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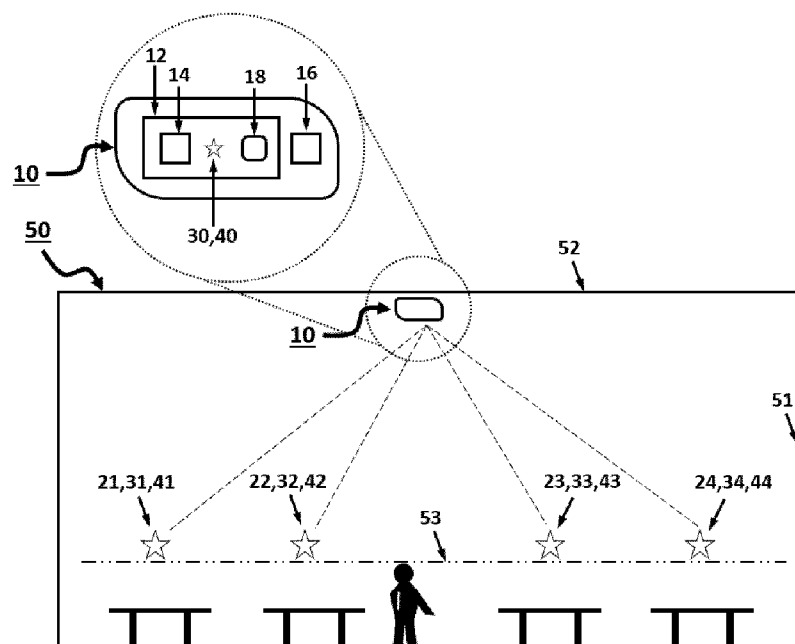


FIG. 1.

(57) Abstract: The invention provides a sensor arrangement (10) for calculating relative humidities (31, 32, 33, 34) at a plurality of locations (21, 22, 23, 24) within a space (50), the sensor arrangement (10) comprising: a housing (12); a humidity sensor (14) for determining a relative humidity at a local temperature within the housing (12); a temperature sensor (16) for measuring, from a distance, the temperatures (41, 42, 43, 44) at the plurality of locations (21, 22, 23, 24) within said space (50); a processor (18) in connection with the humidity sensor (14) and the temperature sensor (16) and configured to calculate the relative humidities (31, 32, 33, 34) at the plurality of locations (21, 22, 23, 24) within said space (50), based on said temperatures (41, 42, 43, 44) at the plurality of locations (21, 22, 23, 24) and said relative humidity at the local temperature within the housing (12).

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REMOTE SENSING OF RELATIVE HUMIDITY AT A PLURALITY OF LOCATIONS

FIELD OF THE INVENTION

The invention relates to a sensor arrangement for calculating a relative humidity at a plurality of locations within a space. The invention further relates to a lighting device comprising said sensor arrangement. The invention further relates to a system for managing a space comprising said sensor arrangement or said lighting device, and at least one actuator device. The invention further relates to a method of calculating a relative humidity at a plurality of locations within a space; and a corresponding computer program product for performing said method.

BACKGROUND OF THE INVENTION

Humidity describes the amount of water vapor present in air. Absolute humidity describes the actual water content in air (e.g. expressed in grams of water per cubic meter of air). However, the capacity of air to hold water increases as air is warmed, and decreases as air is cooled. Relative humidity therefore describes the absolute humidity (i.e. actual water content in air) relative to the maximum humidity at a given temperature (i.e. the maximum amount of water vapor which the air is able to hold at that temperature). Relative humidity is thereby expressed as a percentage, which e.g. describes how close the air is to being saturated with water vapor. Taken the above, relative humidity is thus inversely correlated to the temperature of the air (at which the relative humidity is measured).

Besides e.g. temperature, relative humidity may be a relevant parameter in determining a comfort level of a person residing within a space. The sensing of relative humidity within a space is commonly performed by a wall-mounted relative humidity sensor; e.g. in a home setting or in an office environment. Such a wall-mounted relative humidity sensor may often be very accurate with a deviation of $\pm 2\%$ for relative humidity, but may also be relatively expensive with a market price $> 50\$$, which not even includes installation and commissioning costs.

Thus, a disadvantage of such a wall-mounted relative humidity sensor is that it can only validly measure the relative humidity at the mounted location, and a plurality of such sensors is required to measure the relative humidity at other locations. This may

undesirably lead to higher costs and a more cumbersome installation and/or commissioning. Moreover, it is more difficult to provide a complete mapping of relative humidity within a space. Hence, a clear need exists to measure relative humidity at a plurality of locations within a space, and to do this at least more efficiently.

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SUMMARY OF THE INVENTION

It is an object of the invention to provide an improved sensor arrangement for calculating a relative humidity at a plurality of locations within a space, which at least alleviates the problems mentioned above. Thereto, the invention provides a sensor arrangement for calculating a relative humidity at a plurality of locations within a space, the sensor arrangement comprising: a housing; a humidity sensor for determining a relative humidity at a local temperature within the housing; a temperature sensor for determining a temperature at the plurality of locations within said space; a processor, in connection with the humidity sensor and the temperature sensor, configured to calculate a relative humidity at the plurality of locations within said space based on said temperature at the plurality of locations within said space and the relative humidity at the local temperature within the housing; wherein the processor is configured to output a signal comprising a mapping of the relative humidity at the plurality of locations within said space.

Hence, a sensor arrangement is provided for calculating a relative humidity at a plurality of locations within a space by advantageously making use of a temperature sensor, which determines a temperature at the plurality of locations within said space. The sensor arrangement is located within said space. Namely: The sensor arrangement comprises at least a housing, a humidity sensor, a temperature sensor and a processor. The processor is in connection with the humidity sensor and the temperature sensor, which being in connection may either be wired or wirelessly. The humidity sensor determines a relative humidity, which relative humidity is determined at a local temperature within the housing of the sensor arrangement.

However, the relative humidity at the plurality of locations within said space may be different to said relative humidity determined at a local temperature within the housing of the sensor arrangement; because a temperature (therefore also the maximum amount of water vapor which the air is able to hold) at each respective location of the plurality of locations within said space may be different. Consequently, due to the insight that relative humidity is inversely correlated to the temperature of the air, the processor of the sensor arrangement is configured to calculate the relative humidity at the plurality of

locations within said space based on both the determined temperature at the plurality of locations within said space and the determined relative humidity at the local temperature within the housing. Hereby, the local temperature may be taken as a given, but may alternatively be determined specifically, so as to improve the accuracy of said calculation.

5 As a result, since the relative humidity at the plurality of locations within said space may advantageously be determined, a mapping of the relative humidity within said space may be established, thereby providing valuable data for assessing and/or mapping a comfort level within said space with a single sensor arrangement, which may be embodied in a single device (capable of providing this). Such a mapping of a comfort level may e.g. be a
10 heat mapping.

As mentioned, the temperature sensor is configured to determine a temperature at the plurality of locations within said space. The temperature sensor may be a single sensor, which may be measuring each respective temperature at the plurality of locations within said space from a distance (and e.g. unobtrusively). Hence, in an embodiment, the temperature
15 sensor is one of: a thermopile single pixel, thermopile array sensor, a microbolometer sensor, a thermal camera, Pyroelectric Linear Arrays, etc.

As mentioned, the local temperature, at which the relative humidity is determined by the humidity sensor, may be taken as a given in the calculation performed by the processor. For example, in an embodiment, the local temperature may be a constant local
20 temperature. Such a constant local temperature may e.g. be programmed in the processor and/or the humidity sensor during commissioning, calibration and/or installation of the sensor arrangement and/or the humidity sensor; (whereby the processor and/or the humidity sensor may e.g. comprise a local memory, e.g. a cache).

As mentioned, the local temperature, at which the relative humidity is
25 determined by the humidity sensor, may be taken as a given in the calculation performed by the processor. However, the real local temperature may be different, for example, compared to a given (predetermined) constant temperature. The processor is configured to calculate a relative humidity at the plurality of locations within said space based on said temperature at the plurality of locations within said space and the relative humidity at the local temperature
30 within the housing. The accuracy of said calculation may be improved further by determining said local temperature within the housing by means of a sensor. Two options according to the invention may be proposed below.

Hence, in an embodiment, the temperature sensor may be configured to determine said local temperature within the housing by averaging the determined temperature

at the plurality of locations within said space. Since the temperature sensor is already comprised by the sensor arrangement, and since averaging the determined temperature at the plurality of locations within said space may be an accurate approximation of the local temperature within said housing (as the sensor arrangement is located within said space),
5 having the temperature sensor determine the local temperature may be advantageous. Namely, by determining (via the averaging of the measurements of the temperature sensor) and thereby knowing the local temperature within the housing, the relative humidity determined by the humidity sensor may be accurately associated to said local temperature determined with the temperature sensor; thereby improving the accuracy of the calculation
10 performed by the processor according to the present invention.

However, in some examples, a disadvantage of said embodiment may be that the averaging of the temperatures within said space may not be a close enough approximation of the local temperature within said housing, so as to provide very accurate applications of the determined relative humidity within said space.

15 Hence, in an alternative embodiment, the sensor arrangement may comprise a local temperature sensor for determining said local temperature within the housing. Said local temperature sensor may be any one of a known temperature sensor, such as e.g. a thermocouple. The local temperature sensor determines said local temperature within the housing of the sensor arrangement by e.g. measuring the local temperature within the
20 housing. Consequently, by determining and knowing the local temperature within the housing, the relative humidity determined by the humidity sensor may be accurately associated to said local temperature determined with the local temperature sensor; thereby (significantly) improving the accuracy of the calculation performed by the processor according to the present invention; since the determined temperature at the plurality of
25 locations within said space may be correlated to the determined humidity and temperature relation within the housing. The processor may be in connection and/or communication with said local temperature sensor as well.

In aspects, the temperature sensor (e.g. a thermopile sensor) may have a temperature sensing means (e.g. integrated in the temperature sensor) for measuring the
30 ambient reference temperature inside the temperature sensor (i.e. based on the Seebeck effect). This ambient reference temperature may be equal to the local temperature.

In a further embodiment thereof, the local temperature sensor and the humidity sensor may be embedded in a same sensor unit within the housing. Such a sensor unit may for example be a humidity sensor unit for determining relative humidity at a local

temperature within the housing and for determining said local temperature within the housing. Thus, the sensor arrangement may comprise such a humidity sensor unit according to the present embodiment. Such a humidity sensor unit may therefore be compact and may be determining all relevant information required for e.g. a processor to perform calculations, because such a sensor unit may determine both the relative humidity and the local temperature at substantially the same location, i.e. at the sensor unit, within the housing.

In the latter embodiment, wherein the sensor arrangement comprises a local temperature sensor and/or a (humidity) sensor unit comprising the local temperature sensor and the humidity sensor, an additional problem may occur for calculating a relative humidity at a plurality of locations within said space. Namely: The local temperature sensor (and/or said sensor unit) may be affected by temperature differences, temperature gradients and/or heat sources in the vicinity of the local temperature sensor. This may particularly occur when such a temperature sensor (and/or said sensor unit) is embedded within another device, such as e.g. an electronic device with a heat source, such as e.g. a luminaire. As a consequence, the humidity sensor may determine a relative humidity, whereas the local temperature sensor may determine a deviating local temperature not corresponding to the local temperature at which the humidity sensor determines said relative humidity. This may introduce an error to the calculation according to the invention. Hence, in an embodiment comprising said local temperature sensor for determining said local temperature within the housing, the processor may be arranged to correct, based on a function of the temperature sensor, the humidity sensor determining a relative humidity at the local temperature determined by the local temperature sensor. More specifically, by determining and/or approximating the local temperature with the temperature sensor instead of the 'affected' local temperature sensor, a determination and/or measurement of the humidity sensor of the relative humidity at the local temperature may be corrected accordingly. Hence, even though a local temperature sensor is present for determining said local temperature, in conditions wherein said local temperature sensor is affected by heating / cooling as mentioned, the temperature sensor may be configured to determine said local temperature within the housing; for example, by averaging the determined temperature at the plurality of locations within said space as mentioned, or by determining a temperature in or just outside the housing wherein the humidity sensor is present. Such examples being the function onto which said correction is based.

In an embodiment, the housing may comprise at least one of: the temperature sensor, the humidity sensor, the processor. Such an embodiment may be advantageous, as one or more components of the sensor arrangement may be present within the same single

housing, which may ensure compactness of the sensor arrangement and/or easy manufacturing. In some examples, the temperature sensor may be present distant to the housing, whereas the humidity sensor and/or the processor are still comprised within the housing. In some other examples, the processor may be present distant to the housing, whereas the humidity sensor and/or the temperature sensor are still comprised within the housing. Such a distant processor, hence (at least partly) remote processing, may e.g. be performed on a server, a mobile device, a computing device, etc.

In an embodiment, said space may be one of: an office, a home, a room, a hallway, a retail space, a stadium, a sports arena, a warehouse, a factory, a vehicle such as a ship, train, bus or an airplane interior space, a meeting room, a library, a laboratory, a greenhouse, a tent, etc. Said space may be phrased as a volume, area, or environment.

As partly mentioned before, next to temperature, relative humidity may be a relevant parameter in determining a comfort level of a person residing within a space. A clear need exists in determining thermal comfort for humans in a space, wherein the term 'thermal comfort' is used here to include both the parameters temperature as well as humidity. For example, in an office or factory environment, thermal comfort may enable a higher worker productivity. For example, in a retail environment, thermal comfort may enable higher sales due to consumer satisfaction. For example, in a home setting, determining thermal comfort may facilitate establishing an improved living climate. Alternatively, yet similarly, thermal comfort may also relate to products, animals and/or plants. For example, in a greenhouse setting and/or horticulture setting, determining thermal comfort may enable higher growth rate of plants requiring a dedicated temperature/humidity. For example, in a retail area, thermal comfort may enable to keep products fresh. For example, in a poultry or a livestock environment, thermal comfort may facilitate establishing an improved living climate for animals.

As partly mentioned before, a space according to the present invention may comprise a plurality of locations with a respective, possibly different, temperature and relative humidity. The sensor arrangement according to the present invention may advantageously determine a temperature at the plurality of locations within said space and calculate the corresponding relative humidity at the plurality of locations within said. As a result, gradients in temperature and/or relative humidity within said space may be determined. Such gradients may provide insights into the thermal comfort associated with said space.

Hence, as mentioned, the processor is configured to output a signal comprising a mapping of the relative humidity at the plurality of locations within said space. Such an embodiment may be advantageous, because said signal comprising a mapping of the relative humidity at the plurality of locations within said space may provide valuable information on the relative humidity distribution within said space. Thus, the thermal comfort of said space may be determined. The signal may in other examples also comprise the temperature determined at the plurality of the locations within said space.

Moreover, the signal may e.g. be communicated via wired and/or wireless communication means. For example, via a wired connection, such as a data line, ethernet, a power line communication; or via a wireless connection, such as a broadcast message, an unicast message, via modalities such as Wi-Fi, Bluetooth, ZigBee, RF, Infrared, Visible Light Communication, Li-Fi, LoRa, or 4G/5G, etc.

In a further embodiment, the processor is configured to annotate at least one region within said mapping of the relative humidity at the plurality of locations within said space with a classification. Such an annotation of at least one region within said mapping may add more information to the signal comprising said mapping of the relative humidity at the plurality of locations within said space. Therefore, as more intelligence is put into the signal before outputting the signal by means of the processor of the sensor arrangement, less processing power may be required by any device receiving said signal. Such a device may for example be a HVAC device, a heating device, a lighting device, a blind controller, a building management device, a smartphone, etc. The lighting device may be a luminaire. Hence, such an embodiment advantageously utilizes local processing and enables a better insight in the relative humidity distribution (and/or temperature distribution) between regions within said space. That is: a better insight may be provided in e.g. the thermal comfort within said space, as at least one region may be annotated with said classification.

Moreover, in an embodiment, said classification is indicative of a comfort level. Thus, such a mapping may be advantageously used for indicating a comfort level within said space, and be indicative of differences in comfort level between regions within said space, because the relative humidity at the plurality of locations within said space is determined and at least one region is annotated with an indication of a comfort level based thereon. Said signal e.g. enables to determine high/low comfort regions within said space.

In an embodiment, the processor is configured to output said signal to at least one of: a HVAC device, a lighting device, a heating device, a fan, a ventilation device, a window blind controller, a building management device, a smartphone, a user interaction

device, a fodder supplying device, a tap or a water regulator device, etc. The lighting device may be a luminaire

In an embodiment, the processor is configured to output said signal periodically. Such an embodiment is advantageous to dynamically obtain an insight in the thermal comfort within said space, as such thermal comfort may change dynamically due to e.g. sunlight entering, people presence, and/or HVAC activity, etc.

In an embodiment, the sensor arrangement is configured to be mounted to a ceiling confining said space. Such an embodiment may be advantageous, because the sensor arrangement may determine the relative humidity and/or the temperature at a plurality of locations within said space being substantially parallel to the ceiling. This allows the sensor arrangement to observe a more relevant plane (i.e. e.g. the floor plane) and observe a larger coverage area within said space.

Hence, in a related embodiment, the temperature sensor is a thermopile array sensor, and wherein the thermopile array monitors at least one surface substantially horizontal with said ceiling. Such a sensor arrangement, wherein the temperature sensor being a thermopile array sensor monitoring at least one surface substantially horizontal with said ceiling (e.g. the floor level, or the desk level), may be advantageous; because a larger surface area of said space may be monitored and because the distance between a floor and ceiling is generally constant, thereby allowing the thermopile array to not be inefficiently looking into a depth of space.

In further aspects: Said constant local temperature, as mentioned above, may e.g. be a commonly accepted ambient room temperature, such as e.g. 20 degrees Celsius during daytime. Although such a constant local temperature may introduce a deviation in the calculation of the relative humidity at the plurality of locations within said space, the accuracy of the resulting relative humidity at the plurality of locations within said space may still be sufficient, e.g. for indicating differences in relative humidity between regions within said space. In further examples, said constant local temperature may be time dependent, which may further improve the accuracy of said calculation, whereby the programming mentioned above comprises programming the constant local temperature with its time dependency. For example, the constant local temperature during nighttime may be different to daytime, which may be retrieved based on empirical data. Said time dependency may also be programmed seasonally or monthly or daily. For example, said local temperature may be programmed according to a diurnal pattern of the local temperature, which may be measured only once during commissioning.

In aspects of the invention, said local temperature may be retrieved from an external device. Such an external device may be a HVAC device. In alternative aspects, such a HVAC device may e.g. inform the sensor arrangement on the local temperature, wherein the sensor arrangement may comprise an input means for receiving said local temperature from the HVAC device.

Considering developments in the lighting industry, more intelligence is added to and/or combined with the lighting infrastructure. For example, luminaires may comprise sensors, which provide more information and enable various services. This may for example be advantageous, because luminaires may e.g. provide a dense grid of locations to embed sensors, provide a (e.g. mains) power supply and/or provide IoT connectivity. This may often be paired with less costs for installation and/or commissioning of sensors, because the location of luminaires may e.g. be known. Thus, considering the sensor arrangement according to the present invention, it may be advantageous to integrate such a sensor arrangement with a lighting device, so as to improve measuring relative humidity within a space.

Hence, it is a further object of the invention to provide an improved lighting device, which at least alleviates the problems and disadvantages mentioned above. Thereto, the invention further provides a lighting device comprising the sensor arrangement according to the present invention. Said lighting device may e.g. further comprise a light source, and/or a lighting device housing, wherein said lighting device housing may be the same housing (of the sensor arrangement) according to the invention. In an embodiment, the lighting device is a ceiling-mounted luminaire. However, alternatively, the lighting device may for example be: a luminaire, a light panel, a light emitting ceiling-tile, a spotlight, a pixilated LED spot, or a TLED, etc.

Said improved lighting device, which comprises the sensor arrangement according to the invention, may further be advantageous because the lighting device may be prone to significant temperature changes due to the operation of the lighting device (e.g. on/off) or due to its very design features (e.g. size; proximity of sensor arrangement to the light source, driver, or heat sink; shape of its housing defining e.g. the convective cooling properties), and because such temperature changes may not be affecting the sensor arrangement according to the present invention due to its features to correct for a deviating local temperature affecting the calculation according to the invention. Thus, the sensor arrangement of the present invention may advantageously be embedded into a wide variety and range of lighting devices, thereby enabling a new humidity sensing functionality to said

lighting devices, whereas other (not improved) sensor arrangements may not be able to deal with temperature changes. Thus, for example, whenever the local temperature sensor of the sensor arrangement comprised by the lighting device is affected (in its readings) by heat transfer from the lighting device to the local temperature sensor, the processor is arranged to correct, based on a function of the temperature sensor, the humidity sensor determining a relative humidity at the local temperature determined by the local temperature sensor.

Thereby, the advantages and/or embodiments applying to the sensor arrangement according to the invention may also apply mutatis mutandis to the present lighting device according to the invention.

In an embodiment, the processor of the sensor arrangement may be configured to output a signal comprising a mapping of the relative humidity at the plurality of locations within said space, wherein said signal may be outputted by a light source of said lighting device by means of visible light communication. Such an embodiment is advantageous, because the visible light communication may be received within the line of sight of the lighting device, thereby providing only the mapping of the relative humidity to a device used by a person in the vicinity of said lighting device. For example, a person working in an office may want to assess the thermal comfort within the office, thereby using its smartphone (and its camera) to tap into / received the signal emitted which comprises the mapping of the relative humidity at the plurality of locations within said space. Hereby, the signal may also limit the mapping (hence the data content of the signal) to a defined range around the lighting device, which defined range is the field of view range of the visible light communication signal emitted by the lighting device.

It is a further object of the invention to provide an improved lighting system, which at least alleviates the problems and disadvantages mentioned above. Thereto, the invention further provides a system for managing a space, the system comprising: the sensor arrangement according to the invention, or the lighting device according to the invention, and at least one actuator device; wherein the sensor arrangement and/or lighting device is further arranged for providing a control signal to the at least one actuator device. Such a system is advantageous, because the sensor arrangement is able to act accordingly in response to the determination (or: measurement, or: calculation) of the relative humidity at the plurality of locations within said space. For example, based on a mapping of the relative humidity at the plurality of locations within said space according to the invention, the processor of the sensor arrangement may provide a control signal to the at least one actuator device to manage a comfort level within said space.

Hence, in an embodiment, the at least one actuator device is one of: a HVAC, a lighting device, a heating element, a fan, a ventilation device, and/or a window blind; and wherein said at least one actuator device, in response to said control signal, is arranged for changing the temperature within said space. The lighting device may be a luminaire.

Thus, advantageously, climate control may be provided. In an alternative embodiment, the at least one actuator device is one of: a lighting device, a speaker, a user interaction device or a signal transmitter; and wherein said at least one actuator device, in response to said control signal, is arranged for outputting a signal indicative of the relative humidity at the plurality of locations within the space calculated with the sensor arrangement.

The lighting device may be a luminaire

Thereby, the advantages and/or embodiments applying to the sensor arrangement and/or lighting device according to the invention may also apply mutatis mutandis to the present system according to the invention.

It is a further object of the invention to provide an improved method of calculating a relative humidity at a plurality of locations within a space. Thereto, the invention further provides a method performed by a sensor arrangement comprising a housing, a humidity sensor, a temperature sensor and a processor in connection with the humidity sensor and the temperature sensor, the method comprising: determining, with the humidity sensor, a relative humidity at a local temperature within the housing of the sensor arrangement; determining, with the temperature sensor, a temperature at the plurality of locations within said space; calculate, with the processor, the relative at the plurality of locations within said space based on said temperature at the plurality of locations within said space and the relative humidity at the local temperature within the housing.

As mentioned, the local temperature, at which the relative humidity is determined by the humidity sensor, may be taken as a given in the calculation performed by the processor. The processor is namely configured to calculate a relative humidity at the plurality of locations within said space based on said temperature at the plurality of locations within said space and the relative humidity at the local temperature within the housing. The accuracy of said calculation may be improved further by determining said local temperature within the housing by means of a sensor. Two options may be proposed below.

In an embodiment, the method according to the invention is provided, wherein the method further comprising: determining said local temperature within the housing by averaging the determined temperature at the plurality of locations within said space.

In an embodiment, the method according to the invention is provided, wherein the method further comprising: determining, with a local temperature sensor, said local temperature within the housing; compensate, with the processor, the humidity sensor determining a relative humidity at the local temperature determined by the local temperature sensor based on a function of said temperature sensor.

The advantages and/or embodiments applying to the sensor arrangement, lighting device and/or system according to the invention may also apply mutatis mutandis to the present method according to the invention.

The invention further relates to a computer program product for calculating a relative humidity at a plurality of locations within a space. Hence, the invention provides <x> a computer program product for a computing device, the computer program product comprising computer program code to perform a method of the invention when the computer program product is run on a processing unit of the computing device. The computing device may be the sensor arrangement or lighting device according to the invention.

Thus, aspects of the invention may be implemented in a computer program product, which may be a collection of computer program instructions stored on a computer readable storage device which may be executed by a computer. The instructions of the present invention may be in any interpretable or executable code mechanism, including but not limited to scripts, interpretable programs, dynamic link libraries (DLLs) or Java classes. The instructions can be provided as complete executable programs, partial executable programs, as modifications to existing programs (e.g. updates) or extensions for existing programs (e.g. plugins). Moreover, parts of the processing of the present invention may be distributed over multiple computers or processors.

Further, in further aspects of the invention, the invention provides: An alternative sensor arrangement for calculating a relative humidity at within a space, the sensor arrangement comprising: a housing; a local temperature sensor for determining a local temperature within the housing; a humidity sensor for determining a relative humidity at a local temperature within the housing; a temperature sensor for determining a temperature within said space; a processor, in connection with the humidity sensor, the local temperature sensor, and the temperature sensor, configured to calculate a relative humidity within the housing based on said temperature within said space and the relative humidity at the local temperature within the housing. In an embodiment, the processor may be arranged to correct, based on a function of the temperature sensor, the humidity sensor determining a relative humidity at the local temperature determined by the local temperature sensor. In an

embodiment, said correction may be caused by an external heat source affecting the measurement of the local temperature sensor and/or said humidity sensor within the housing. In an embodiment, the temperature sensor is one of: a thermopile single pixel, a thermopile array sensor, a microbolometer sensor, a thermal camera, Pyroelectric Linear Arrays. In an embodiment, the humidity sensor and the local temperature sensor are embedded within a same humidity sensor module. In an embodiment, said alternative sensor arrangement is embedded within a luminaire. In an embodiment, said luminaire is a ceiling-mounted luminaire. Hence, in an aspect of the invention, a lighting device may be provided with said alternative sensor arrangement.

Considering the above, such an alternative sensor arrangement may be advantageous: Due to external heat sources, e.g. whenever the alternative sensor arrangement may be embedded within a luminaire and is affected by the cooling down / heating up of the luminaire, the alternative sensor arrangement may render less accurate temperature and relative humidity measurements with respectively the local temperature sensor and the humidity sensor. The local temperature within the housing may be dependent on its design and also e.g. of the design of a luminaire into which it is embedded, such as luminaire size, illuminance, power consumption, etc. Depending on the external heat source, for example taking a luminaire, the local temperature within the housing can change up to 10°C - 20°C during normal operation of said luminaire compared to the space. When for example the local temperature within the housing increases with 12°C, the relative humidity measured by the humidity sensor is decreasing more than 13%. This means that the humidity determined with the humidity sensor, which ought to represent the relative humidity of said space, will be comprising an error of 13% off, which is not acceptable. Since the temperature sensor, which in an embodiment may be a thermopile array sensor, measures the actual temperature within said space, said error may be corrected. Namely: The humidity sensor measures the relative humidity at the local temperature within said housing, and the local temperature sensor measures said local temperature. The temperature sensor (e.g. the thermopile array sensor) measures the temperature within said space accurately. By means of the magnus equation, and/or a derivation thereof, the difference in temperature between the local temperature within said housing and the temperature within said space may be compensated and the corresponding relative humidity measurement at the local temperature within said housing be corrected (to an error of nearly zero).

The advantages and/or embodiments applying to the sensor arrangement, lighting device and/or system according to the invention may also apply *mutatis mutandis* to the alternative sensor arrangement according to the present further aspect of the invention.

5 BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be further elucidated by means of the schematic non-limiting drawings:

Fig. 1 depicts schematically an embodiment of a sensor arrangement according to the invention;

10 Fig. 2 depicts schematically an embodiment of a system according to the invention, the system comprising a lighting device comprising the sensor arrangement according to the invention, and at least one actuator device;

Fig. 3 depicts schematically an embodiment of a method according to the invention.

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DETAILED DESCRIPTION OF THE EMBODIMENTS

As mentioned: Besides e.g. temperature, relative humidity may be a relevant parameter in determining a comfort level of a person residing within a space. The sensing of relative humidity within a space is commonly performed by a wall-mounted relative humidity
20 sensor; e.g. in a home setting or in an office environment. A disadvantage of such a wall-mounted relative humidity sensor is that it can only validly measure the relative humidity at the mounted location, and a plurality of such sensors is required to measure the relative humidity at other locations. Thus, it is an object of the invention to provide an improved sensor arrangement for calculating a relative humidity at a plurality of locations within a
25 space.

Hence, according to the present invention, a sensor arrangement is provided for calculating a relative humidity at a plurality of locations within a space by advantageously making use of a temperature sensor, which determines a temperature at the plurality of locations within said space, and a humidity sensor within a housing of the sensor
30 arrangement, which determines a relative humidity at a local temperature within said housing. Consequently, due to the insight that relative humidity is inversely correlated to the temperature of the air, the sensor arrangement is configured to calculate the relative humidity at the plurality of locations within said space based on both the determined temperature at the

plurality of locations within said space and the determined relative humidity at the local temperature within the housing.

As a result, since the relative humidity at the plurality of locations within said space may advantageously be determined, a mapping of the relative humidity within said space may be established, thereby providing valuable data for assessing and/or mapping a comfort level within said space with a single sensor arrangement, which may be embodied in a single device (capable of providing this).

Figure 1 depicts schematically, by non-limiting example, an embodiment of a sensor arrangement 10 for calculating a relative humidity 31, 32, 33, 34 at a plurality of locations 21, 22, 23, 24 within a space 50. Here, only four locations 21, 22, 23, 24 are depicted for convenience. Here, the space 50 is an office floor, but may alternatively be any other space wherein the computation of relative humidity may be relevant. The space 50 further has a window 51 through which natural sunlight is entering and thereby for example influencing the temperatures levels and the humidity levels within the space 50. A person may be residing and/or working within said space 50.

Referring to Figure 1, and zooming into the sensor arrangement 10, the sensor arrangement 10 comprises: a housing 12, a humidity sensor 14, a temperature sensor 14 and a processor 18, wherein the processor 18 is in connection (or: in communication) with the humidity sensor 14 and the temperature sensor 16 (said connection not explicitly depicted). Furthermore, the housing 12 comprises the humidity sensor 14 and the processor 18, thereby providing a compact and intelligent module with the humidity sensor 14 and the processor. The temperature sensor 16 is separate from said housing 12. However, in alternative examples, the housing may at least comprise said humidity sensor, the temperature sensor and the processor, or any other component in relation thereto, or any combinations thereof. Furthermore, the housing is made of a polymer, but may alternatively be made of a metal, a ceramic, a composite, or a combination thereof.

Still referring to Figure 1, the temperature sensor 16 is a thermopile array sensor, which determines a temperature 41, 42, 43, 44 at the plurality of locations 31, 32, 33, 34 within said space 50 by means of measurement. The determined (or: measured) temperature 41, 42, 43, 44 at the plurality of locations 21, 22, 23, 24 within said space 50 is subsequently communicated to the processor 18. Such communication may either be via wired connection, or wireless communication. Alternatively, the temperature sensor may be a microbolometer sensor or a thermal camera.

Furthermore, the sensor arrangement 10 is mounted to a ceiling 52 confining said space 50. This allows the sensor arrangement 10 to observe a more relevant plane 53, which is a plane 53 at person-height and parallel (i.e. substantially horizontal) to the floor plane, and observe a larger coverage area within said space 50.

Moreover, here, the temperature sensor 16 (i.e. the thermopile array sensor 16) determines said local temperature 40 within the housing 12 by averaging the determined temperature 41, 42, 43, 44 at the plurality of locations 21, 22, 23, 24 within said space 50. As a result, said local temperature 40 at which the humidity sensor 12 measures said relative humidity 30 may be approximated accordingly with the average temperature within said space 50 as determined with the thermopile array sensor 16.

The humidity sensor 14 determines a relative humidity 30 at a local temperature 40 within the housing 12. Consequently, the relative humidity 30 at the local temperature 40 is known and the local temperature 40 is considered known as the approximated average of the thermopile array sensor 16. The temperature at the plurality of locations 21, 22, 23, 24 is also measured and known.

However, the relative humidity 31, 32, 33, 34 at the plurality of locations 21, 22, 23, 24 may be different to said relative humidity 30 determined at the local temperature 40 within the housing 12 of the sensor arrangement 10; because a temperature (therefore also the maximum amount of water vapor which the air is able to hold) at each respective location of the plurality of locations 21, 22, 23, 24 within said space 50 may be different and deviating from the average temperature in said space 50. For example, at the location 24 close to the window 51 the temperature 44 may be higher than at the location 21 further inside the space 50. Consequently, due to the insight that relative humidity is inversely correlated to the temperature of the air, the processor 18 is configured to calculate a relative humidity 31, 32, 33, 34 at the plurality of locations 21, 22, 23, 24 within said space 50 based on said temperature 41, 42, 43, 44 at the plurality of locations 21, 22, 23, 24 within said space 50 and the relative humidity 30 at the local temperature 40 within the housing 12. Known equations such as the Magnus equation may suffice for this calculation.

After calculating the relative humidity 31, 32, 33, 34 at the plurality of locations 21, 22, 23, 24 within said space 50, the processor 18 of the sensor arrangement 10 is configured to output a signal comprising a mapping of the relative humidity 31, 32, 33, 34 at the plurality of locations 21, 22, 23, 24. Said mapping may for example be forwarded via a wireless communication protocol, such as e.g. Wi-Fi, ZigBee, RF, VLC, IR, LiFi, to another

device. Said another device may for example be a user interaction device for visualizing said mapping, and/or a HVAC device for controlling the climate of said space 50.

Figure 2 depicts schematically, by non-limiting example, an embodiment of a system 1000 for managing a space 50. The space 50 is similar to the space of the embodiment depicted in Figure 1 and is an office floor with a ceiling 52. The space 50 further has a window 51 through which natural sunlight is entering and thereby influencing the temperatures and the humidity within regions within said space 50.

Further: The system 1000 comprises a lighting device 80, which lighting device 80 comprises a light source 81 and a sensor arrangement 60 according to the invention. The sensor arrangement 60 is a module plugged into said lighting device 80. The light source 81 is a TLED. The lighting device 80 is a TLED luminaire, which is mounted to the ceiling 52 of said space 50, such that the sensor arrangement 60 has a full overview of the space 50 and is able to look into a substantially limited depth (as the floor parallel to said ceiling is limiting said space).

The sensor arrangement 60 is configured to calculate a relative humidity 31, 32, 33, 34 at a plurality of locations 21, 22, 23, 24 within said space 50. The sensor arrangement 60 comprises a housing 62. The housing 62 comprises a humidity sensor 64, a local temperature sensor 65, a temperature sensor 66 and a processor 68. All of said components are in communication with each other. The measurements of said sensors 64, 65, 66 are provided to the processor 68 for processing.

The humidity sensor 64 measures the relative humidity 300 at a local temperature 400 within the housing 62. The local temperature sensor 65 is a thermocouple, but may alternatively be another temperature sensor or sensing means. The local temperature sensor 65 measures the local temperature 400 within the housing. The humidity sensor 64 and the local temperature sensor 65 are embedded within a same humidity sensor unit (not depicted) within the housing 62. The temperature sensor 66 is a thermopile array sensor, but may alternatively be a microbolometer sensor, a thermal camera. The temperature sensor 66 (unobtrusively) measures the temperature 41, 42, 43, 44 at the plurality of locations 21, 22, 23, 24 within said space 50 from a distance. Hereby, the temperature sensor 66, which is the thermopile array sensor 66, measures in the plane 53 substantially horizontal to the ceiling 52 onto which the TLED luminaire 80 and hence the sensor arrangement 60 is mounted.

Furthermore, as the sensor arrangement 60 and in particular the humidity sensor unit with the humidity sensor 64 and the local temperature sensor 65 are embedded within the TLED luminaire 80, the heating and/or cooling of the TLED luminaire 80 may

affect the humidity sensor unit. The determined relative humidity 300 at the local temperature 400 within the housing may therefore by itself not be representative for the relative humidity and temperature within said space 50.

Thus, considering the above, due to the insight that relative humidity is
5 inversely correlated to the temperature of the air, the processor 68 of the sensor arrangement 60 is configured to calculate the relative humidity 31, 32, 33, 34 at the plurality of locations 21, 22, 23, 24 within said space 50 based on both the determined temperature 41, 42, 43, 44 at the plurality of locations 21, 22, 23, 24 within said space 50 and the determined relative humidity 300 at the local temperature 400 within the housing 62. This may be required,
10 because the humidity sensor 64 measures the relative humidity 300 at the local temperature 400 within said housing 62; which is a single point measurement which may not be representative enough for the remaining plurality of locations 21, 22, 23, 24 within said space 50. Thus, to determine the relative humidity 31, 32, 33, 34 at the plurality of locations 21, 22, 23, 24 within said space 50 said calculation compensates for the temperature difference
15 between the temperature 41, 42, 43, 44 at the plurality of locations 21, 22, 23, 24 and the local temperature 400. Said calculation may be based on the Magnus equation.

For example, the following simplified calculation may be formulated based on a linear assumption: Suppose an equilibrium state wherein the space 50 has everywhere the same relative humidity (i.e. 80%) and the same temperature (i.e. 25 degrees Celsius). In the
20 same equilibrium state, the humidity sensor 64 may read an 80% relative humidity at a local temperature of 25 degrees Celsius within the housing 50. This is correct. Suppose now the lighting device 80 is turned on and therefore the local temperature within the housing 62 rises to 50 degrees Celsius. Due to heating up of the TLED luminaire 80, the humidity sensor 64 may now read a relative humidity of 40% at a local temperature of 50 degrees Celsius. Such
25 values for relative humidity and temperature are not representative anymore for said space 50. Therefore, the humidity sensor unit (not depicted) alone may not be able to determine and provide an accurate relative humidity measurement within said housing 62. Said determined relative humidity (i.e. relative humidity of 40% at a local temperature of 50 degrees Celsius) needs to be corrected. For convenience, considering a linear relation for the insight that
30 relative humidity is inversely correlated to the temperature of the air: knowing a temperature at a location within said space 50 may render a corrected relative humidity value for that particular location within said space 50. Suppose the thermopile array sensor 66 measures a temperature of 25 degrees Celsius on the location 21 at the windowless edge of the space 50, the relative humidity may linearly be calculated as 80% relative humidity, which is the

correct value as started in the equilibrium state. Going further with the calculation: Suppose the location 24 next to the window 51 is measured with the thermopile array sensor 66 having a temperature of 30 degrees Celsius (e.g. due to the proximity to the window 51 and sunshine warming up said location 24), the relative humidity at that location may be (linearly)

5 calculated as a relative humidity of 72%.

Consequently, by determining and knowing the local temperature 400 within the housing 62, the relative humidity 300 determined by the humidity sensor 64 is accurately associated to said local temperature 300 determined with the local temperature sensor 65; thereby (significantly) improving the accuracy of the calculation performed by the processor
10 68 according to the present invention; since the determined temperature 41, 42, 43, 44 at the plurality of locations 21, 22, 23, 24 within said space 50 are correlated to the determined humidity and temperature relation within the housing 62.

Still referring to Figure 2, the processor 68 outputs a signal (not depicted) comprising a mapping 75 of the relative humidity 31, 32, 33, 34 at the plurality of locations
15 21, 22, 23, 24 within said space 50. Said mapping provides valuable information on the relative humidity distribution within said space 50. Said signal is outputted periodically every second via a wireless communication protocol such as ZigBee or Bluetooth, but may alternatively be provided as a single broadcast/unicast, in different periods, at fixed times, upon request (of another device), etc.; and alternatively, via other known wireless
20 communication protocols as mentioned and known. Here, the processor 68 also annotates at least one region, that is the regions 71, 72, 73, 74 denoted by the plurality of locations 21, 22, 23, 24 within said space 50, within said mapping 75 with a classification 76, 77, 78, 79. The classification 76, 77 provides a positive comfort level, the classification 78 provides an intermediate comfort level, and the classification 79 provides a bad comfort level.

Still referring to Figure 2, the system 1000 comprises at least one actuator
25 device 70, 90, 91. The signal (not depicted) outputted by the processor 68 is a control signal (not depicted). The sensor arrangement 60 and its processor 68 provides a control signal to said at least one actuator device 70, 90, 91. Here, the first actuator device 70 is a user interaction device 70 with a display for displaying said mapping 75 with the annotated
30 classifications 76, 77, 78, 79 as corresponding to said regions 71, 72, 73, 74 of the mapping 75. Alternatively, said first actuator device may be e.g. lighting device, such as a luminaire, a speaker, another user interaction device such as a tablet, laptop, smart glasses, etc. Said lighting device may for example be a luminous tile or luminous textile on the floor of said space for providing said mapping so as to visualize the relative humidity within said space.

The second actuator device 90 is a HVAC device 90, which upon receiving said control signal (not depicted) from the processor 68 of the sensor arrangement 60 and controls the climate within said space 50, e.g. by changing the temperature. The third actuator device 91 is a signal transmitter 91, which receives said control signal (not depicted) from the processor 68 of the sensor arrangement 60 and forwards it as a beacon to any other device requesting said information comprised within the signal outputted by the sensor arrangement 60. Such beacon 91 also comprises local intelligence, e.g. by a connection to a backend or cloud, to perform further processing to said information provided by the sensor arrangement 60 via said control signal.

As a result, the system 1000 is able to manage said space 50, in particular either control its climate or provide insights into comfort zones within said space.

Figure 4 depicts schematically, by non-limiting example, a method 800 of calculating a relative humidity at a plurality of locations within a space. The method is performed by a sensor arrangement according to the invention comprising a housing, a humidity sensor, a temperature sensor and a processor in connection with the humidity sensor and the temperature sensor. The first step 801 of the method comprises determining, with the humidity sensor, a relative humidity at a local temperature within the housing of the sensor arrangement. In a second step 802 the method comprises determining, with the temperature sensor, a temperature at the plurality of locations within said space. In a third step 803 the method comprises calculating, with the processor, the relative humidity at the plurality of locations within said space based on said temperature at the plurality of locations within said space and the relative humidity at the local temperature within the housing.

As mentioned, the local temperature, at which the relative humidity is determined by the humidity sensor, may be taken as a given in the calculation performed by the processor. The processor is namely configured to calculate a relative humidity at the plurality of locations within said space based on said temperature at the plurality of locations within said space and the relative humidity at the local temperature within the housing. The accuracy of said calculation may be improved further by determining said local temperature within the housing by means of a sensor. Two options may be proposed below.

In an embodiment, the method further comprises a step 804 of determining said local temperature within the housing by averaging the determined temperature at the plurality of locations within said space.

In an embodiment, method further comprises a step 805 of determining, with a local temperature sensor, said local temperature within the housing; and a step 806 of

compensating, with the processor, the humidity sensor determining a relative humidity at the local temperature determined by the local temperature sensor based on a function of said temperature sensor.

CLAIMS:

1. A sensor arrangement for calculating a relative humidity at a plurality of locations within a space, the sensor arrangement comprising:
 - a housing;
 - a humidity sensor for determining a relative humidity at a local temperature
- 5 within the housing;
 - a temperature sensor for determining a temperature at the plurality of locations within said space;
 - a processor, in connection with the humidity sensor and the temperature
- 10 sensor, configured to calculate a relative humidity at the plurality of locations within said space based on said temperature at the plurality of locations within said space and the relative humidity at the local temperature within the housing;
 - wherein the processor is configured to output a signal comprising a mapping of the relative humidity at the plurality of locations within said space.
- 15 2. The sensor arrangement according to claim 1, wherein the temperature sensor is configured to determine said local temperature within the housing by averaging the determined temperature at the plurality of locations within said space.
3. The sensor arrangement according to claim 1, wherein the sensor arrangement
- 20 comprises:
 - a local temperature sensor for determining said local temperature within the housing.
4. The sensor arrangement according to claim 3, wherein the processor is
- 25 arranged to correct, based on a function of the temperature sensor, the humidity sensor determining a relative humidity at the local temperature determined by the local temperature sensor.

5. The sensor arrangement according to any one of the preceding claims, wherein the processor is configured to annotate at least one region within said mapping of the relative humidity at the plurality of locations within said space with a classification; wherein said classification is indicative of a comfort level.

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6. The sensor arrangement according to any one of the preceding claims, wherein the temperature sensor is one of: a thermopile single pixel, a thermopile array sensor, a microbolometer sensor, a thermal camera, Pyroelectric Linear Arrays.

10 7. The sensor arrangement according to any one of the preceding claims, wherein the sensor arrangement is configured to be mounted to a ceiling confining said space.

8. The sensor arrangement according to claim 7, wherein the temperature sensor is a thermopile array sensor, and wherein the thermopile array monitors at least one surface
15 parallel with said ceiling.

9. A lighting device comprising the sensor arrangement according to any one of the preceding claims 1-10.

20 10. A system for managing a space, the system comprising:
- the sensor arrangement according to any one of the preceding claims 1-7, or
- the lighting device according to any one of the preceding claims 8-9, and
- at least one actuator device;
wherein the sensor arrangement and/or lighting device is further arranged for
25 providing a control signal to the at least one actuator device.

11. The system according to claim 10,
wherein the at least one actuator device is one of: a HVAC, a further lighting device, a heating element, a fan, a ventilation device, and/or a window blind; and
30 wherein said at least one actuator device, in response to said control signal, is arranged for changing the temperature within said space.

12. The system according to claim 10,
wherein the at least one actuator device is one of: a further lighting device, a

speaker, a user interaction device or a signal transmitter; and

wherein said at least one actuator device, in response to said control signal, is arranged for outputting a signal indicative of the relative humidity at the plurality of locations within the space calculated with the sensor arrangement.

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13. A method of calculating a relative humidity at a plurality of locations within a space, the method being performed by a sensor arrangement comprising a housing, a humidity sensor, a temperature sensor and a processor in connection with the humidity sensor and the temperature sensor, the method comprising:

- 10 - determining, with the humidity sensor, a relative humidity at a local temperature within the housing of the sensor arrangement;
- determining, with the temperature sensor, a temperature at the plurality of locations within said space;
- calculating, with the processor, the relative humidity at the plurality of
- 15 locations within said space based on said temperature at the plurality of locations within said space and the relative humidity at the local temperature within the housing;
- outputting a signal comprising a mapping of the relative humidity at the plurality of locations within said space.

- 20 14. The method according to claim 13, the method further comprising:
- determining said local temperature within the housing by averaging the determined temperature at the plurality of locations within said space.

15. The method according to claim 13, the method further comprising:
- 25 - determining, with a local temperature sensor, said local temperature within the housing;
- compensate, with the processor, the humidity sensor determining a relative humidity at the local temperature determined by the local temperature sensor based on a function of said temperature sensor.

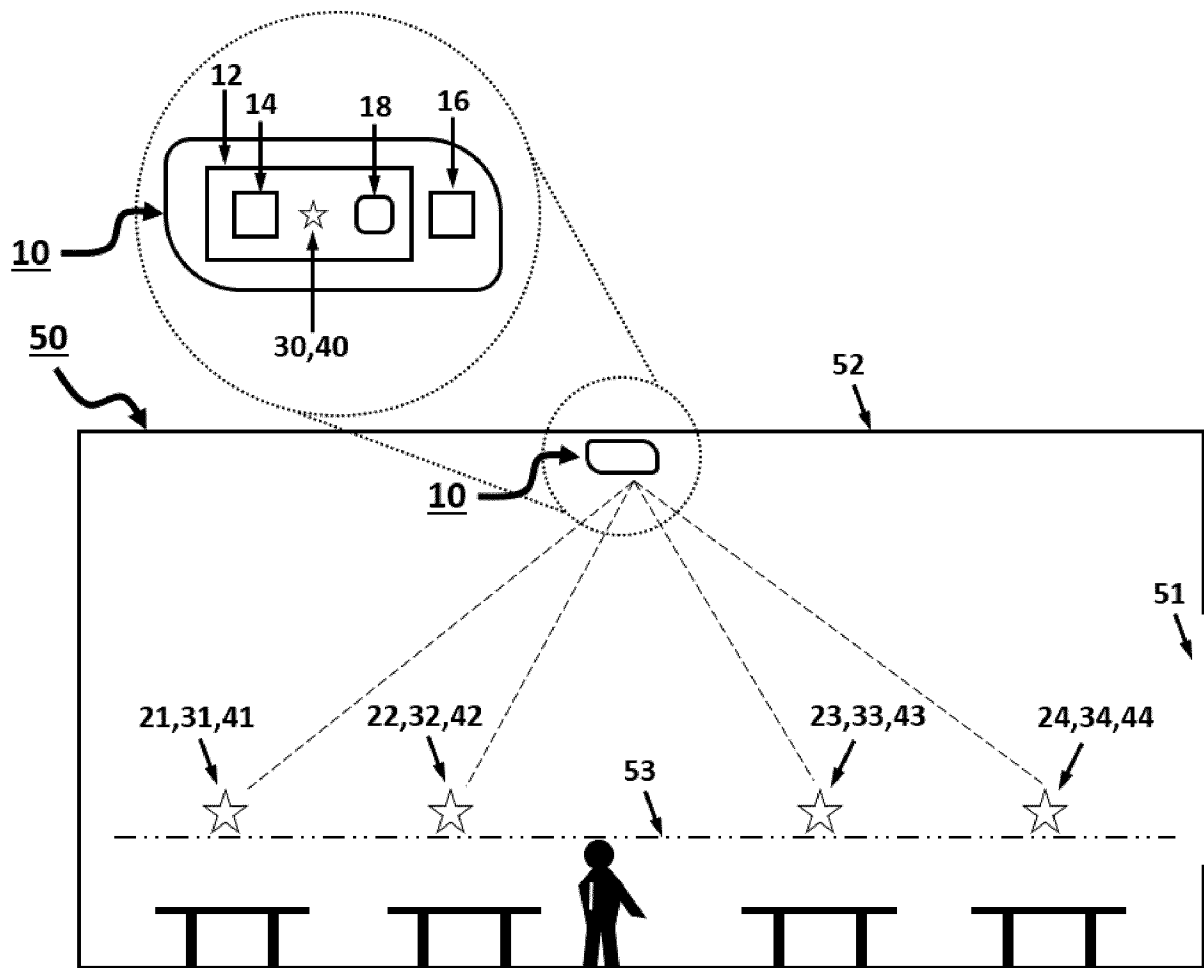


FIG.1.

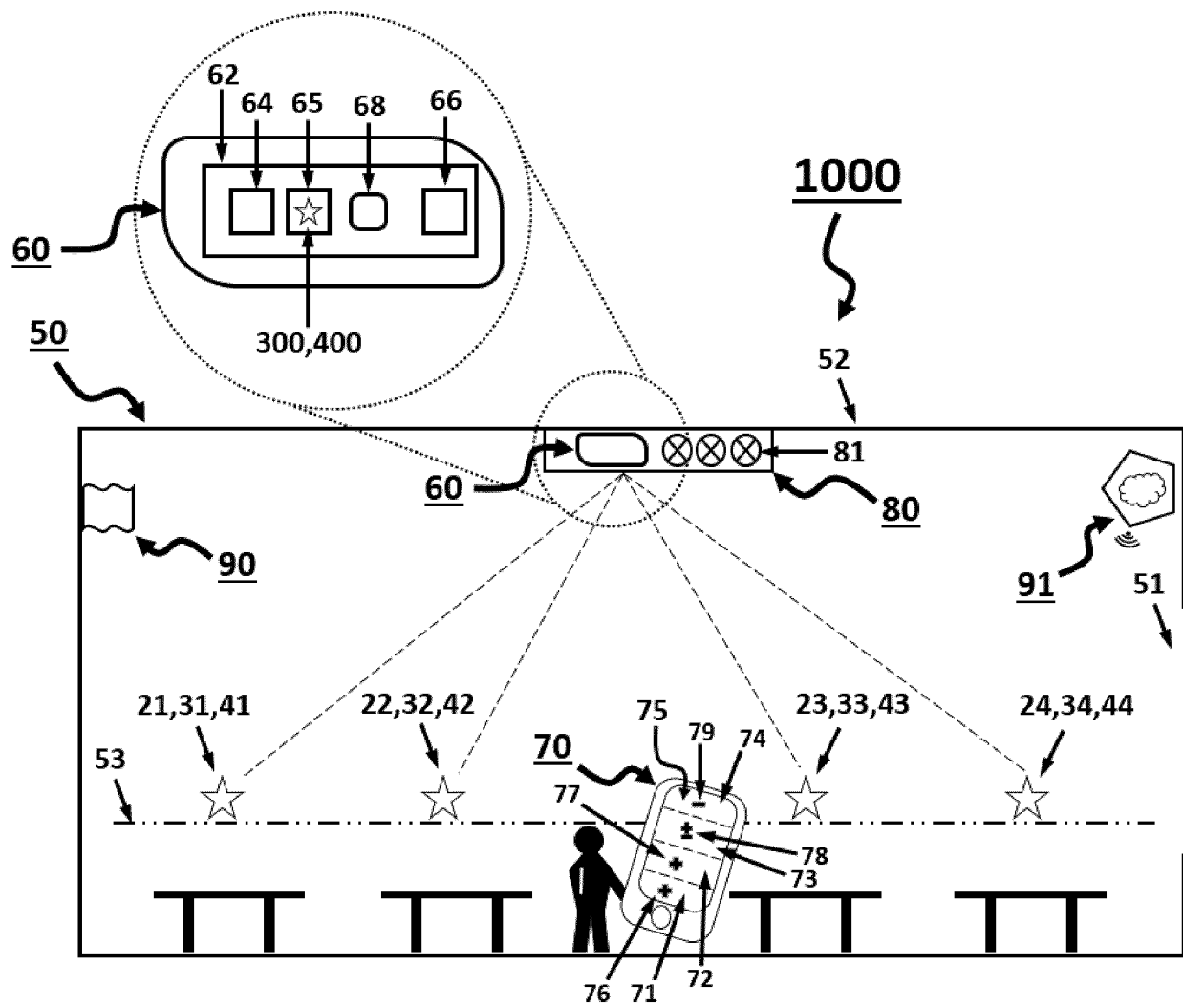


FIG.2.

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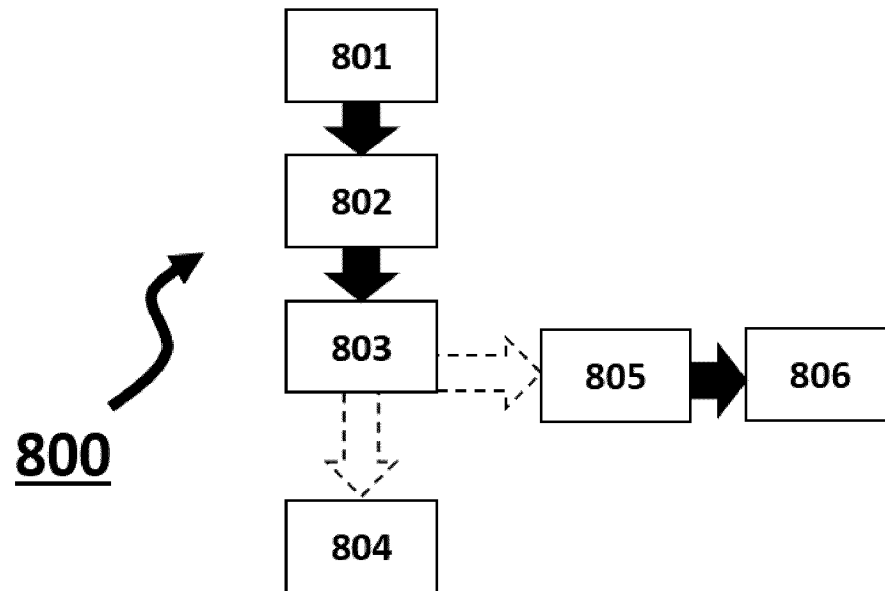


FIG.3.

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2019/079326

A. CLASSIFICATION OF SUBJECT MATTER
INV. G01N25/56 G01J5/08
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)
G01N G01J

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

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2009/304041 A1 (STREICHER MANFRED [DE] ET AL) 10 December 2009 (2009-12-10) paragraphs [0022] - [0027]; figure 1 -----	1-7,9-15
X	KR 2013 0093246 A (HALLA VISTEON CLIMATE CONTROL [KR]) 22 August 2013 (2013-08-22) paragraphs [0038] - [0049]; figures 4,5 -----	1,2,5-8, 10-14
A	CN 207 882 683 U (TRULY OPTO ELECTRONICS LTD) 18 September 2018 (2018-09-18) claim 1 -----	1-15



Further documents are listed in the continuation of Box C.



See patent family annex.

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"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

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INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2019/079326

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