow to correlate events in time like movements of people from corresponding, but time-shifted occupancy sensor signals from the least one pair of the external occupancy sensors.

In other embodiments, a plurality of different correlation measures is determined and used in combination by the processing unit, to combine the different aspects of field-of-view modification information that is derivable from each of the different correlation measures.

A second aspect of the invention is formed by an occupancy evaluation arrangement. The occupancy evaluation unit comprises a plurality of occupancy sensors and an occupancy evaluation unit in accordance with the first aspect of the invention. Each occupancy sensor of the plurality of occupancy sensors is configured to detect whether or not a human is currently present within a respective field of view of the given occupancy sensor and to provide a respective occupancy sensor signal indicative thereof. The input interface of the occupancy evaluation unit of the first aspect receives the occupancy sensor signals from the occupancy sensors.

The occupancy evaluation arrangement of the second aspect thus additionally includes the occupancy sensor signals as a part of an arrangement and thus represents a field application of the occupancy evaluation unit of the first aspect of the present invention, and thus also shares its advantages. Furthermore, embodiments of the occupancy evaluation unit have a correspondence in embodiments of the occupancy evaluation arrangement described hereinabove.

In the following, further embodiments of the occupancy evaluation arrangement of the second aspect will be described.

Occupancy sensors can be arranged in any suitable form of arrangement within a given building. To achieve at least one overlap region of the fields of view of different occupancy sensors in a given room, a plurality of occupancy sensors per room is advantageously provided. Thus, in preferred embodiments, the occupancy sensors of the occupancy evaluation arrangement are arranged to let the field of view of a given one of the occupancy sensors share an overlap region with the field of view of at least one other of the occupancy sensors. By virtue of this overlapping arrangement of the fields of view, the current correlation of the occupancy sensor signals of such occupancy sensors is particularly high in the overlap region for any correlation measure that can be used.

In preferred applications, the occupancy sensors are comprised by respective luminaires. Suitably, these luminaires have at least one embedded, attached or otherwise incorporated occupancy sensor. Preferred arrangements have at least one luminaire with an occupancy sensor per room.

In another embodiment, the occupancy evaluation arrangement further comprises an occupancy database for receiving and storing the occupancy sensor signals of the plurality of occupancy sensors as respective functions of time. As has been explained in the context of embodiments of the occupancy evaluation unit, a history of occupancy sensor signals may be useful in determining the reference correlation and performing other

evaluations using the time dependence of the occupancy sensor signals. For instance, a current correlation can be compared to the correlation of the stored occupancy sensor signals of the plurality of occupancy sensors at a same time of day or to an averaged correlation of the stored occupancy sensor signals over the last hours, e.g. 1 hour, 12 hours, or 24 hours.

In another embodiment, the occupancy database further stores floorplan data indicative of a floorplan defining a physical layout of an interior space of a building and field-of-view data indicative of a position of the respective occupancy sensors and a respective spatial extension of a field-of-view of the respective occupancy sensors with reference to the floorplan. In such embodiments, the occupancy evaluation arrangement suitably comprises that previously described embodiment of the occupancy evaluation unit, which is configured to receive the floorplan data and the field-of-view data for determining the reference correlation for at least one pair of the external occupancy sensors (claim 2). Previous occupancy sensor signals are suitably stored in the occupancy database, e.g., as occupancy sensor signals associated with a specific time or time span.

According to a third aspect of the present invention, a method for operating an occupancy evaluation unit in detecting a field-of-view modification of at least one external occupancy sensor is described. The method comprises:

- receiving occupancy sensor signals from a plurality of external occupancy sensors, wherein a respective one of the occupancy sensor signals is indicative of whether or not a human is currently present within a respective field of view of the given occupancy sensor;
- determining a reference correlation, which is indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the external occupancy sensors;
- determining a current correlation which is indicative of a current amount of the correlation measure between the occupancy sensor signals of the at least one pair of occupancy sensors; and
- providing a field-of view modification signal upon determining that the current correlation differs from the reference correlation by more than a predetermined threshold amount.

The method of the third aspect of the invention shares the advantages of the occupancy evaluation unit of the first aspect.

According to a fourth aspect of the present invention, a method for operating an occupancy evaluation arrangement is described. The method comprises:

- providing a plurality of occupancy sensors, which each are configured to detect whether or not a human is currently present within a respective field-of-view of the given occupancy sensor;
- providing a respective occupancy sensor signals indicative thereof to an occupancy evaluation unit; wherein
- the occupancy evaluation unit performs the method in accordance with the third aspect of the invention.

The method of the fourth aspect of the invention shares the advantages of the occupancy evaluation arrangement of the second aspect.

According to a fifth aspect of the present invention, a computer program is provided. The computer program comprises instructions which, when the program is executed by a computer, cause the computer to carry out the method of the third aspect.

It shall be understood that the occupancy evaluation unit of claim 1, the occupancy evaluation arrangement of claim 7, the method for operating an occupancy evaluation unit of claim 12, the method for operating an occupancy evaluation unit of claim 13 and the computer program of claim 14 have similar and/or identical preferred embodiments, in particular, as defined in the dependent claims.

It shall be understood that a preferred embodiment of the present invention can also be any combination of the dependent claims or above embodiments with the respective independent claim.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

BRIEF DESCRIPTION OF THE DRAWINGS

In the following drawings:

Fig. 1 shows a schematic block diagram representing an embodiment of an occupancy evaluation unit.

Fig. 2 shows a schematic block diagram representing another embodiment of an occupancy evaluation unit.

Fig. 3 schematically shows block diagram representing one layout situation of an occupancy evaluation arrangement.

Fig. 4 schematically shows block diagram representing another layout situation of an occupancy evaluation arrangement.

Fig. 5 shows floorplan data and field-of-view data of the layout situation of an occupancy evaluation arrangement represented in Fig. 3.

Fig. 6 shows floorplan data and field-of-view data of the layout situation of an occupancy evaluation arrangement represented in Fig. 4.

Fig. 7 shows a flow diagram representing an embodiment of a method for operating an occupancy evaluation unit.

DETAILED DESCRIPTION OF EMBODIMENTS

Fig. 1 shows a schematic block diagram representing an embodiment of an occupancy evaluation unit 100. The occupancy evaluation unit 100 comprises an input interface 112 and a processing unit 114. The input interface 112 is configured to receive current occupancy sensor signals OSS from a plurality of external occupancy sensors.

The current occupancy sensor signals OSS of the external occupancy sensor provides information about whether or not a human is currently present within a respective field of view of the given occupancy sensor. The current occupancy sensor signal OSS suitably is a digital signal, and may comprise an occupancy data field that can carry the value "0" for indicating "no presence of a human" in a respective field of view of the given occupancy sensor, or "1" for indicating "presence of a human" in the respective field of view of the given occupancy sensor. Of course, other definitions of the occupancy data field may be used. In addition, the occupancy sensor signal suitably contains some identification of the occupancy sensor providing it. This may be another data field for identification data. Other known ways of providing an identification of the occupancy sensor may be used.

In operation, the processing unit 114 is configured to determine a reference correlation and a current correlation and to provide a field-of-view modification signal MS upon determining that the current correlation differs from the reference correlation by more than a predetermined threshold amount. The reference correlation is determined as a value indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the external occupancy sensors. To determine the reference correlation, the present embodiment uses previous occupancy sensor signals of the external occupancy sensors. In another embodiment, an initialization phase is used to determine ´the reference correlations for pairs of external sensor signals. Suitably, the reference correlation amount is calculated as an average correlation value from a number of occupancy sensor signal samples of a respective pair of occupancy sensor signals. In this embodiment, the

previous occupancy sensor signals are stored in a memory (not shown) connected with the processing unit 114.

The threshold for issuance of a field-of-view modification signal is determined by calculating a standard deviation of the determined reference correlation. In other embodiments it is a value provided by user input. Suitably, the reference correlation and the predetermined threshold amount are adaptable to changed conditions, for instance after a layout modification.

The current correlation is determined in operation from currently received occupancy sensor signals of an any given pair of occupancy sensors. The mutual association of sensor pairs for determination of the current correlation can be determined in an initialization phase or provided by user input.

The processing unit 114 provides a field-of-view modification signal MS, if the current correlation significantly differs from the reference correlation. The field-of-view modification signal MS is suitably provided for transmission to a building management system, where a system manager can further process and validate the information provided by field-of-view modification signal MS.

Fig. 2 shows a schematic block diagram representing another embodiment of an occupancy evaluation unit 200. The following description will focus on the differences between the occupancy evaluation unit 100 of Fig. 1 and the occupancy evaluation unit 200 of Fig. 2. Those features that are not altered are referred to using the same reference numerals except for the first digit, which was “1” for the occupancy evaluation unit 100 of Fig. 1 and will be “2” for the occupancy evaluation unit 200 of Fig. 2.

In the occupancy evaluation unit 200, the processing unit 214 comprises a reference correlation unit 216, a current correlation unit 218 and a comparison unit 220.

The reference correlation unit 216 is configured to receive floorplan data FP, and field-of-view data FoV, and a history of occupancy sensor signals hOSS. The floorplan data FP are indicative of a floorplan defining a physical layout of an interior space of a building and are stored in an occupancy database (not shown). The field-of-view data FoV, which are indicative of a position of the respective occupancy sensors and a respective spatial extension of a field-of-view of the respective occupancy sensors with reference to the floorplan, are also stored in the occupancy database. The occupancy database is not part of the occupancy evaluation unit 200. Alternatively, the occupancy database can be comprised in the occupancy evaluation unit 200.

The floorplan data FP and the field-of-view data FoV are already used for determining the reference correlation. Both, the floorplan data FP and the field-of-view data FoV, are part of a building information model for a building management system.

With the information on the position in an actual floorplan and the fields of view of the occupancy sensors, an expected reference correlation is estimated. Therefore, a plurality of local reference correlations which are indicative of a respective expected amount of the correlation measure between the occupancy sensor signals of the pairs of external occupancy sensors for a respective fraction of the respective spatial extensions of the field of view of the respective occupancy sensors is used. With the local reference correlations, a reference correlation for a given one of the pairs of occupancy sensors is determined by a weighted average of the plurality of the local reference correlations.

The occupancy database of the building management system also provides the history of the occupancy sensor signals hOSS. The history of the occupancy sensor signals hOSS arises from the last measured occupancy sensor signal and the occupancy sensor signals measured before the last measured occupancy sensor signal. A calculated reference correlation based on an average of calculated correlation measures between the respective occupancy sensor signals OSS in the history of the occupancy sensor signals hOSS. The average of the calculated correlation measure is always updated due to the current measured occupancy sensor signal received by the occupancy database.

The usage of the history of the occupancy sensor signals hOSS together with the floorplan data FP and the field-of-view data FoV provides the possibility to reflect the most recent floorplan. For instance, outdated floorplan data can be identified or reflected, or actual floorplan data can be verified.

The reference correlation unit 216 is further configured to determine a threshold amount. The threshold amount is determined by estimation of a deviation from the reference correlation measure. For instance, the threshold amount of the reference correlation determined by the history of occupancy sensor signals hOSS is determined by calculation of a statistical deviation of the history of occupancy sensor signals hOSS.

The current correlation unit 218 is receiving the current occupancy sensor signals OSS of the at least one pair of external occupancy sensors via the input interface 212 of the occupancy evaluation unit 200. The current correlation unit 218 is configured to determine a current correlation which is indicative of a current amount of the correlation measure between the received occupancy sensor signals OSS of the at least one pair of external occupancy sensors.

The comparison unit 220 is configured to receive the reference correlation from the reference correlation unit 216 and the current correlation from the current correlation unit 218. The comparison unit 220 is further configured to compare the reference correlation and the current correlation and to determine if the current correlation differs from the reference correlation by more than a predetermined threshold amount and to provide a field-of-view modification signal MS thereof.

The occupancy evaluation unit is suitable for use in an occupancy evaluation arrangement as explained in Fig. 3 and Fig. 4. The occupancy evaluation unit is suitable as an add-on unit that can be used with pre-installed occupancy sensor installations. The occupancy evaluation unit can be provided as a separate hardware part. In other embodiments, it is provided as a software product for implementation using a programmable computer.

Fig. 3 and Fig. 4 schematically show block diagrams representing different layout situations of an occupancy evaluation arrangement 300. The following description will refer to both figures in parallel. The letters "A" and "B" in the reference numerals refer to two different situations in the same area 350. The occupancy evaluation arrangement 300 comprises two occupancy sensors 309, 310 which are part of two luminaires 301, 302 in the area 350. The occupancy sensors 309, 310 are configured to detect whether or not a human 30 is currently present within a respective field of view 303A, 304A. The occupancy sensors 309, 310 are configured to send a respective occupancy sensor signal S_1, S_2 to the occupancy evaluation unit 100. In the exemplary embodiment of the occupancy evaluation arrangement the occupancy sensors 309, 310 are passive infrared sensors, which detect a temperature different from the temperature of the background as human occupancy within a respective field of view 303A, 304A. Alternatively, the occupancy sensors 309, 310 are ultrasonic or microwave sensors, which work with the Doppler shift principle or optical sensors, such as camera sensors. In a variant, the occupancy sensors 309, 310 are stand-alone devices arranged separately from the luminaires 301, 302.

Furthermore, the occupancy evaluation arrangement 300 comprises an occupancy evaluation unit. For instance, the present example comprises the occupancy evaluation unit 100 of Fig. 1. In another embodiment (not shown), the occupancy evaluation arrangement comprises the occupancy evaluation unit 200 of Fig. 2.

The occupancy sensors 309, 310 of Fig. 3 are located in the area 350A. Due to a given layout in the area 350A, the occupancy sensors 309, 310 have a respective field of view indicated by reference labels 303A, 304A. The respective fields of view 303A, 304A of

the two occupancy sensors 309, 310 of Fig. 3 have an overlap in their fields of view, which forms an overlap region 307A.

In the situation illustrated in Fig. 3, the human 30 is detected in the overlap region 307A of the occupancy sensors 309, 310. As a consequence, both occupancy sensors prove a "1" indicating presence of a human to the occupancy sensor unit 100. As a result, the current correlation determined in the processing unit 114 of the occupancy evaluation unit 100 is high. Due to the overlap region 307A, the reference correlation for the sensors 309 and 310 is equally high. Thus, there is no significant difference between the reference correlation and the current correlation. For that reason, the situation illustrated in Fig. 3 will not trigger the provision of a field-of-view modification signal.

Fig. 4 shows a layout situation after a change in comparison with the layout situation illustrated in Fig. 3. In the layout situation shown in Fig. 4, the layout of the area 350A of Fig. 3 is modified by addition of a wall 351. Thus, the new layout situation has an area 350B part of the which has been separated. The two occupancy sensors 309, 310 are now located in different parts of the area 350B. In the situation of Fig. 4 the human 30 is again at the same position as in the situation shown in Fig. 3. However, now only the occupancy sensor 309 detects the presence of the human 30 in its field of view 303B, whereas the occupancy sensor 310 does not detects the presence of a human 30 in its field of view 304B due to a partial shielding of its field of view by the wall 351. As a consequence, the occupancy sensor 309 which detects the human 30 sends a "1" to the occupancy evaluation unit 100, and the occupancy sensor 310 which does not detect the human 30 sends a "0" to the occupancy evaluation unit 100. The current correlation between the occupancy sensor signals S1 and S2 determined by the processing unit 114 of the occupancy evaluation unit 100 is therefore low in the changed situation of Fig. 4. Since the layout situation, on which the determination of the reference correlation was based, is the layout situation of Fig. 3, a significant difference between the current correlation and the reference correlation is determined. This triggers the provision of a layout modification signal MS by occupancy evaluation unit 100 to a building information system (not shown).

In the building information system, the layout situation represented by the floorplan of the area where the occupancy sensors 309, 310 are located, can be compared with previous or current maintenance plans. The floorplan can be updated.

Depending on the specific occupancy sensors used, a material change in the interior structures due to construction measures can be detected. In such embodiments, the occupancy sensors 309, 310 are suitably ultrasonic or microwave sensors. For instance, if the

wall 351 in Fig. 4 present during determination of the reference correlation is made from wood or drywall material and subsequently replaced by a glass wall, the occupancy sensor 310 will after the change have an increased field of view 304B that allows detecting the human 30 through the wall. The processing unit 114 of the occupancy evaluation unit 100 thus will determine a current correlation which has a significant deviation in comparison with the reference correlation, and will therefore provide the layout modification signal MS.

Fig. 5 and Fig. 6 show floorplan data and field-of-view data of the layout situations of an occupancy evaluation arrangement represented in Fig. 3 and Fig. 4, respectively. The following description will refer to both figures in parallel. The features are referred to using the same reference numerals except for the first digit, that is "3" in Fig. 3 and Fig. 4 and "4" in Fig. 5 and Fig. 6. "A" and "B" in the reference numerals refers to two different situations in the same area.

The floorplan data of an area 450A is shown in Fig. 5 and of an area 450B is shown in Fig. 6. The field-of-view data in the area 450A and 450B are shown. The field-of-view data show positions 420, 430 of the two occupancy sensors 309, 310 of Fig. 3 and 4 and respective spatial extensions of the fields of view 403, 404 of the respective occupancy sensors with reference to the floorplan.

The occupancy sensors are located at the same position 420, 430 in the floorplan for the layout situations in Fig. 5 and Fig. 6. In the layout situation of Fig. 5 the fields of view 403A, 404A share an overlap region 407. In the layout situation of Fig. 6 the fields of view 403B, 404B have no overlap region due to a wall 541 in the floorplan which is separating the area 450B. The physical layout of the interior space defined by the floorplan data thus restricts the spatial extension of the field of view of the respective occupancy sensors. For instance, a field of view of the occupancy sensor can be blocked by a cabinet.

Fig. 7 shows a flow diagram representing an embodiment of a method 500 for operating an occupancy evaluation unit. The method 500 comprises, in a step 502, receiving occupancy sensor signals from a plurality of external occupancy sensors. Each of the occupancy sensor signals is indicative of whether or not a human is currently present within a respective field of view of the given occupancy sensor. It also comprises, in a step 504, determining a reference correlation. The reference correlation is indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the external occupancy sensors. The method 500 also comprises, in a step 506, determining a current correlation which is indicative of a current amount of the correlation measure between the occupancy sensor signals of the at least one pair of occupancy sensors. The

method 500 also comprises, in a step 508, providing a field-of view modification signal upon determining that the current correlation differs from the reference correlation by more than a predetermined threshold amount.

In summary, the invention is directed to an occupancy evaluation unit that comprises an input interface for receiving current occupancy sensor signals from a plurality of occupancy sensors. The occupancy sensor signals are indicative of whether or not a human is currently present within a respective field of view of the given occupancy sensor. A processing unit is configured to determine a reference correlation, which is indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the occupancy sensors. Comparison with a current correlation, which is indicative of a current amount of the correlation measure between the occupancy sensor signals of the at least one pair of occupancy sensors, triggers provision of a field-of-view modification signal upon determining that the current correlation differs from the reference correlation by more than a predetermined threshold amount.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality.

A single unit or device may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

A computer program may be stored/distributed on a suitable medium, such as an optical storage medium or a solid-state medium, supplied together with or as part of other hardware, but may also be distributed in other forms, such as via the Internet or other wired or wireless telecommunication systems.

Any reference signs in the claims should not be construed as limiting the scope.

CLAIMS:

1. An occupancy evaluation unit (111) comprising:

- an input interface for receiving occupancy sensor signals, from a plurality of external occupancy sensors, wherein a respective one of the occupancy sensor signals is indicative of whether or not a human is currently present within a respective field of view of the given occupancy sensor;

- a processing unit, which is configured

- to determine a reference correlation, which is indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the external occupancy sensors;

- to determine a current correlation which is indicative of a current amount of the correlation measure between the occupancy sensor signals received, in operation, of the at least one pair of external occupancy sensors; and

- to provide a field-of-view modification signal upon determining that the current correlation for the at least one pair of the external occupancy sensors differs from the reference correlation for the at least one pair of the external occupancy sensors by more than a predetermined threshold amount.

2. The occupancy evaluation unit of claim 1, wherein the processing unit is configured

- to receive floorplan data indicative of a floorplan defining a physical layout of an interior space of a building and field-of-view data indicative of a position of the respective occupancy sensors and a respective spatial extension of a field-of-view of the respective occupancy sensors with reference to the floorplan;

- to determine, using the floorplan data, and using the field-of-view data or using previous occupancy sensor signals of the external occupancy sensors, the reference correlation for at least one pair of the external occupancy sensors.

3. The occupancy evaluation unit of claim 2, wherein the processing unit is configured to determine, using the respective field-of-view data, a distance between a first

external occupancy sensor and a second external occupancy sensor, each of the plurality of external occupancy sensors, and to determine the reference correlation for the pair formed by the first and second external occupancy sensor only if the determined distance is smaller than a predefined threshold distance.

4. The occupancy evaluation unit of claim 2, wherein the processing unit is configured

- to determine, using the floorplan data and the field-of-view data, for a given one of the pairs of external occupancy sensors, a plurality of local reference correlations, which each are indicative of an expected amount of the correlation measure between the occupancy sensor signals of the given pair of external occupancy sensors for a respective fraction of an accumulated spatial extension formed by a combination of the fields of view of the given pair of occupancy sensors; and
- to determine the reference correlation for the given pair of external occupancy sensors by determining an average of the plurality of determined local reference correlations for the given pair.

5. The occupancy evaluation unit of claim 1, wherein the processing unit is configured,
in an initialization mode and during an initialization time span,

- to determine for all possible pairs of the external occupancy sensors, a plurality of samples of the current correlation;
- to determine respective average amounts of the plurality of samples of the current correlations of all possible pairs of the external occupancy sensors in the initialization time span;
- to determine the reference correlation only for those selected pairs of the external occupancy sensors, for which the respective average amount of the plurality of samples of the current correlation exceeds a threshold amount; and,

in a regular operation mode,

- to determine the current correlation only for the selected pairs of external occupancy sensors.

6. The occupancy evaluation unit of claim 1, wherein the processing unit is configured

- to determine reference occupancy sensor signals of the external occupancy sensors as a function of time at a plurality of sampling points of a predetermined model time window that comprises an occurrence of at least one predetermined model event;
- to determine the reference correlation by determining a reference cross correlation between the reference occupancy sensor signals as a function of time in the predetermined model time window and by determining a reference cross correlation amount from the determined reference cross correlation;
- to determine the occupancy sensor signals of the external occupancy sensors as a function of time at a plurality of sampling points of a predetermined measurement time window; and
- to determine the current correlation by determining a current cross correlation between the occupancy sensor signals as a function of time in the predetermined measurement time window and by determining a current cross correlation amount from the determined current cross correlation.

7. An occupancy evaluation arrangement, comprising
- a plurality of occupancy sensors, which each are configured to detect whether or not a human is currently present within a respective field of view of the given occupancy sensor and to provide a respective occupancy sensor signal indicative thereof; and comprising
- an occupancy evaluation unit according to claim 1, wherein the input interface of the occupancy evaluation unit receives the occupancy sensor signals from the occupancy sensors.

8. The occupancy evaluation arrangement of claim 7, wherein the occupancy sensors are arranged such that the field of view of a given one of the occupancy sensors shares an overlap region with the field of view of at least one other of the occupancy sensors.

9. The occupancy evaluation arrangement of claim 7, further comprising an occupancy database for receiving and storing the occupancy sensor signals of the plurality of occupancy sensors as respective functions of time.

10. The occupancy evaluation arrangement of claim 9 comprising the occupancy evaluation unit of claim 2, wherein
- the occupancy database further stores the floorplan data.

11. The occupancy evaluation arrangement of claim 7, wherein the occupancy sensors are comprised by respective luminaires.

12. A method for operating an occupancy evaluation unit in detecting a field-of-view modification of at least one external occupancy sensor, the method comprising:

- receiving occupancy sensor signals from a plurality of external occupancy sensors, wherein a respective one of the occupancy sensor signals is indicative of whether or not a human is currently present within a respective field of view of the given occupancy sensor;
- determining a reference correlation, which is indicative of an expected amount of a correlation measure between the occupancy sensor signals of at least one pair of the external occupancy sensors;
- determining a current correlation which is indicative of a current amount of the correlation measure between the occupancy sensor signals received, in operation, of the at least one pair of occupancy sensors; and
- providing a field-of view modification signal upon determining that the current correlation differs from the reference correlation by more than a predetermined threshold amount.

13. A method for operating an occupancy evaluation arrangement, comprising:

- providing a plurality of occupancy sensors, which each are configured to detect whether or not a human is currently present within a respective field-of-view of the given occupancy sensor;
- providing a respective occupancy sensor signals indicative thereof to an occupancy evaluation unit; wherein
- the occupancy evaluation unit performs the method of claim 12.

14. A computer program comprising instructions which, when the program is executed by a computer, cause the computer to carry out the method of claim 12.

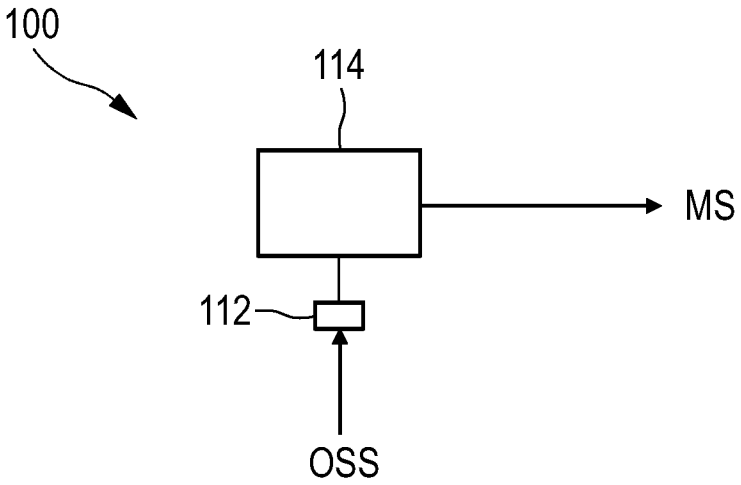


FIG. 1

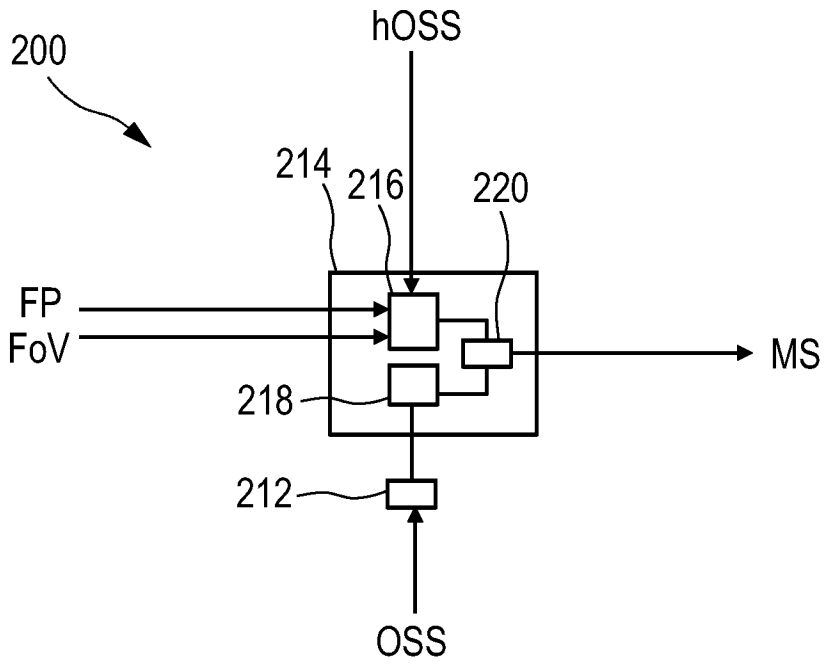


FIG. 2

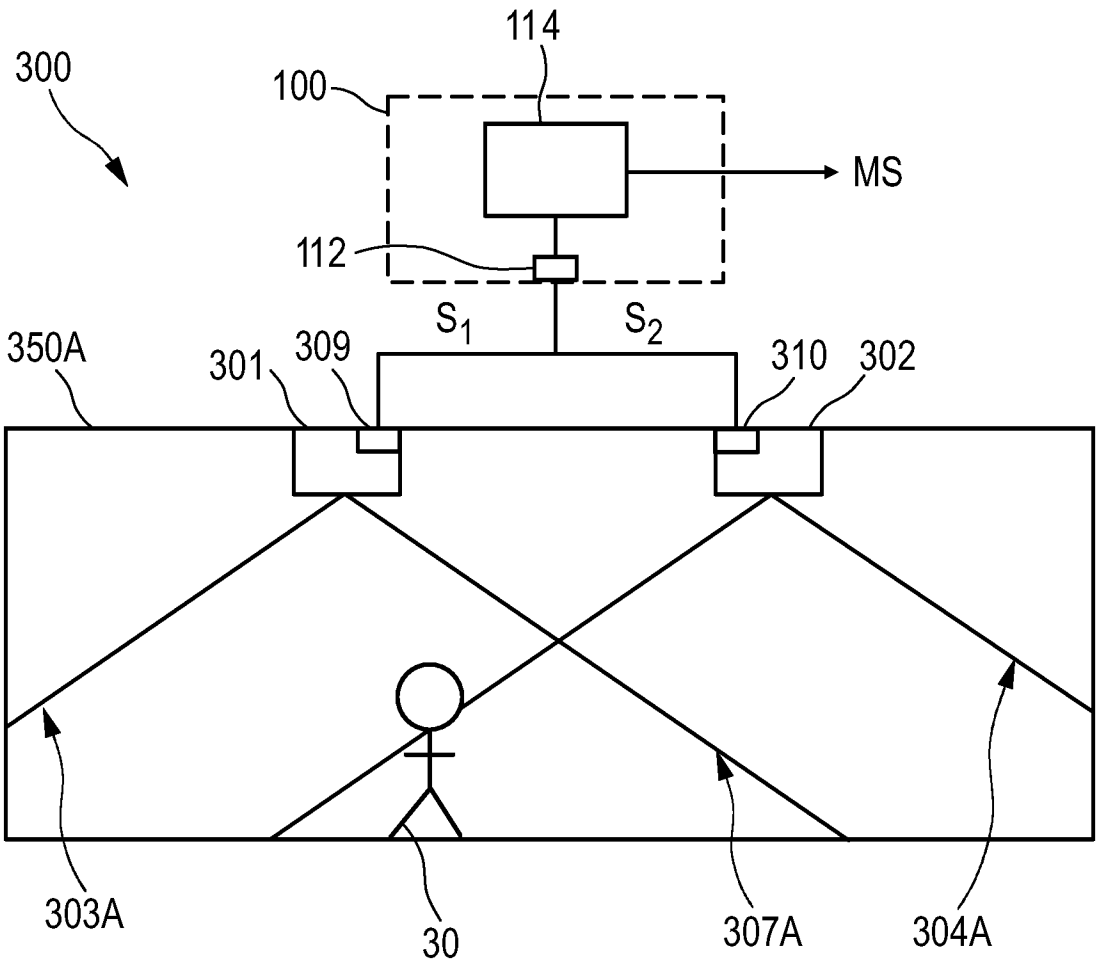


FIG. 3

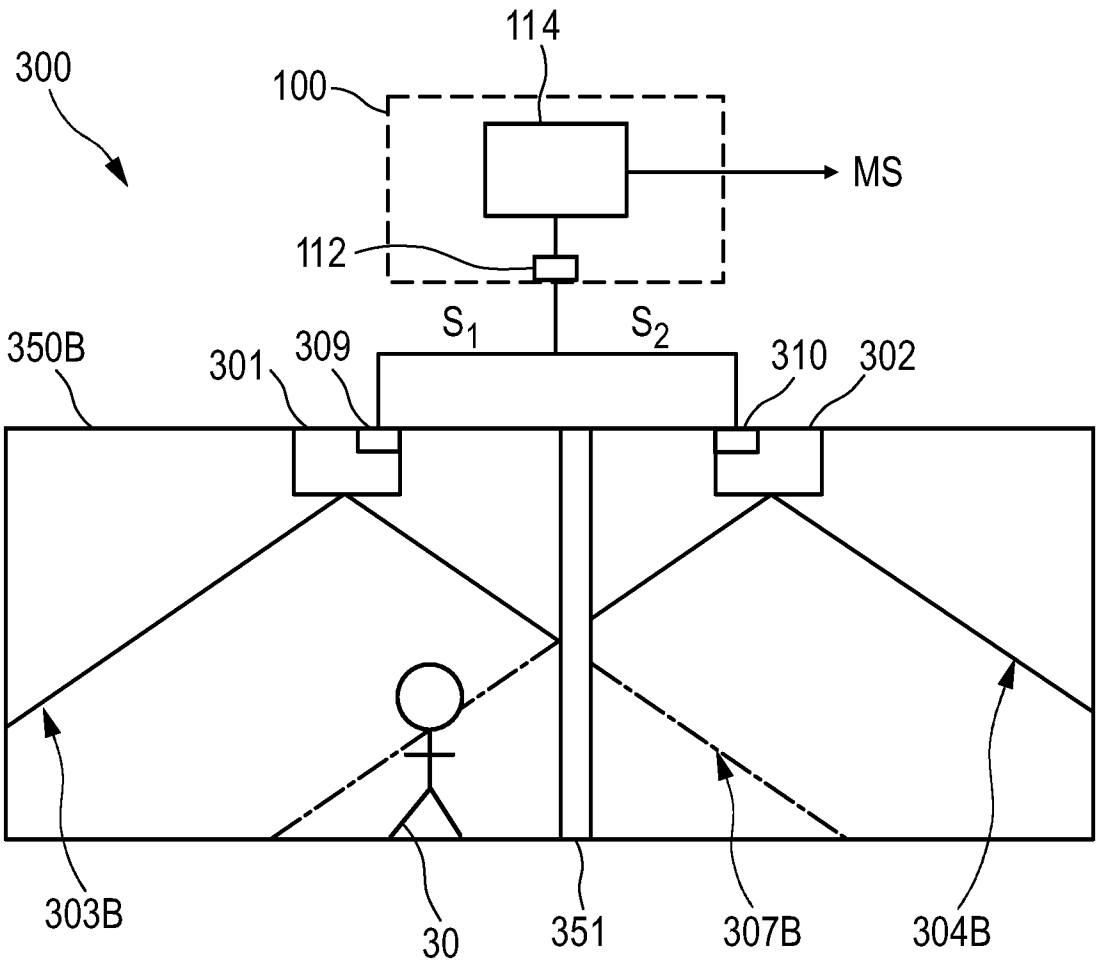

300
114
100
MS
112
S1
S2
350B
301
309
310
302
303B
30
351
307B
304B

FIG. 4

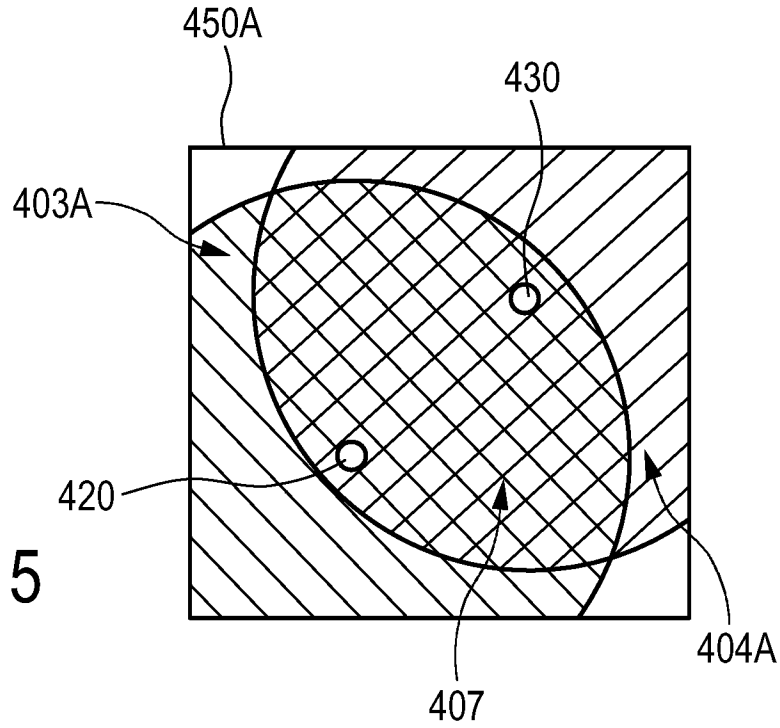


FIG. 5

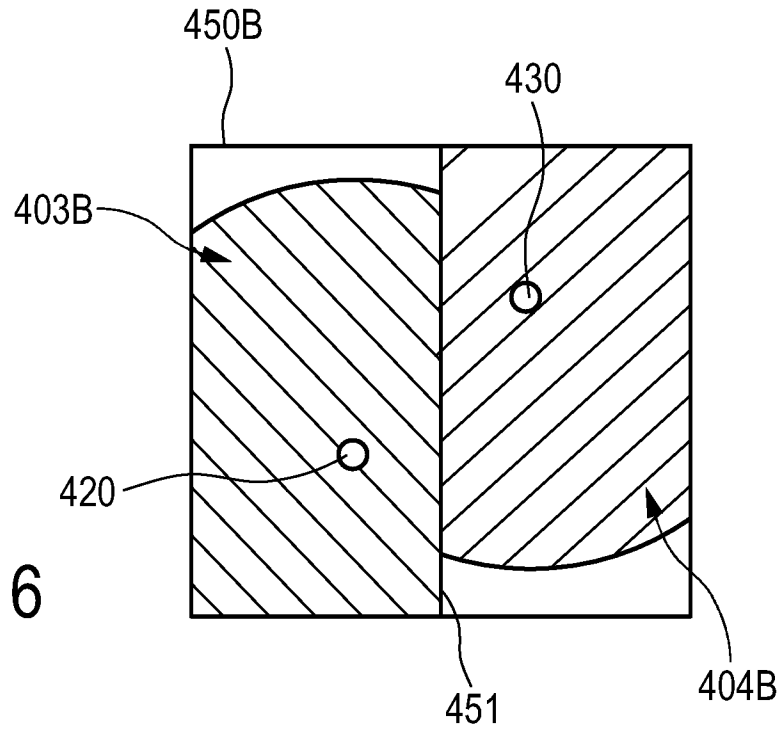


FIG. 6

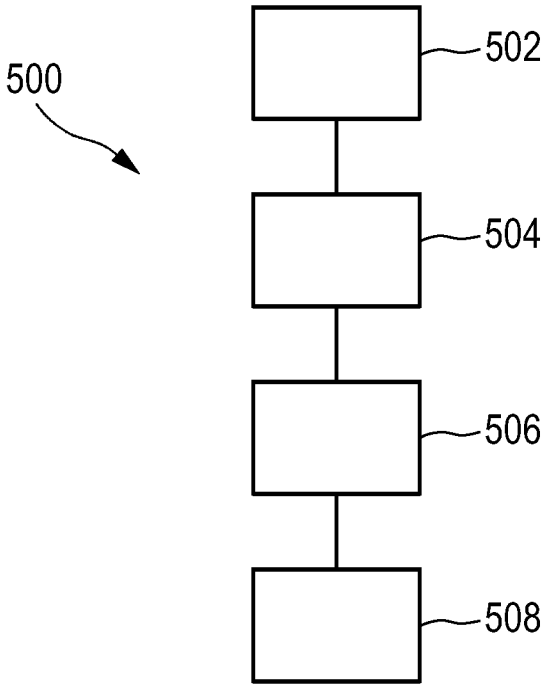


FIG. 7

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/059384

A. CLASSIFICATION OF SUBJECT MATTER
INV. H05B47/105
ADD.

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H05B

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

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

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[X] Further documents are listed in the continuation of Box C.

[X] See patent family annex.

* Special categories of cited documents :

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

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
20 May 2020	04/06/2020

Name and mailing address of the ISA/	Authorized officer
European Patent Office, P.B. 5818 Patentlaan 2 NL - 2280 HV Rijswijk Tel. (+31-70) 340-2040, Fax: (+31-70) 340-3016	Müller, Uta

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Form PCT/ISA/210 (second sheet) (April 2005)

INTERNATIONAL SEARCH REPORT

International application No
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C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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Y	WO 2009/038558 A1 (UNITED TECHNOLOGIES CORP [US]; TOMASTIK ROBERT N [US]) 26 March 2009 (2009-03-26) page 1, lines 15-26	1,12
Y	WO 2010/053469 A1 (UTC FIRE & SECURITY CORP [US]; MEYN SEAN [US] ET AL.) 14 May 2010 (2010-05-14) figure 2	1,12

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