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(54) **METHODS AND ARRANGEMENTS FOR CONTROLLING A BUILDING AUTOMATION SYSTEM ACCORDING TO USER DETECTION**

(57) An arrangement for controlling a building automation system comprises a detection subsystem that produces detection signals (302) indicative of detected users within an area. A control signal generator (303) generates control signals (304) for the building automation system in response to said detection signals (302). A motion detecting part (306) receives indications (307) of moving objects, and the detection subsystem (301)

produces said detection signals (302) at least partly based thereon (307). A radio quality part (308) provides (309) a quality indicator (310) indicative of an observed quality of radio frequency transmissions between nodes. The detection subsystem (301) produces said detection signals (302) also at least partly based on observed changes in the quality indicator (310).

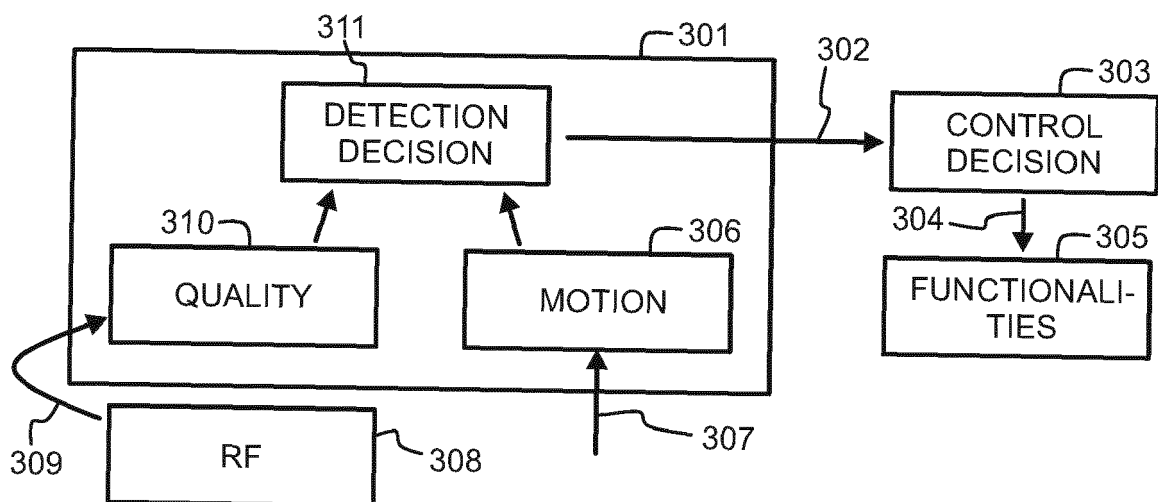


Fig. 3

Description

FIELD OF THE INVENTION

[0001] The invention is related to the field of controlling a building automation system, such as a lighting system for example, according to user detection. In particular, the invention is related to making the system react more accurately and reliably to the detection of users.

BACKGROUND OF THE INVENTION

[0002] User detection is a known way of optimizing the control of a building automation system. As an example, one may consider a lighting system in which the lights are switched on and off and/or dimmed to predetermined brightness levels according to the detection of users. A room or other space in a constructed environment may be equipped with sensors, such as PIR (passive infrared) detectors that detect warm objects such as humans and keep the lights on as long there is anyone in the room. In addition to lighting, other aspects of building automation that may utilize user detection as a controlling factor include - but are not limited to - heating, ventilation, blinds, access control, and elevator control.

[0003] PIR detectors are inexpensive and simple to use, but they are typically not well suited for detecting stationary objects. Often it happens that a PIR detector appropriately detected a person coming into the room and switched on the lights, but subsequently fails to detect that the person remains sitting at a desk in the room, which causes the lights to be dimmed down or switched off prematurely.

[0004] Other approaches to detecting users have been suggested for the purpose of controlling building automation. Some of them rely upon the users almost invariably carrying along a smartphone or other portable electronic device that makes regular radio frequency transmissions. The control arrangement of the building automation system may detect such transmissions in one form or another and draw conclusions concerning either the mere presence of users or even the identity of the detected users. In the latter case the detecting may lead to optimizing the operation of the building automation system according to known personal preferences of the identified users. A downside of using the detected radio frequency transmissions from the users' devices as a controlling factor is related to the relative difficult predictability of what kind of transmissions there will be, at which transmission power, from which locations, and how the radio waves propagate in each room or other space served by the building automation system.

SUMMARY

[0005] It is an objective of the solutions described below to present methods and arrangements for controlling a building automation system according to user detection

in a consistent and reliable manner. It is another objective to achieve such consistent and reliable control with little or no need for additional devices and major functionalities compared to existing systems. Yet another objective is to ensure that the control methods and arrangements adapt themselves to various kinds of building automation systems and their use scenarios.

[0006] These and other advantageous objectives are achieved by examining how changes in the state of occupancy in a space, or in structural features in or close to the space, affect the attenuation of radio signals that carry messages between nodes of the building automation system. The effects on attenuation can be treated as indications of occupancy or as indications of temporary or permanent structural changes that should be taken into account in providing users with the services of the building automation system.

[0007] According to a first aspect, there is provided an arrangement for controlling a building automation system. The arrangement comprises a detection subsystem configured to produce detection signals indicative of detected users within an area. Coupled to the detection subsystem is a control signal generator for generating control signals for one or more functionalities of the building automation system in response to said detection signals. The detection subsystem comprises a motion detecting part configured to receive indications of moving objects detected within at least a part of said area. Said detection subsystem is configured to produce said detection signals at least partly based on said received indications. The arrangement comprises a radio quality part configured to provide the detection subsystem with a quality indicator indicative of an observed quality of radio frequency transmissions between nodes of the building automation system within said area. The detection subsystem is configured to produce said detection signals also at least partly based on observed changes in the quality indicator.

[0008] According to an embodiment, said detection subsystem is configured to operate in at least a first state and a second state, of which the first state differs from the second state in respect of criteria applied in producing detection signals based on observed changes in the quality indicator. Said detection subsystem may then be configured to change from said first state to said second state in response to receiving an indication of at least one moving object detected within at least a part of said area. This involves at least the advantage that false positive and false negative findings of presence can be avoided.

[0009] According to an embodiment, said detection subsystem is configured to change from said second state to said first state in response to the expiry of a time-out without producing further detection signals. This involves at least the advantage that the operation of the system in said two states can automatically adapt itself to intervals of time when there is nobody present in the space.

[0010] According to an embodiment, in the first state

the detection subsystem is configured to apply stricter criteria in producing detection signals based on observed changes in the quality indicator than in the second state. This involves at least the advantage that false positive and false negative findings of presence can be avoided.

[0011] According to an embodiment, the quality indicator is a received signal strength indicator indicative of mean received radio frequency power, a signal to noise ratio indicative of a ratio of received signal power in relation to received noise power, a retransmission indicator indicative of a number of retransmissions required for successfully conveying a message, or a transmission error indicator indicative of the occurrence of errors in received signals. This involves at least the advantage that previously well known functionalities of radio frequency devices can be employed without having to figure out any completely new ways of evaluating the quality of radio frequency transmissions.

[0012] According to an embodiment, the detection subsystem is configured to apply at least one learning algorithm to set the criteria applied in producing detection signals based on observed changes in the quality indicator in at least one of the first and second states. This involves at least the advantage that the operation of the system may adapt itself to particular conditions at the site where the system is installed and used.

[0013] According to an embodiment, the arrangement comprises a history storage configured to store data representing previously received indications of moving objects and/or previously provided quality indicators. The arrangement may then be configured to apply at least one pattern detection algorithm to detect, in the data stored in the history storage, a pattern that preceded a given incident detected by the detection subsystem. The arrangement may be configured to change, based on the detected pattern, the way in which the detection signals are produced, so that any further occurrence of a similar pattern causes detection signals to be produced differently than they were produced within a period preceding said given incident. This involves at least the advantage that the operation of the system may adapt itself to particular conditions at the site where the system is installed and used.

[0014] According to an embodiment, the building automation system is or comprises a lighting system. This involves at least the advantage that the advantageous new features may be harnessed to serve users in a way where this kind of controlled operation of a building automation system is very much appreciated.

[0015] According to an embodiment, the arrangement comprises a luminaire that comprises a sensor module, a radio communications module, a control module, a light source, and a power stage for powering said light source. Said detection subsystem and said control signal generator may then be parts of the control module, which is coupled to control the power stage for controlling an amount of light emitted by the light source. The control module may be coupled to receive the indications of mov-

ing objects from said sensor module. Said radio communications module may be coupled to provide the control module with said quality indicator. This involves at least the advantages that hardware that is in any case present in devices of lighting systems can be reused for the new purpose in a practical and economical way.

[0016] According to an embodiment, the arrangement comprises a luminaire and a sensor device as separate parts capable of communicating with each other. The luminaire may then comprise a light source and a power stage for powering said light source. The arrangement may comprise a radio communications module and a control module in either the sensor device or in the luminaire. Said detection subsystem and said control signal generator may be parts of the control module, which is configured to control the power stage for controlling an amount of light emitted by the light source. Said control module may be configured to receive the indications of moving objects from said sensor device, and said radio communications module may be configured to provide the control module with said quality indicator. This involves at least the advantage that one may use hardware of a lighting system in a versatile and easily adaptable way.

[0017] According to an embodiment, the arrangement is a network that comprises at least one sensor device, at least one luminaire, and at least one controller as separate parts capable of communicating with each other. Said detection subsystem and said control signal generator may then be parts of the controller, which controller may be configured to receive the indications of moving objects from said at least one sensor device. Said controller may also be configured to receive the quality indicator from a radio communications module of at least one of: the at least one sensor device, the at least one luminaire, the controller itself. This involves at least the advantage that the arrangement may be made scalable to cover spaces of very different sizes.

[0018] According to a second aspect, there is provided a method for controlling a building automation system. The method comprises receiving indications of moving objects detected within at least a part of an area, producing detection signals indicative of detected users within an area at least partly based on said received indications, and generating control signals for one or more functionalities of the building automation system in response to said detection signals. The method comprises providing the producing of detection signals with a quality indicator indicative of an observed quality of radio frequency transmissions between nodes of the building automation system within said area, so that said producing of said detection signals is also at least partly based on observed changes in the quality indicator.

[0019] According to an embodiment, the method comprises operating in at least a first state and a second state, of which the first state differs from the second state in respect of criteria applied in producing detection signals based on observed changes in the quality indicator.

The method may then comprise changing from said first state to said second state in response to receiving an indication of at least one moving object detected within at least a part of said area. This involves at least the advantage that false positive and false negative findings of presence can be avoided.

[0020] According to an embodiment, the method comprises changing from said second state to said first state in response to the expiry of a timeout without producing further detection signals. This involves at least the advantage that the operation of the system in said two states can automatically adapt itself to intervals of time when there is nobody present in the space.

[0021] According to an embodiment, in the first state stricter criteria are applied in producing detection signals based on observed changes in the quality indicator than in the second state. This involves at least the advantage that false positive and false negative findings of presence can be avoided.

BRIEF DESCRIPTION OF THE DRAWINGS

[0022] The accompanying drawings, which are included to provide a further understanding of the invention and constitute a part of this specification, illustrate embodiments of the invention and together with the description help to explain the principles of the invention. In the drawings:

Figure 1 illustrates radio communications between two nodes without any attenuating body,
figure 2 illustrates radio communications between two nodes in the presence of an attenuating body,
figure 3 illustrates an arrangement,
figure 4 illustrates an example of a time series of a quality indicator,
figure 5 illustrates an example of a time series of a quality indicator,
figure 6 illustrates an example of making detection decisions,
figure 7 illustrates an arrangement or a method in the form of a state diagram,
figure 8 illustrates radio communications between two nodes without a movable obstacle therebetween,
figure 9 illustrates radio communications between two nodes with a movable obstacle therebetween,
figure 10 illustrates an example of making detection decisions,
figure 11 illustrates an arrangement,
figure 12 illustrates an example of controlled lighting intensity, and
figure 13 illustrates an arrangement.

DETAILED DESCRIPTION

[0023] Fig. 1 illustrates schematically a pair of nodes of a building automation system. The first node 101

makes a radio frequency transmission, which the second node 102 receives. A radio quality part in the second node 102 may produce one or more quality indicators indicative of an observed quality of the received radio frequency transmission. Such capability of producing one or more quality indicators is schematically shown in fig. 1 with the dial 103.

[0024] A large variety of quality indicators are known from the field of wireless transmission of signals. For example, the quality indicator may be a received signal strength indicator (RSSI) indicative of mean received radio frequency power. Another example of a quality indicator is a signal to noise ratio (S/N ratio) indicative of a ratio of received signal power in relation to received noise power. Another example of a quality indicator is a retransmission indicator indicative of a number of retransmissions required for successfully conveying a message. Yet another example of a quality indicator is a transmission error indicator indicative of the occurrence of errors in received signals. For the purpose of the present description, the actual character of the quality indicator is not important, as long as it can be expected to be somewhat consistently dependent on the presence of attenuating bodies and/or other wireless transmitters. In particular, one may expect that attenuating bodies and/or other wireless transmitters may temporarily sojourn close enough to at least one of the first node 101 and second node 102 so that their presence may significantly affect the observed quality of radio transmissions between said nodes.

[0025] The last-mentioned is schematically illustrated in fig. 2. An attenuating body, such as a person 201, has appeared in the space between the first node 101 and the second node 102. Some of the radio frequency power that conveys the radio frequency transmission from the first node 101 to the second node 102 becomes attenuated in the attenuating body. As a result, the second node 102 receives less radio frequency power, which in turn causes it to observe a lower quality of the received radio frequency transmission.

[0026] In the case of RSSI, the lower quality of the received radio frequency transmission is simply a smaller value produced by the RSSI measurement. If S/N ratio is used as a quality indicator, the second node 102 may similarly observe a lower value of the S/N ratio. If the quality indicator involves some aspect of a retransmission indicator, the lower quality of the received radio frequency transmission may be observed as an increasing number of retransmissions that were required to get a certain amount of information correctly conveyed. If the quality indicator is an error indicator indicative of the occurrence of errors in received signals, its value too can be expected to increase in the presence of an attenuating body in the space in which the radio frequency transmission propagates. In an analogous manner, any properly defined quality indicator may reveal important information about whether the space close to the first and second nodes is free of possible temporarily appearing attenu-

ating bodies or whether there are one or more such temporarily appearing attenuating bodies present.

[0027] Attenuation caused by solid bodies is not the only mechanism that may cause temporary weakening in the observed quality of radio frequency transmissions. Simultaneous transmissions by some other radio frequency transmitter may be observed as interference in the intended radio frequency communications between the nodes 101 and 102. A node may observe such interference for example as a decreasing S/N ratio, an increasing number of required retransmissions, an increasing number of errors detected in a received signal, and/or some other noticeable effect on a quality indicator.

[0028] While producing a quality indicator indicative of an observed quality of radio frequency transmissions between nodes is most straightforward in a receiving node, it is not restricted to that. Also a transmitting node may produce - or at least become aware of - such a quality indicator and utilize it in its operation. As an example, if the quality indicator is a retransmission indicator, the transmitting node may produce it of its own initiative by noting how many retransmissions it had to make. The transmitting node may also become aware of any quality indicator originally produced by a receiving node if the receiving node e.g. transmits the quality indicator in acknowledgement messages or the like.

[0029] An important conclusion of the considerations above is that fluctuations in a quality indicator indicative of an observed quality of radio frequency transmissions may be of assistance to nodes of a building automation system in detecting the presence of users and/or other temporarily occurring changes in the environment where the radio frequency transmissions propagate. In many cases, if the nodes of a building automation system are capable of exchanging radio frequency transmissions, they are programmed to do so on a regular basis or at least according to some deterministic schedule. There will probably be periods of time, such as night times in an ordinary office of daytime workers, when the space around the nodes will remain empty of users. Also other kinds of changes in the space, like the opening and closing of doors and divider curtains, will not occur. If the nodes exchange radio transmissions also during such periods, they may observe relatively little variation in the quality indicator around what may be called a base level of the quality indicator. Significant detected variations of the quality indicator from the base level may then be considered as a form of presence detection.

[0030] In the development work leading to the present invention, it was found that solely the detection of variations of the quality indicator may as such be a relatively error-prone basis for deducing e.g. the changing needs of light and/or other service produced by a building automation system. On the other hand, solely the detection of motion may also be an error-prone basis for said deducing, because a user may remain stationary in a space and need the services of the building automation system even if said user is not moving. As a more advanced

approach, the detection of variations of the quality indicator may be combined with motion detecting, for example so that detected motion is used as a trigger for changing the way in which the subsequently observed quality indicator values are interpreted.

[0031] Fig. 3 illustrates an example of an arrangement for controlling a building automation system. The arrangement comprises a detection subsystem 301, which is configured to produce detection signals 302 indicative of detected users within (and/or close to) an area. Coupled to the detection subsystem 301 is a control signal generator 303 for generating control signals 304 for one or more functionalities 305 of the building automation system. The control signal generator 303 generates the control signals 304 at least partly in response to the detection signals 302. As a non-limiting example, the functionalities 305 may comprise lighting within said area, so that the control signals 304 go from the control signal generator 303 to one or more luminaires capable of illuminating said area. The control signal generator 303 may then use the control signals 304 to switch the luminaire(s) on and off, and/or dim the luminaire(s) to appropriate levels, depending on what the detection signals 302 reveal about users having been detected within (and/or close to) the area.

[0032] The detection subsystem 301 comprises a motion detecting part 306 that is configured to receive indications 307 of moving objects detected within at least a part of said area. According to an embodiment, the motion detecting part 306 may comprise a sensor, such as a PIR detector, in which case the indications 307 consist of infrared radiation emitted by moving objects within (and/or close to) the area. According to another embodiment, the motion detecting part 306 may comprise a receiver coupled to receive signals from a remote sensor or other external device, in which case said signals constitute the indications 307. The detection subsystem 301 is configured to produce the detection signals 302 at least partly based on the received indications 307.

[0033] The arrangement shown in fig. 3 comprises a radio quality part 308 that is configured to provide, as shown with the arrow 309, the detection subsystem 301 with a quality indicator 310. As described above, the quality indicator 310 is indicative of an observed quality of radio frequency transmissions between nodes of the building automation system within the area. The detection subsystem 301 is configured to produce the detection signals 302 not only based on the received indications 307 but also at least partly based on observed changes in the quality indicator 310.

[0034] The radio quality part 308 is shown in fig. 3 as a functionality external to the detection subsystem 301. This is because a node of a building automation system may have its wireless communications capabilities concentrated in a radio communications module, which forms a subsystem of its own in the node or which may constitute an entity external to the node. The actual measurement of an RSSI, S/N ratio, and/or other quality

indicator may take place in such a radio communications module, which just delivers measured values of the quality indicator to the detection subsystem 301. Some storing, averaging, and/or other kind of further processing of the quality indicator may take place in the detection subsystem 301, which explains the separate blocks 308 and 310 in fig. 3. However, this is not a limitation, and the radio quality part 308 (or even the whole radio communications module, if one exists) may be an integral part of the detection subsystem 301. Alternatively, even the storing, averaging, and/or other kind of further processing of the quality indicator represented by block 310 may take place outside the detection subsystem 301, with only the completed results delivered to a decision-making block 311 of the detection system 301 that also receives the output of the motion detecting part 306.

[0035] Figs. 4 and 5 illustrate schematically two cases where a quality indicator is considered as a function of time. The quality indicator is here assumed to be a scalar value, so a graph can be used to describe it in a two-dimensional coordinate system. Another assumption is that the quality indicator has been found to vary within a range shown as the hatched horizontal band 401 under "no presence" conditions, i.e. when there are no users or other attenuating bodies (or other quality-weakening factors) present in the monitored space.

[0036] In fig. 4, between times 402 and 403, a period occurs during which the value of the quality indicator varies clearly in a wider range than the "no presence" range 401. However, also during this period, some readings of the quality indicator are within the "no presence" range 401. In contrast, in fig. 5 between times 502 and 503, the value of the quality indicator remains clearly outside the "no presence" range 401. Almost immediately after time 502, the value of the quality indicator drops below a threshold value 504 and remains there until time 503.

[0037] Figs. 4 and 5 illustrate the challenges that might apply if the detection subsystem 301 of fig. 3 utilised the quality indicator 310 as a sole basis for making detection decisions. While the temporary presence of a user in the monitored space may cause a change in the quality indicator, the change may not always be clear enough to serve as a reliable basis for presence detection as such. It must be noted that while the quality indicator will mostly remain within the "no presence" range 401 when no users are present, random factors like interfering radio transmissions may give rise to occasional quality factor readings outside said range. Mistakes could be made in both directions, i.e. both false positives (assuming the presence of a user or other attenuating body when none is actually present) and false negatives (concluding that no user or other attenuating body is present even if actually there is one).

[0038] The occurrence and disadvantageous effect of mistakes can be greatly reduced by producing, as explained above with reference to fig. 3, the detection signals 302 at least partly based on the received indications 307 that correspond to detected motion. In particular, one

may use detected motion to change, at least temporarily, the criteria used to decide, whether an observed behaviour of the quality indicator should be interpreted as a sign of presence.

[0039] An example of the last-mentioned is explained in the following with reference to figs. 6 and 7. In this example, the decision-making block 311 of the detection system receives inputs from the motion detecting part 306; these may be for example the signals produced by a PIR detector. In fig. 6 the decision-making block 311 comprises a motion comparison functionality 601, which compares the inputs received from the motion detecting part 306 to at least one motion criterion 602. The purpose of the motion comparison functionality 601 is to enable making motion decisions 603, i.e. deciding whether the inputs received from the motion detecting part 306 should actually be interpreted as signs of detected motion. As such, the motion comparison functionality 601 and motion criteria 602 may not be needed, if the inputs received from the motion detecting part 306 are reliable enough as such. In such a case, the motion decisions 603 may simply follow what the motion detecting part 306 tells about motion having been detected or not.

[0040] The decision-making block 311 receives also the quality indicator 310 as an input. The received quality indicator goes to a quality comparison functionality 604, which compares it to at least one quality criterion 605. Based on this comparison, a quality decision 606 is made. Similar to the motion decision 603, the quality decision 606 is about whether the current quality indicator 310 should be interpreted as a sign of presence. With reference to figs. 4 and 5, the quality comparison functionality 604 may for example compare the current quality indicator 310 to the limits of the "no-presence" range 401 and/or to the threshold value 504.

[0041] Additionally, in the example shown in fig. 3, the decision-making block 311 comprises a timer 607, based on which the decision-making block 311 may make timer decisions 608. An example of a timer decision is a case in which neither motion nor presence has been detected after some most recent detection. When the timer 607 reaches a predetermined delay value, the decision-making block 311 may decide that there is no reason to keep the lights on (or provide some other service of the building automation system) anymore.

[0042] The outputs of blocks 603, 606, and 608 are all coupled together to form the output of the decision-making block 311 in fig. 3. Any of them may thus be the source of detection signals 302.

[0043] Fig. 7 is a state diagram that illustrates an example of how a detection subsystem may operate. According to fig. 7, the detection subsystem is configured to operate in at least a first state 701 and a second state 703. The first state 701 differs from the second state 703 in respect of the criteria applied in producing the detection signals 302. In particular, this means those criteria 605 that are applied in producing the detection signals 302 based on observed changes in the quality indicator 310.

The detection subsystem is configured to change from the first state 701 to the second state 703 in response to receiving an indication of at least one moving object detected within at least part of the monitored area.

[0044] In fig. 7, said receiving of an indication of at least one moving object is illustrated as the oval 702. The transition from the first state 701 to the second state 703 goes through and intermediate step 704, which comprises so-called sensitizing. In fig. 7 the quality indicator is assumed to be the RSSI, so the intermediate step 704 comprises sensitizing with respect to RSSI. This is a special case that represents the more general concept of changing the criteria applied in producing the detection signals based on observed changes in the quality indicator 310.

[0045] The concept of "sensitizing" may be considered by briefly referring back to figs. 4 and 5. Before detecting any motion, i.e. when operating in the first state 701 of fig. 7, only a significant change in the quality indicator (such as falling below the threshold value 504 in fig. 5, and/or remaining below such a threshold value for a pre-defined minimum duration of time) could be considered alone as a sufficient indicator of presence. This ensures that random short-term excursions that the quality indicator may make outside the "no-presence" range 401 are not incorrectly interpreted to indicate presence. After detecting motion, i.e. when operating in the second state 703 of fig. 7, the detection subsystem is more sensitive to changes in the quality indicator in interpreting these as signs of presence. This ensures that even if the quality indicator is only slightly and/or only intermittently outside the "no-presence" range 401, like between moments 402 and 403 in fig. 4, this is still interpreted to indicate presence and not incorrectly interpreted as no presence.

[0046] In general, the concept of sensitizing may be described so that in the first state 701 the detection subsystem 301 is configured to apply stricter criteria 605 in producing detection signals 302 based on observed changes in the quality indicator 310 than in the second state 703.

[0047] In the embodiment of fig. 7, the transition from the first state 701 to the second state 703 may also take place in response to a so-called RSSI trigger 705. This means that a significant change in the quality indicator (such as falling below the threshold value 504 in fig. 5, and/or remaining below such a threshold value for a pre-defined minimum duration of time) is considered alone as a sufficient indicator of presence. As shown in fig. 7, it is possible to make also the RSSI trigger 705 cause sensitizing at step 704. Compared to fig. 5, where the quality indicator stays below the threshold 504 throughout the period between times 502 and 503, sensitizing in step 704 could mean that after the initial RSSI trigger, one would not require the RSSI (or other quality indicator) to stay strictly below the threshold to interpret it as a sign of presence. As sensitizing makes the detection subsystem more sensitive to changes in the quality indicator in interpreting these as signs of presence, it would suffice

that the RSSI (or other quality indicator) fulfils the sensitized criteria.

[0048] As also shown in fig. 7, if further detections of motion 702 are made while operating in the second state 703, these cause just trivially returning back to the second state 703. Similarly, further detections of presence (through further RSSI triggers 705, interpreted in light of the previously executed sensitizing in step 704) while operating in the second state 703 cause just trivially returning back to the second state 703.

[0049] A timer may be reset at the initial transition from the first state 701 to the second state 703, and thereafter as a response to each trivial return to the second state through further detections of motion and/or further RSSI triggers while in the second state 703. The purpose of such a timer, if used, is to measure the time since the last time an indication was obtained about a user being present and needing the services of the building automation system in the area concerned. A timeout may be defined, setting the maximum period of time for the duration of which said services are kept fully on without further indications of presence. As illustrated by the timeout criterion 706 in fig. 7, the detection subsystem may be configured to change from the second state 703 to the first state 701 in response to the expiry of the timeout without further detection signals having been produced.

[0050] Figs. 8 and 9 illustrate a possible scenario in which the nodes 101 and 102 of the building automation system have been installed in a common space, which however has a movable divider curtain 801 that can be drawn aside as in fig. 8 or deployed between the nodes as in fig. 9. The material of the divider curtain 801 attenuates radio signals to a certain extent. The divider curtain 801 of figs. 8 and 9 serves as an example of the more general concept of a structural obstacle or movable structure in (or at a perimeter of) the space served by the nodes 101 and 102. While it represents temporary presence of attenuating material on the radio path somewhat similar to one or more users in the space, and consequently may lead to an observable change in the quality indicator, it may be preferable to make the nodes 101 and 102 react differently in the situation of figs. 8 and 9 than in that of figs. 1 and 2. For example, while the situation of fig. 2 might call for keeping on the lights at both nodes 101 and 102 because there is a user in the common space, the situation of fig. 9 might call for controlling the lights at nodes 101 and 102 separately, depending on whether users are detected on the left and/or right side of the deployed divider curtain 801.

[0051] A structural obstacle such as the divider curtain 801 can be assumed to cause a relatively constant change in the propagation conditions of radio signals. Consequently, corresponding to the difference between the situations of fig. 8 and fig. 9 and assuming that no other changes occurred, the second node 102 can be assumed to observe a relatively constant change from one relatively narrow range of quality indicator values to another relatively narrow range of quality indicator val-

ues. If, instead of deploying the divider curtain 801, a user had come to the space served by the nodes 101 and 102, the observed change in the quality indicator could be assumed to have a more random nature.

[0052] It is possible to deliberately train the detection subsystem(s) controlling the nodes 101 and 102 to more accurately recognize, what kind of changes in the quality indicator are due to temporary structural changes (such as deploying a divider curtain). This may involve for example downloading and analysing stored quality indicator measurements from at least one of the nodes after repeatedly making the temporary structural changes, noting the effect of such structural changes, and uploading corresponding information in the form of programmed threshold values into the nodes.

[0053] In order to prepare for situations like that in figs. 8 and 9, and also for many other purposes, it may be advantageous to configure the detection system to apply at least one learning algorithm. The purpose of a learning algorithm may be to set the criteria applied in producing detection signals based on observed changes in the quality indicator in at least one of the first and second states 701 and 703 described above with reference to fig. 7.

[0054] For example, the learning algorithm may be one that monitors for changes in the quality indicator that appear to have a relatively regular form, such as a change from one relatively narrow range to another relatively narrow range. The learning algorithm may additionally monitor for any further regularities associated with such changes, like for their repeated occurrence at roughly the same time of day. Such further regularities may be of assistance in correctly recognizing similar changes in the future. Based on detected changes in the quality indicator that appear to have a relatively regular form and that may appear to occur with certain regularity in time, the learning algorithm may e.g. change thresholds applied in making decisions, or otherwise affect the operation of the arrangement.

[0055] Fig. 10 illustrates schematically another example case in which a learning algorithm may be utilized. In general, even without any learning algorithms involved, the timeout up to which the timer 607 counts before producing a timer decision 608 may depend on whether the most recent decision about detected user presence was a motion decision 603 or a quality decision 606. As another example, a relatively simple way of learning may be applied to increase the dimming timeout in cases where a timer decision to start dimming the lights is found to frequently result in a subsequent motion and/or quality decision to switch the lights back on. Namely, the repeated occurrences of such decision sequences may indicate that the dimming timeout is too short, so that users sitting relatively still in the space have insufficient time to cause enough further motion- and/or quality-based detections with sufficient probability and must start waving a hand or otherwise trigger the detection subsystem when they notice that lights begin to dim down.

[0056] Fig. 11 illustrates a systematic approach to construct an arrangement capable of utilizing one or more learning algorithms. Fig. 12 illustrates an example of operating such an arrangement in the relatively simple example of learning described above. In fig. 12, the building automation system is assumed to control lighting, the brightness of which is shown in the vertical axis of the two-dimensional coordinate system. The horizontal axis is time.

[0057] The arrangement of fig. 11 comprises a history storage 1101 that is configured to store data representing previously received indications 307 of moving objects and/or previously provided quality indicators 310. The arrangement is configured to apply at least one pattern detection algorithm, generally represented by the learning algorithms block 1102, to detect, in the data stored in the history storage 1101, a pattern that preceded a given incident detected by the detection subsystem.

[0058] Compared to fig. 12, one detected incident (such as motion or a sufficiently large change in a quality indicator) caused switching the lights to full brightness at moment 1201. At moment 1202 a decision was made to start dimming down the lights. Very shortly thereafter, at moment 1203, another incident (such as motion or a sufficiently large change in a quality indicator) was detected, causing the lights to be switched to full brightness again. Obviously, while the decision to start dimming down the lights at moment 1202 was based on not making further detections during a preceding timeout period 1204, that decision was incorrect, because someone was still present in the space to be illuminated and had to wave a hand at moment 1203 to stop the dimming and to switch the lights fully on again.

[0059] Now, as data representing received indications of moving objects received and/or quality indicators provided during the timeout period 1204 remains stored in the history storage 1101, the arrangement may apply said pattern detection algorithm to detect any pattern that preceded the "hand-waving" incident at moment 1203. For example, the data in the history storage 1101 may reveal that there were quality indicators that deviated from a "no presence" range, although not enough to be considered as a sign of user presence. The arrangement may be configured to change, based on the detected pattern, the way in which the detection signals 302 are produced. The meaning is to make such a change that any further occurrence of a similar pattern causes detection signals 302 to be produced differently than they were produced within the period 1204 that preceded the incident detected at moment 1203. For example, the arrangement may lower the threshold of considering a certain provided quality indicator as a sign of user presence when the arrangement is operating in the second state 703 shown in the state diagram of fig. 7.

[0060] As such, the building automation system may involve any aspect of building automation, such as lighting, heating, ventilation, blinds, access control, elevator control, or the like. As a particular example, the building

automation system may be or comprise a lighting system. In such a case, the various parts of the arrangement described above may be located in the hardware elements of the lighting system in various ways.

[0061] According to a first example, the arrangement may comprise a luminaire, which in turn comprises a sensor module, a radio communications module, a control module, a light source, and a power stage for powering said light source. The detection subsystem 301 and the control signal generator 303 shown in fig. 3 may be parts of the control module, which is coupled to control the power stage for controlling an amount of light emitted by the light source. Such a control module may then be coupled to receive the indications 307 of moving objects from the sensor module. The radio communications module may be coupled to provide the control module with the quality indicators 310.

[0062] According to a second example, the arrangement may comprise a luminaire and a sensor device as separate parts capable of communicating with each other. The luminaire may then comprise a light source and a power stage for powering said light source. The arrangement may comprise a radio communications module and a control module in either the sensor device or in the luminaire. The detection subsystem 301 and the control signal generator 303 may be parts of such a control module, which is configured to control the power stage for controlling an amount of light emitted by the light source. The control module may also be configured to receive the indications 307 of moving objects from said sensor device, and said radio communications module may be configured to provide the control module with the quality indicators 310.

[0063] Yet another example is shown in fig. 13. In this example, the arrangement is a network that comprises at least one sensor device 1301, at least one luminaire 1302, and at least one controller 1303 as separate parts capable of communicating with each other. The network may also comprise one or more switches 1304 or other user-operable control means. The detection subsystem 301 and the control signal generator 303 may be parts of the controller 1303. The controller 1303 may be configured to receive the indications 307 of moving objects from the at least one sensor device 1301, and to receive the quality indicator 310 from a radio communications module of the at least one sensor device 1301, the at least one luminaire 1302, the controller 1303 itself, or any combination of these.

[0064] It is obvious to a person skilled in the art that with the advancement of technology, the basic idea of the invention may be implemented in various ways. The invention and its embodiments are thus not limited to the examples described above, instead they may vary within the scope of the claims.

Claims

1. An arrangement for controlling a building automation system, the arrangement comprising:

- a detection subsystem (301) configured to produce detection signals (302) indicative of detected users within an area, and
- coupled to the detection subsystem (301), a control signal generator (303) for generating control signals (304) for one or more functionalities (305) of the building automation system in response to said detection signals (302);
- wherein the detection subsystem (301) comprises a motion detecting part (306) configured to receive indications (307) of moving objects detected within at least a part of said area,
- and wherein said detection subsystem (301) is configured to produce said detection signals (302) at least partly based on said received indications (307);

characterized in that:

- the arrangement comprises a radio quality part (308) configured to provide (309) the detection subsystem (301) with a quality indicator (310) indicative of an observed quality of radio frequency transmissions between nodes of the building automation system within said area, and
- the detection subsystem (301) is configured to produce said detection signals (302) also at least partly based on observed changes in the quality indicator (310) .

2. An arrangement according to claim 1, wherein:

- said detection subsystem (301) is configured to operate in at least a first state (701) and a second state (703), of which the first state (701) differs from the second state (703) in respect of criteria (605) applied in producing detection signals (302) based on observed changes in the quality indicator (310), and
- said detection subsystem (301) is configured to change from said first state (701) to said second state (703) in response to receiving an indication (307) of at least one moving object detected within at least a part of said area.

3. An arrangement according to claim 2, wherein said detection subsystem (301) is configured to change from said second state (703) to said first state (701) in response to the expiry of a timeout (706) without producing further detection signals (302) .

4. An arrangement according to any of claims 2 or 3,

wherein in the first state (701) the detection subsystem (301) is configured to apply stricter criteria (605) in producing detection signals (302) based on observed changes in the quality indicator (310) than in the second state (703).

5. An arrangement according to any of the preceding claims, wherein the quality indicator (310) is one of:

- a received signal strength indicator indicative of mean received radio frequency power,
- a signal to noise ratio indicative of a ratio of received signal power in relation to received noise power,
- a retransmission indicator indicative of a number of retransmissions required for successfully conveying a message,
- a transmission error indicator indicative of the occurrence of errors in received signals.

6. An arrangement according to any of the preceding claims, wherein the detection subsystem (301) is configured to apply at least one learning algorithm (1102) to set the criteria (605) applied in producing detection signals (302) based on observed changes in the quality indicator (310) in at least one of the first (701) and second (703) states.

7. An arrangement according to any of the preceding claims, wherein:

- the arrangement comprises a history storage (1101) configured to store data representing at least one of: previously received indications (307) of moving objects, previously provided quality indicators (310),
- the arrangement is configured to apply at least one pattern detection algorithm (1102) to detect, in the data stored in the history storage, a pattern that preceded a given incident (1203) detected by the detection subsystem, and
- the arrangement is configured to change, based on the detected pattern, the way in which the detection signals (302) are produced, so that any further occurrence of a similar pattern causes detection signals (302) to be produced differently than they were produced within a period (1204) preceding said given incident.

8. An arrangement according to any of the preceding claims, wherein the building automation system is or comprises a lighting system.

9. An arrangement according to claim 8, wherein:

- the arrangement comprises a luminaire,
- the luminaire comprises a sensor module, a radio communications module, a control mod-

ule, a light source, and a power stage for powering said light source,

- said detection subsystem (301) and said control signal generator (303) are parts of the control module, which is coupled to control the power stage for controlling an amount of light emitted by the light source,
- said control module is coupled to receive the indications (307) of moving objects from said sensor module, and
- said radio communications module is coupled to provide the control module with said quality indicator (310).

10. An arrangement according to claim 8, wherein:

- the arrangement comprises a luminaire and a sensor device as separate parts capable of communicating with each other,
- the luminaire comprises a light source and a power stage for powering said light source,
- the arrangement comprises a radio communications module and a control module in either the sensor device or in the luminaire,
- said detection subsystem (301) and said control signal generator (303) are parts of the control module, which is configured to control the power stage for controlling an amount of light emitted by the light source,
- said control module is configured to receive the indications (307) of moving objects from said sensor device, and
- said radio communications module is configured to provide the control module with said quality indicator (310).

11. An arrangement according to claim 8, wherein:

- the arrangement is a network that comprises at least one sensor device (1301), at least one luminaire (1302), and at least one controller (1303) as separate parts capable of communicating with each other,
- said detection subsystem (301) and said control signal generator (303) are parts of the controller (1303),
- said controller (1303) is configured to receive the indications (307) of moving objects from said at least one sensor device (1301),
- said controller (1303) is configured to receive the quality indicator (310) from a radio communications module of at least one of: the at least one sensor device (1301), the at least one luminaire (1302), the controller (1303) itself.

12. A method for controlling a building automation system, the method comprising:

- receiving indications (307) of moving objects detected within at least a part of an area,
 - producing detection signals (302) indicative of detected users within an area at least partly based on said received indications (307), and 5
 - generating control signals (304) for one or more functionalities (305) of the building automation system in response to said detection signals (302); **characterized in that** the method comprises providing the producing of detection signals (302) with a quality indicator (310) indicative 10
 of an observed quality of radio frequency transmissions between nodes of the building automation system within said area, so that said producing of said detection signals (302) is also at 15
 least partly based on observed changes in the quality indicator (310).

13. A method according to claim 12, comprising:

- operating in at least a first state (701) and a second state (703), of which the first state (701) differs from the second state (703) in respect of criteria (605) applied in producing detection signals (302) based on observed changes in the 20
 quality indicator (310), and 25
 - changing from said first state (701) to said second state (703) in response to receiving an indication (307) of at least one moving object detected within at least a part of said area. 30

14. A method according to claim 13, comprising changing from said second state (703) to said first state (701) in response to the expiry of a timeout (706) without producing further detection signals. 35

15. A method according to any of claims 13 or 14, wherein in the first state (701) stricter criteria (605) are applied in producing detection signals (302) based on observed changes in the quality indicator (310) 40
 than in the second state (703). 45

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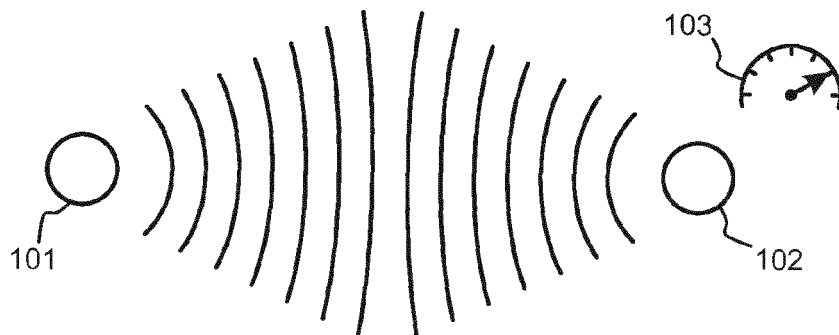


Fig. 1

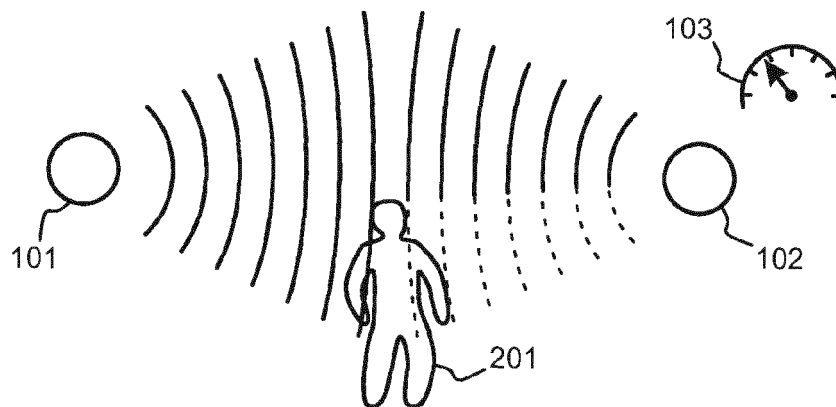


Fig. 2

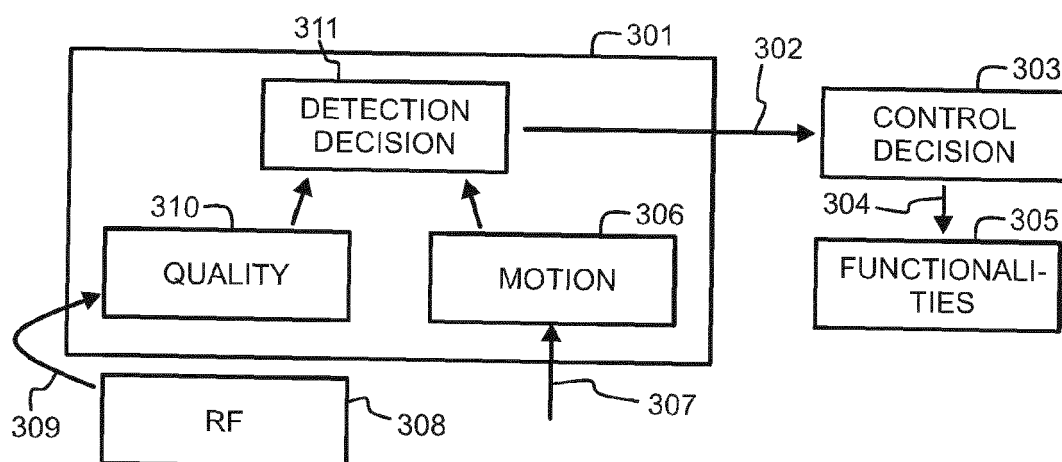


Fig. 3

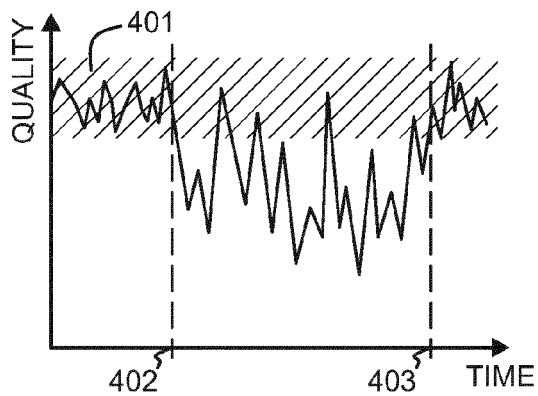


Fig. 4

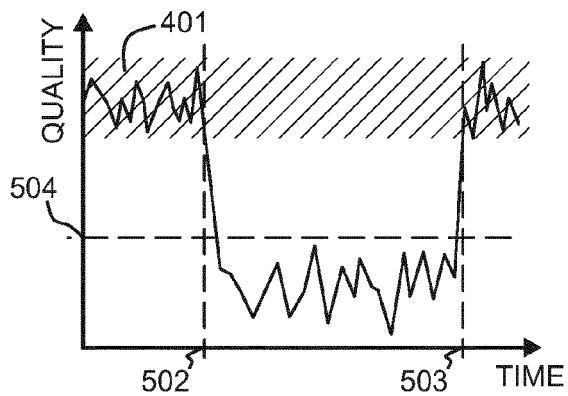


Fig. 5

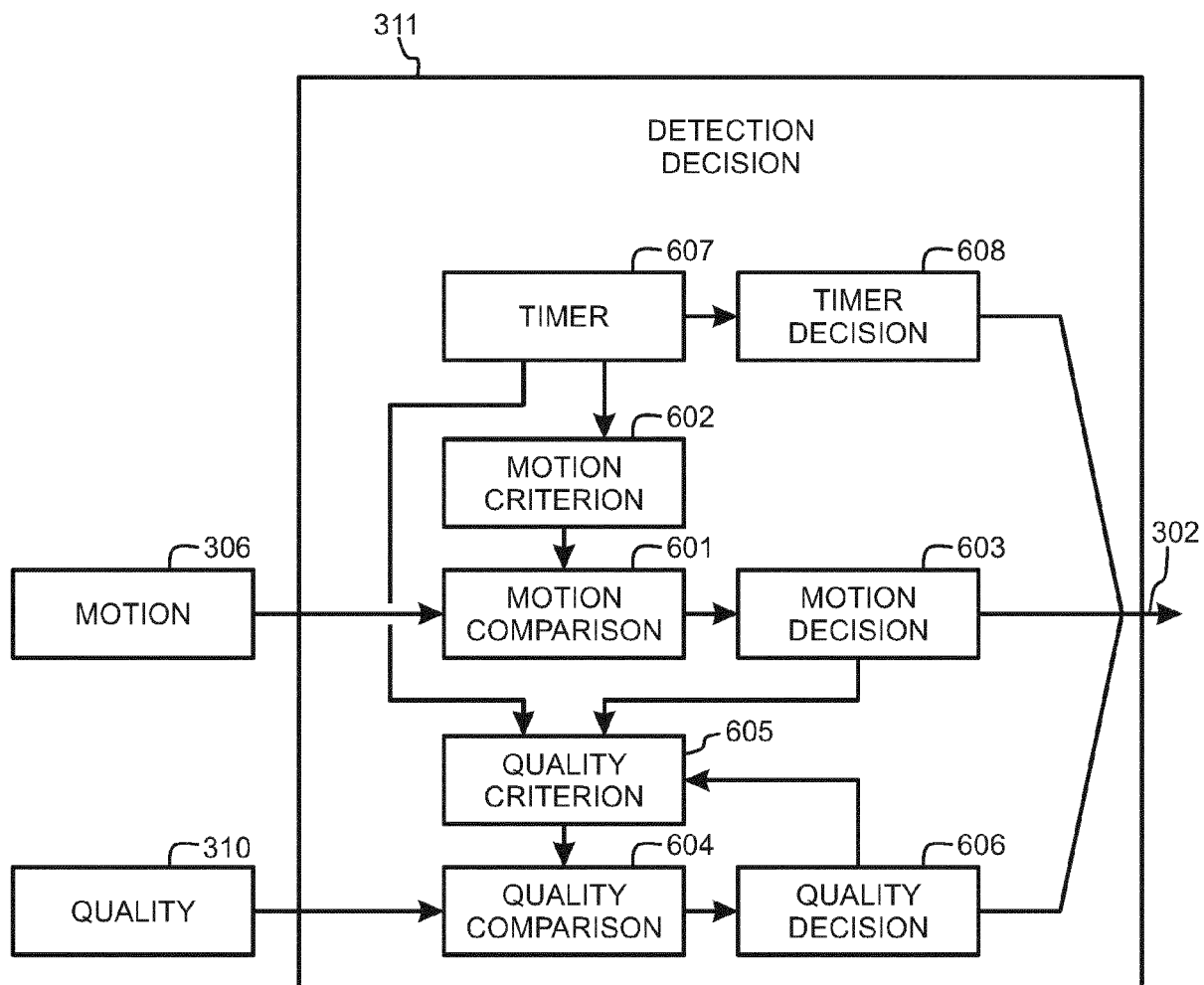


Fig. 6

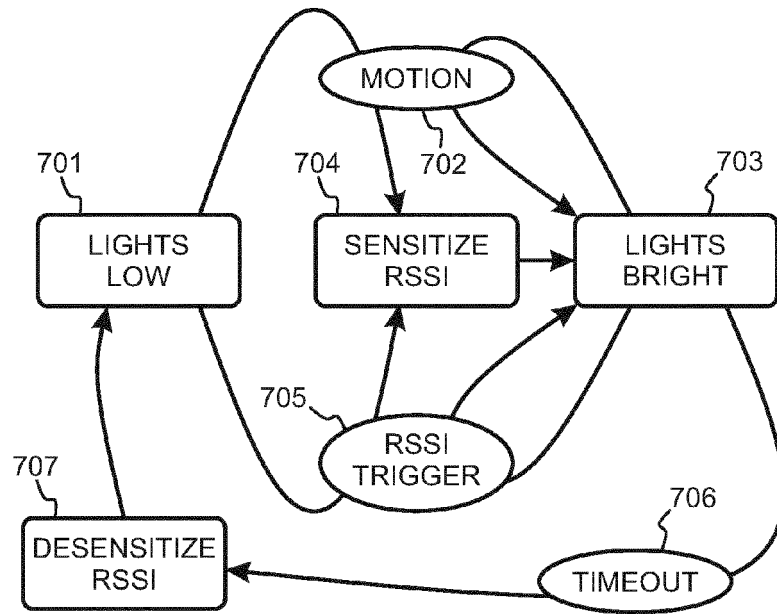


Fig. 7

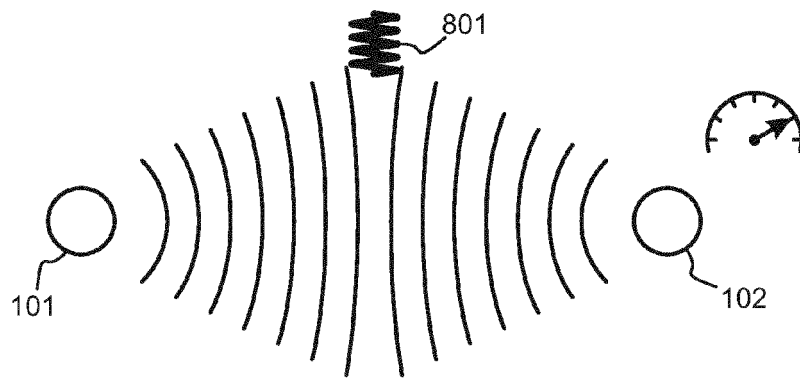


Fig. 8

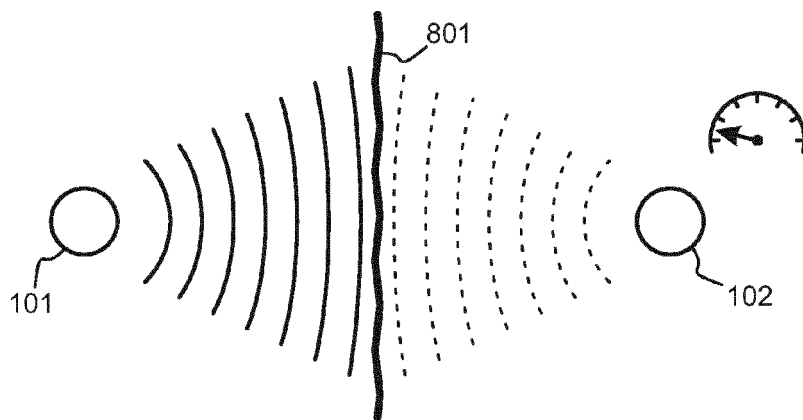


Fig. 9

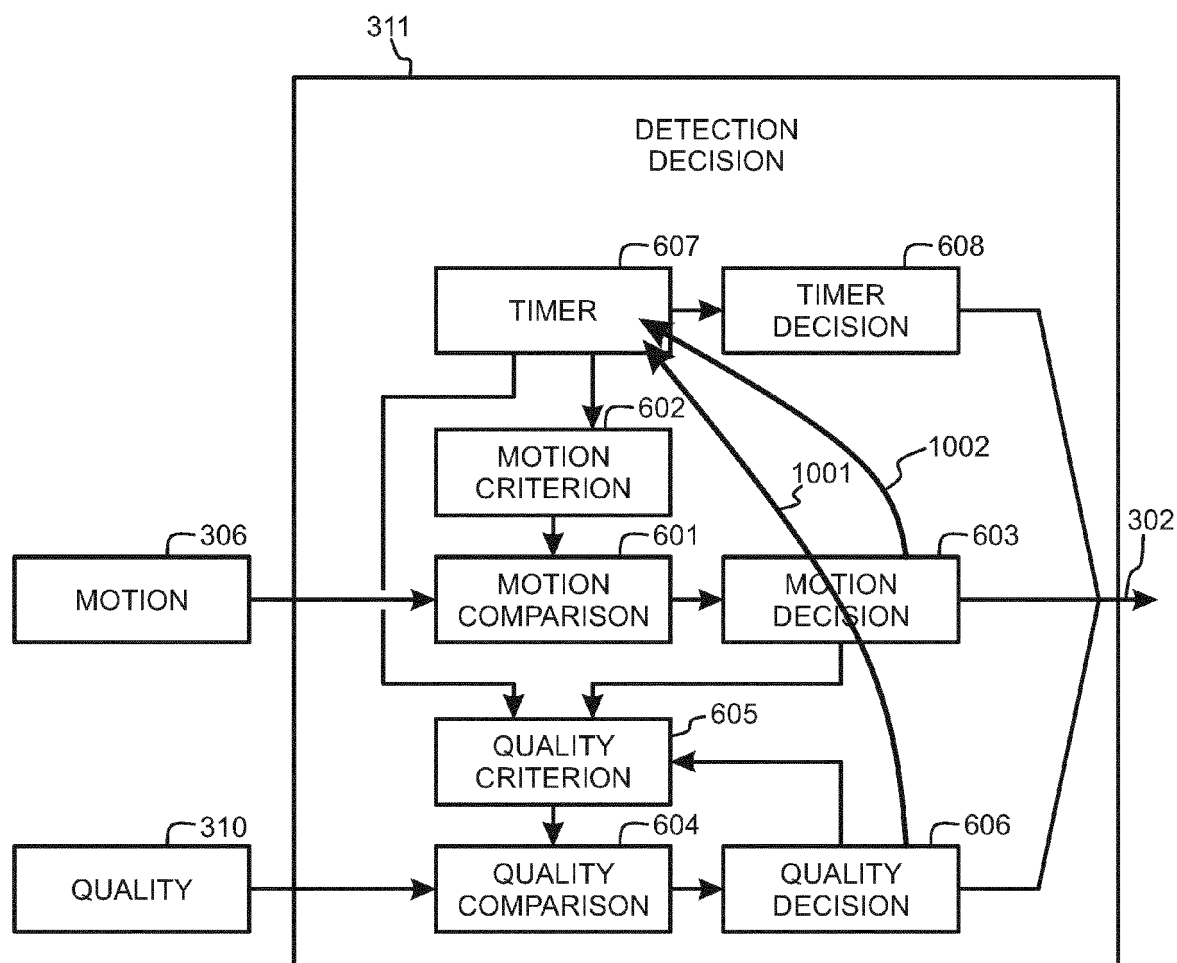


Fig. 10

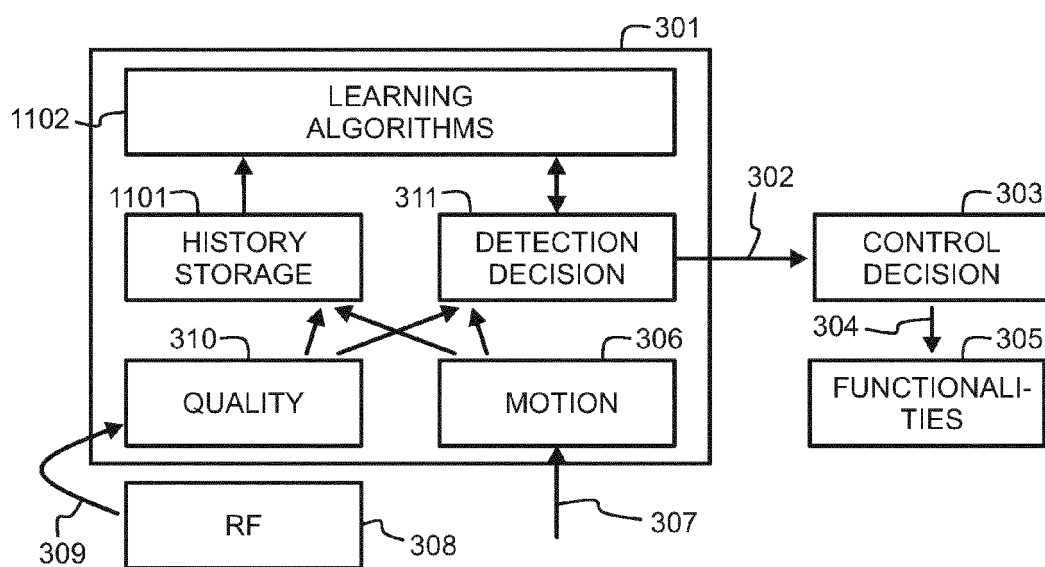


Fig. 11

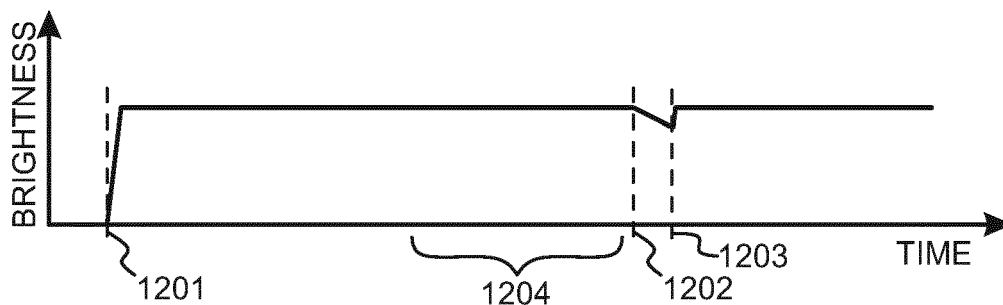


Fig. 12

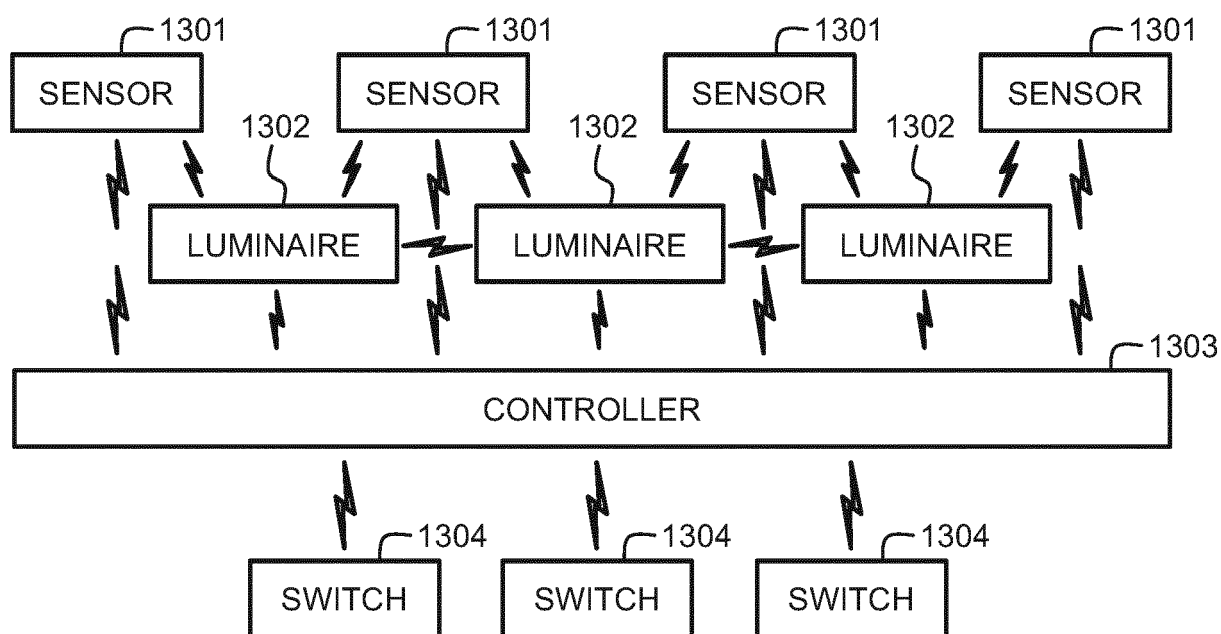


Fig. 13



EUROPEAN SEARCH REPORT

Application Number

EP 22 15 2419

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2019/182933 A1 (LU MIN-HAO MICHAEL [US] ET AL) 13 June 2019 (2019-06-13) * paragraphs [0120], [0142]; figures 2-5 * -----	1-15	INV. H05B47/115 G01S13/00 H04W4/80 H05B47/19
			TECHNICAL FIELDS SEARCHED (IPC)
			H05B H04W G01S
The present search report has been drawn up for all claims			
Place of search		Date of completion of the search	Examiner
Munich		5 July 2022	Boudet, Joachim
CATEGORY OF CITED DOCUMENTS			
X : particularly relevant if taken alone Y : particularly relevant if combined with another document of the same category A : technological background O : non-written disclosure P : intermediate document			
T : theory or principle underlying the invention E : earlier patent document, but published on, or after the filing date D : document cited in the application L : document cited for other reasons & : member of the same patent family, corresponding document			

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ANNEX TO THE EUROPEAN SEARCH REPORT
ON EUROPEAN PATENT APPLICATION NO.

EP 22 15 2419

5 This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report.
The members are as contained in the European Patent Office EDP file on
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05-07-2022

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US 2019182933 A1	13-06-2019	CA 3025741 A1	13-06-2019
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		US 2019261497 A1	22-08-2019
