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(54) Title: A METHOD FOR CONTROLLING A PLURALITY OF LIGHTING UNITS OF A LIGHTING SYSTEM

(57) Abstract: A computer implemented method for controlling a plurality of lighting units of a lighting system is disclosed. The method comprises: obtaining (402) a set of light settings, analyzing (404) the set of light settings to extract one or more features of the light settings, wherein the features relate to light characteristics of the light settings, receiving one or more signals indicative of the number of lighting units of the plurality of lighting units, determining a number of clusters based on (equal to) the number of lighting units, clustering (406) the set of light settings into the determined number of clusters based on the extracted one or more features, determining (408) respective lighting control settings for respective clusters based on the light settings of each respective cluster, associating (410) the respective clusters with respective lighting units of the lighting system, and controlling (412) the plurality of lighting units according to the respective lighting control settings of the respective associated clusters.

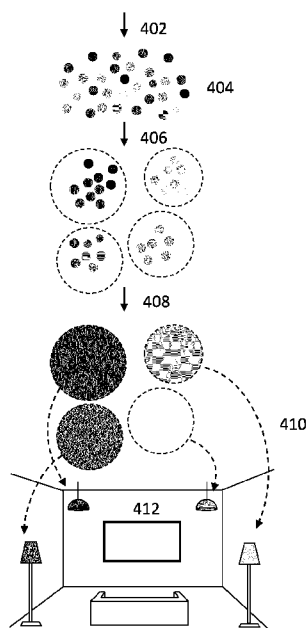


Fig. 6

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A METHOD FOR CONTROLLING A PLURALITY OF LIGHTING UNITS OF A LIGHTING SYSTEM

FIELD OF THE INVENTION

The invention relates to a computer implemented method for controlling a plurality of lighting units of a lighting system, and to a computer program product for executing the method. The invention further relates to a controller.

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BACKGROUND

Smart lighting systems enable users to control lighting units in an environment, such as the user's home. Such smart lighting systems may comprise multiple lighting units and lighting control devices (such as light switches and smartphones) that are connected via a network. The light output of the lighting units is typically controlled based on, for example, user inputs received via a user input device, preprogrammed routines, user actuated sensor inputs, etc. In certain cases, it may be desirable to use other sources as an input for controlling the light.

In a first example, it may be desirable to control the light in a user's environment (e.g. a user's home) based on light settings of lighting units in a second environment (e.g. a public environment such as a concert venue). In another example, it may be desirable to control the light in a user's environment based on the light settings of multiple other users. In a further example, it may be desirable to control the light in a user's environment based on multiple colors extracted from an image. For each of these examples, an initial set of light settings (e.g. the light settings of the venue, the light settings of the other users, or light settings extracted from an image) is to be mapped onto the lighting units located in the environment of the user. It may occur that the number of light settings of the initial set does not correspond to the number of lighting units located in the environment of the user, and that the light effect generated based on the set of light settings needs to be downscaled. Meanwhile, it is often desirable that if a lighting atmosphere created by the initial set of lighting settings is mapped onto a lighting infrastructure located in the environment of the user, the lighting atmosphere is maintained.

WO 2018/073052 discloses a method for automatically creating lighting settings based on an image or images. An event associated with such images can be detected, such as the uploading of a number of photos to a gallery, or the posting of an image on social media. By assessing the event, and the image or images, it is possible to determine whether and how to create a new lighting scene. If multiple images are present, it may be possible to group or merge the images to downselect to one or a small number of images, or image parameters. The lighting scene or scenes can then be created based on these images or parameters.

10 SUMMARY OF THE INVENTION

It is an object of the present invention to provide a method to maintain a lighting atmosphere created by an initial set of light settings when that set of light settings is mapped onto a (different) lighting infrastructure.

According to a first aspect of the present invention, the object is achieved by a computer implemented method for controlling a plurality of lighting units of a lighting system, the method comprising:

- obtaining a set of light settings,
- analyzing the set of light settings to extract one or more features of the light settings, wherein the features relate to light characteristics of the light settings,
- clustering the set of light settings into a plurality of clusters based on the extracted one or more features,
- determining respective lighting control settings for respective clusters based on the light settings of each respective cluster,
- associating the respective clusters with respective lighting units of the lighting system, and
- controlling the plurality of lighting units according to the respective lighting control settings of the respective associated clusters.

The set of light settings may, for example, be obtained from a remote lighting system (e.g. a public environment such as a concert venue, or from one or more other users' lighting systems) or from a database storing multiple sets of light settings. Alternatively, the set of light settings may be light settings retrieved from or based on image or video content. The set of light settings may comprise a number of light settings larger than the number of lighting units in the lighting system. By analyzing the set of light settings and extracting one or more features of the light settings, the light settings can be clustered into a plurality of

clusters based on the extracted features. Each of the plurality of clusters may be analyzed to determine a lighting control setting for each cluster. The lighting control setting may, for example, be determined by taking an average light setting of the light settings of a respective cluster. This results in a set of lighting control settings which are to be mapped onto the lighting units of a user's lighting system (e.g. a lighting infrastructure located in an environment, e.g. a living room). The respective clusters, and therewith the respective lighting control settings of these clusters, are associated with (or mapped onto) the lighting units of the lighting system, and the lighting units are controlled according to the respective lighting control settings of the respective associated clusters. This method enables downscaling a number of light settings onto a smaller number of lighting units. This provides the benefit that the (initial) lighting atmosphere created by the (initial) set of lighting settings is largely maintained when that set of light settings is mapped onto a lighting infrastructure of the user.

The method may further comprise: receiving one or more signals indicative of a number of lighting units of the plurality of lighting units of the lighting system, determining a number of clusters based on the number of lighting units, and clustering the set of light settings into the determined number of clusters. For many clustering algorithms, such as k-means clustering, which is a widely used clustering algorithm, it is required that the number of clusters (the cardinality) is provided. This is often considered a disadvantage, because the optimal choice of the number of clusters typically creates a balance between maximum compression of the data using a single cluster, and maximum data representation accuracy by assigning each data point to its own cluster. The inventors have realized that for clustering light settings this does not have to be a disadvantage. For lighting control such data representation may be less relevant, whereas maintaining/duplicating the original lighting atmosphere is more relevant. Therefore, the number of clusters may be determined based on the number of lighting units, thereby further improving downscaling of a lighting atmosphere. The number of clusters may be determined such that the number of clusters is (substantially) equal to the number of lighting units. This may further improve downscaling of a lighting atmosphere.

The light settings may be clustered into the clusters such that each cluster to be associated with a respective lighting unit comprises a number of light settings above a threshold. Created clusters that have a number of light settings below the threshold may not be associated with a lighting unit. Hence, outliers (anomalies) may not be mapped onto the lighting units. Alternatively, the number of clusters may be determined such that each cluster

to be associated with a respective lighting unit comprises a number of light settings above the threshold. If certain clusters would have a number of light settings below the threshold, outliers (anomalies) may be merged with the clusters that have the number of light settings below the threshold. Hence, outliers (anomalies) may be taken into account when the lighting control settings for respective clusters are determined.

The method may further comprise: analyzing the set of light settings to extract a plurality of features from the light settings, and the clustering of the set of light settings into the plurality of clusters may be based on the extracted plurality of features. The features, which relate light characteristics of the respective light settings, may, for example, relate to a color of the light setting, a brightness of the light setting, a saturation of the light setting, a beam shape/angle of the light, an orientation of the light, a function of the light, a type of lighting unit by which the light has been emitted, a position of the light or the lighting unit emitting the light settings relative to a reference point, a pattern as provided by the light, or a level of dynamics of the light. Two or more of these features, for instance color and brightness, may be taken into account when the clusters are created. This is beneficial because the data representation accuracy of the set of light settings is improved, resulting in an improved downscaling of the lighting atmosphere. The respective features of the plurality of features may have respective feature ranking values. The step of clustering the set of light settings into the plurality of clusters based on the extracted plurality of features may be further based on the feature ranking values of the plurality of features. These feature ranking values may, for example, be predefined, based on user preferences, based on light rendering characteristics of the lighting units of the lighting system, based on a time of day, based on a current user activity, etc. A first feature (e.g. color) may have a higher ranking value than a second feature (e.g. beam angle). Some features may be more influential on the lighting atmosphere. It may therefore be beneficial to provide features ranking values to the different types of features, because it improves maintaining the lighting atmosphere.

The method may further comprise: receiving a subsequent set of light settings, and reclustering the light settings of the subsequent set of light settings. The sets of light settings may be received as a stream of sets of light settings. The sets of light settings may, for example, be received from a remote lighting system (e.g. a public environment such as a concert venue, or from one or more other users' lighting systems), or from a database storing multiple sets of light settings, which database is updated periodically. Alternatively, the set of light settings may be light settings retrieved from video content which may be rendered on a display located in the user's environment. When the subsequent set of light settings has been

received, the light settings of the (original) clusters may be reclustered into new clusters. This is beneficial, because the lighting atmosphere is kept up to date.

The step of reclustering may be executed if a difference between a previous and the subsequent set of light settings is above a threshold. In other words, the step of reclustering occurs when the differences between subsequent sets of light settings is substantial. In embodiments, the step of reclustering may be executed (only) when the lighting atmosphere substantially changes. This is beneficial, because it reduces the required computational power for reclustering the light settings. Additionally or alternatively, the step of reclustering may be executed periodically or randomly. The reclustering may be executed every time period, e.g. every minute, every hour, or at predefined moments in time (e.g. at specific times or every morning, afternoon or evening). The interval between the subsequent reclustering steps may be dependent on to what extent the lighting atmosphere is to be translated. If, for example, the original set of light settings is extracted from a video, the reclustering may be executed every 50 milliseconds, whereas if the original set of light settings originates from a database of current or favorite light settings of multiple other users, the reclustering may be executed every minute. This also may reduce the required computational power for reclustering the light settings. The method may further comprise the step of re-associating the clusters with the respective lighting units for subsequent sets of light settings.

Alternative to reclustering, the method may comprise the step of maintaining the associations between the clusters and the respective lighting units for subsequent sets of light settings. Thus, if a first cluster has been associated with a first lighting unit, and a second cluster has been associated with a second lighting unit, the light settings of these clusters may be maintained in these clusters for subsequent sets of light settings. This may be beneficial when the sets of light settings originate from a remote lighting system, and the lighting atmosphere of that remote lighting system is to be preserved. Each (initial) light setting may have been retrieved from a respective lighting unit of a remote lighting system, and each light setting of the subsequent set of light settings may have been retrieved from the same respective lighting unit of the remote lighting system. When the (initial) light settings of the (initial) set of light settings have been clustered to the (initial) clusters, these clusters and the clustered light settings retrieved from their respective lighting units may be maintained. Thus, the subsequent light settings of the subsequent set of light settings remain in the same (initial) clusters. A subsequent lighting control setting may be determined for the

respective clusters based on the subsequent light settings of each cluster, and the lighting units associated with the (initial) clusters may be controlled according to these light settings.

The step of determining respective lighting control settings for respective clusters based on the light settings of each respective cluster may comprise: determining average light settings for the respective clusters based on the features of one or more light settings of each respective cluster. The features used to determine the lighting control settings of the clusters may be the same features used to create the clusters. Alternatively, the features used to determine the lighting control settings of the clusters may be different from the features used to create the clusters. For instance, the light settings may be clustered based on a first feature (e.g. positions of the light or the lighting units emitting the light settings), and the lighting control settings may be determined based on a second feature (e.g. colors of the light settings of the respective clusters).

The clusters may be associated with the respective lighting units of the lighting system based on at least one of: light rendering characteristics of the lighting units, the function of the lighting units and the types of lighting units. The light rendering characteristics may for example relate to the color, brightness, saturation, beam shape/size/angle of the light that can be rendered by the respective lighting unit. The function of the lighting unit may relate to, for example, providing functional lighting (e.g. for reading a book), providing atmosphere lighting (e.g. for providing an ambience), providing indicator lighting (e.g. for notifying a user), etc. Examples of types of lighting units are LED bulbs, LED strips, pendant luminaires, recessed luminaires, wall washers, table lamps, projector lamp, etc. A larger cluster may, for example, be associated with a first lighting unit (e.g. a wall washer) configured to provide a light effect with a larger area of effect, and a smaller cluster may, for example, be associated with a second lighting unit (e.g. a spot light) configured to provide a light effect with a smaller area of effect (e.g. a narrow beam). This is beneficial, because more prominent light settings of the (initial) set of light settings will be also more prominent in the environment of the user, thereby improving downscaling of the lighting atmosphere.

The association of the respective clusters with respective lighting units of the lighting system may be based on one or more features of the light settings of each respective cluster. A feature used to determine the association may be different from the one or more features used to create the clusters. A feature used to determine the association may be different from one or more features used to determine the lighting control settings for a respective cluster. The light settings of the set of light settings may, for example, be clustered

based on a first (type of) feature (e.g. brightness), and/or the clusters may be associated with lighting units based on a second (type of) feature (e.g. position), and/or the lighting control settings may be determined based on a third (type of) feature (e.g. color).

The method may further comprise the steps of determining cluster sizes of the plurality of clusters, wherein a cluster size is indicative of a number of light settings of a respective cluster, and determining light rendering characteristics of the plurality of lighting units of the lighting system. The association of the respective clusters with the respective lighting units may be further based on the sizes of the respective clusters and the light rendering characteristics of the plurality of lighting units. This is beneficial, because more prominent light settings of the (initial) set of light settings will be also more prominent in the environment of the user, thereby improving downscaling of the lighting atmosphere.

The method may further comprise, if the number of clusters is lower than the number of lighting units, associating at least one of the clusters with at least two lighting units of the lighting system. When number of clusters is lower than number of lighting units, at least two (different) lighting control settings may be determined for a cluster, and the at least two lighting units may be controlled according to the at least two (different) lighting control settings.

The method may further comprise, if the number of clusters of light settings is lower than the number of lighting units, clustering the lighting units of the lighting system based on features of the lighting units, wherein the features of the lighting units relate to positions and/or light rendering characteristics of the lighting units. Thus, if the number of clusters of light settings is lower than the number of lighting units, the lighting units are clustered based on their relative positions or based on their light rendering characteristics. At least one of the clusters of light settings may then be associated with a cluster of lighting units, and the cluster of lighting units may be controlled according to the respective lighting control setting of the respective associated cluster.

A light characteristic of a light setting may, for example, relate to a color of the light setting, a brightness of the light setting, a saturation of the light setting, a beam shape/angle of the light, a function of the light, a type of lighting unit by which the light has been emitted, an orientation/position of the lighting unit emitting the light setting or an orientation/position of the light effect of the emitted light, a level of dynamics of the light, a moment in time when the light setting has been activated (e.g. morning/afternoon), a preference value of the light setting indicative of how often the light setting has been selected relative to other light settings, etc. The light settings may be represented as values indicative

of one or more of these characteristics. The color/brightness of the light settings may, for example, be represented as color/brightness values, the beam width and/or angle may be represented as numerical values, the position of a light or the lighting unit emitting the light setting may be represented as coordinate values, etc. The values of the light settings may be used for clustering the light settings into the plurality of clusters. Alternatively, the light settings may be represented as semantic descriptions. Semantic descriptions are typically textual representations of light settings (or light scenes). Examples of semantic descriptions of light settings include “on”, “off”, “sunset”, “romantic”, “beach”, “office”, etc. The method may further comprise applying a natural language processing (NLP) algorithm to analyze the semantic descriptions, and determining semantic similarities between the semantic descriptions of the light settings to cluster the light settings into the plurality of light settings. The method may further comprise the step of determining the lighting control settings for the respective clusters based on the semantic descriptions of the light settings of the respective cluster. The lighting control settings for the respective clusters may be determined based on semantic similarities between the semantic description of the light settings.

The clustering of the light settings into the plurality of clusters may be performed using machine learning algorithms. The selection of a certain clustering algorithm may depend on different parameters (e.g. the number of light settings, the number of features of the light settings that are to be analyzed, whether the number of clusters is known or not, etc.). A possible clustering algorithm is k-means clustering. The advantage of this way of clustering is that it requires a relatively low amount of computing power, and that it is relatively fast. This algorithm requires that the number of clusters is provided, which number may be substantially equal to the number of lighting units in the lighting system. An alternative type of clustering algorithm uses Mean-Shift clustering, which locates center points of clusters. This type of algorithm may be beneficial when the number of clusters has not been defined, because the mean-shift automatically discovers this. Density-Based Spatial Clustering of Applications with Noise (DBSCAN) is another alternative which, similar to mean-shift, does not require the number of clusters to be defined. Another benefit of DBSCAN is that it identifies outliers as noise (as compared to assigning them to a cluster). It should be understood that these clustering algorithms are mere examples, and that the skilled person is able to apply different clustering algorithms without departing from the scope of the appended claims.

The method may further comprise, if the number of clusters is higher than the number of lighting units, selecting a subset of clusters of the plurality of clusters, and

controlling one or more lighting units of the lighting system according to lighting control settings of the selected subset of clusters.

The method may further comprise, if the number of clusters is higher than number of lighting units, selecting a subset of clusters of the plurality of clusters, and
5 controlling a lighting unit according to the lighting control settings of the subset of clusters over time. The subset of clusters, that may be associated with the (single) lighting unit, may be selected from the plurality of clusters based on the light rendering characteristics of the lighting unit, based on the distance between the clusters, etc.

The method may further comprise, if the number of clusters is higher than
10 number of lighting units, selecting a subset of clusters of the plurality of clusters based on the light rendering characteristics of the lighting units, and associating the subset of clusters with respective lighting units of the lighting system. The subset may be selected based on the light rendering characteristics of the lighting units. If, for example, the lighting units in the lighting system are unable to render a certain color (e.g. turquoise), a cluster comprising this color
15 may be excluded from the subset.

The method may further comprise, if the number of clusters is higher than number of lighting units, selecting a subset of clusters of the plurality of clusters based on at least one of: time of day, a user activity and a user preference, and the method may further
20 comprise associating the subset of clusters with respective lighting units of the lighting system.

The method may further comprise the step of selecting, if the number of clusters is higher than number of lighting units, a subset of clusters based on variability values of the clusters, wherein each variability value is indicative of a level of distinctness of one or more features of a respective cluster with respect to the same one or more features of
25 the other clusters, and associating the subset of clusters with respective lighting units of the lighting system.

The method may further comprise, if the number of clusters is higher than number of lighting units, assigning cluster ranking values to the clusters, wherein the cluster ranking values are based on the number of light settings in the respective cluster, the spread
30 (i.e. the variability between the data points (the light settings) in the respective cluster) and/or the distance (i.e. the distance of the respective cluster with respect to other clusters), selecting a subset of clusters of the plurality of clusters based on the cluster ranking values, and associating the subset of clusters with respective lighting units of the lighting system.

The method may further comprise, if the number of clusters is higher than number of lighting units, clustering the plurality of clusters into group clusters based on linkage criteria of the plurality of clusters. When for example agglomerative hierarchical clustering algorithms are used, the linkage criteria may be determined and the plurality of clusters may be grouped into group clusters based on the linkage criteria.

According to a second aspect of the present invention, the object is achieved by a computer program product for a computing device, the computer program product comprising computer program code to perform any one of the above-mentioned methods when the computer program product is run on a processing unit of the computing device.

According to a third aspect of the present invention, the object is achieved by a controller for controlling a plurality of lighting units of a lighting system, the controller comprising:

- an input configured to obtain a set of light settings,
- a processor configured to analyze the set of light settings to extract one or more features of the light settings, wherein the features relate to light characteristics of the light settings, cluster the set of light settings into a plurality of clusters based on the extracted one or more features, determine respective lighting control settings for respective clusters based on the light settings of each respective cluster, associating the respective clusters with respective lighting units of the lighting system, and controlling the plurality of lighting units according to the respective lighting control settings of the respective associated clusters.

It should be understood that the computer program product and the controller may have similar and/or identical embodiments and advantages as the above-mentioned methods.

In the context of the present invention, the term “set of light settings” relates to a plurality of light settings. Each light setting may comprise information indicative of light characteristics of the light setting or its light effect, which may for example include: a color of the light, a brightness of the light, a saturation of the light, a beam shape/angle of the light, an orientation of the light, a function of the light, a type of lighting unit by which the light has been emitted, a position of the light or the lighting unit by which the light has been emitted, or a level of dynamics of the light (i.e. a degree to which the light changes over time). These characteristics may be represented as values (e.g. a color value, a brightness value, a beam angle value, a location value, etc.) and/or as semantic descriptions (e.g. “on:”, “off”, “sunset”, “romantic”, “beach”, “office”, “living room light”, “down light”, “left TV light”, etc.).

In the context of the present invention, the term “lighting control setting” relates to one or more lighting control instructions for one or more lighting units. The lighting control instructions may be the same for each lighting unit, or be different for different lighting units. The lighting control instructions may relate to one or more light settings, which may for instance be defined as RGB/HSL/HSB color values, CIE color values, brightness values, beam angle/shape values, location values, etc. The lighting control setting may be communicated (e.g. as a message) to the lighting units in order to control the lighting units. The lighting control setting may be communicated via, for example, a wireless communication protocol such as Wi-Fi, Bluetooth, Zigbee, Thread, etc.

BRIEF DESCRIPTION OF THE DRAWINGS

The above, as well as additional objects, features and advantages of the disclosed systems, devices and methods will be better understood through the following illustrative and non-limiting detailed description of embodiments of devices and methods, with reference to the appended drawings, in which:

Fig. 1 shows schematically a lighting system in a user's environment and a remote lighting system,

Fig. 2 shows schematically a lighting system in a user's environment and an image based on which the lighting system is controlled,

Fig. 3a shows schematically a lighting system comprising a controller configured to control one or more lighting units of the lighting system,

Fig. 3b shows schematically a lighting system comprising a controller comprised in a remote device,

Fig. 4 schematically shows a method of controlling a plurality of lighting units of a lighting system,

Fig. 5 schematically illustrates the steps of the method of Fig. 4,

Fig. 6 schematically illustrates the steps of the method of Fig. 4,

Fig. 7a schematically shows a lighting system comprising a controller and a user input device comprising an input element configured to receive a plurality of sequential user inputs,

Fig. 7b schematically shows a lighting system comprising a controller and a user input device comprising a first input element configured to receive a first user input and a second input element configured to receive a second user input,

Fig. 8 schematically shows a method for assigning lighting control settings to a user input device,

Fig. 9 schematically illustrates the steps of a method for downscaling a set of light settings and controlling a plurality of lighting units of a lighting system based thereon,

5 and

Fig. 10 illustrates schematically a method for downscaling a set of light settings and controlling a plurality of lighting units of a lighting system based thereon.

All the figures are schematic, not necessarily to scale, and generally only show parts which are necessary in order to elucidate the invention, wherein other parts may be
10 omitted or merely suggested.

DETAILED DESCRIPTION OF EMBODIMENTS

Smart lighting systems enable users to control lighting units in an environment, such as the user's home. Such smart lighting systems may comprise multiple
15 lighting units and lighting control devices (such as light switches and smartphones) that are connected via a network. Figs. 1 and 2 illustrate examples of such lighting systems 100. The light output of lighting units 110, 112, 114, 116 of such a lighting system 100 is typically controlled based on, for example, user inputs received via a user input device, preprogrammed routines, user actuated sensor inputs, etc. The inventors have realized that it
20 may be desirable to use other sources as an input for controlling the light.

In a first example, as illustrated in Fig. 1, it may be desirable to control the light in a user's environment 100 (e.g. a user's home) based on light settings of lighting units in a second environment 150 (e.g. a public environment such as a concert venue or an outdoor environment). In another example, it may be desirable to control the light in a user's
25 environment based on the light settings of multiple other users. In a further example, as illustrated in Fig. 2, it may be desirable to control the light in a user's environment based on multiple colors in an image 170. For each of these examples, an initial set of light settings (e.g. the light settings of the venue, the light settings of the other users, or light settings extracted from an image) is to be mapped onto the lighting units 112, 114, 116, 118 of the
30 lighting system 100 of the user. It may occur that the number of light settings of the initial set does not correspond to the number of lighting units located in the environment of the user, and that the light effect generated based on the set of light settings needs to be downscaled.

Fig. 3a illustrates a controller 102 configured to control one or more lighting units 112, 114 of a lighting system 100. The controller 102 comprises an input 104

configured to receive or obtain a set of light settings. The controller 102 further comprises a processor 106 configured to analyze the light settings to extract/retrieve one or more features of the light settings. The features may relate to light characteristics of the light settings. The processor 106 is further configured to control the one or more lighting units 112, 114 of the lighting system 100.

The controller 102 may be located in the same environment wherein the lighting units 112, 114 are located. The controller 102 may, for example, be comprised in a hub, a bridge or another central controller of the lighting system 100. In other examples, the controller 102 may be comprised in a personal user device such as a pc, a smartphone, a tablet pc, a wearable device, etc. Alternatively, the controller 102 may be comprised in a remote server, which may communicate with the lighting units 112, 114 via a network such as the internet. An example of a remote server comprising the controller 102 has been illustrated in Fig. 3b. The location of the controller 102 may depend on the system architecture of the lighting system 100.

The input 104 may be configured to obtain the set of light settings from a memory 180. The memory 180 may be a database storing the set of light settings. The memory may be comprised in the controller 102. Alternatively, the memory 180 may be located remotely, and for example accessible via the internet.

The input 104 may be configured to obtain the light settings from a remote lighting system. The light settings may be streamed from the remote lighting system to the lighting system via a network such as the internet.

The input 104 may be an input of the processor 106. Alternatively, the input 104 may be a communication module configured to communicate with other devices via a network (e.g. a LAN, WLAN, the internet, etc.). The input 104 may be a transceiver, further configured to communicate with devices such as the lighting units 112, 114.

The set of light settings may, for example, be a set of light settings that originates from a remote lighting system located in a second environment 150 (e.g. a public environment such as a concert venue or an outdoor environment, a neighbor's lighting system, a friend's lighting system, etc.). The set of light settings of the remote lighting system may be streamed to the processor 106. Alternatively, the set of light settings of the remote lighting system may be periodically communicated to the processor 106.

Fig. 3b illustrates an example of a controller 102 comprised in a remote device. The controller 102 may be configured to receive a set of light settings from a first lighting system 150. The light settings may, for example, be received from a central

controller 160 (e.g. a bridge or a hub) of the first lighting system 150. The set of light settings may be current light settings of lighting units 152, 154 of the first lighting system 150. The processor 106 (not shown in Fig. 3b) may analyze the set of light settings and determine lighting control settings for the lighting units 112, 114 of the lighting system 100. These lighting control settings may be communicated to a central controller 120 of the lighting system 100, which may control the lighting units 112, 114 accordingly.

The set of light settings may, for example, be a set of light settings of multiple other users. The (remote) memory 180 may store these light settings. The set of light settings of the other users may be a set of favorite light settings of these other users, a set of current light settings of the other users, a set of light settings shared by the other users, etc. The set of light settings may be continuously or periodically updated in a database stored in the memory 180. The set of light settings of the remote lighting systems may be streamed to the processor 106 or be periodically communicated to the processor 106. In embodiments, a subset of the set of light settings of the remote lighting systems may be selected, for example based on the preferences of the user of the lighting system 100, an activity of the user, lighting requirements for the user, etc.

The set of light settings may, for example, be a set of light settings extracted from or based on media content (e.g. an image, video or game content). The light settings based on the media content may be streamed (e.g. via the internet) or be determined/calculated by the processor 106. The media content may be received via the input 104, which may be an input of the processor 106. The media content may be analyzed, and the light settings may be extracted from the media content (e.g. based on pixel color values in images of the media content). Alternatively, the light settings of the media content may be predefined light settings. The light settings may, for example, be scripted and rendered in synchronization with rendering of the media content. Such a light script based on media content may be received (e.g. streamed or downloaded) by the input 104 via a network.

The controller 102 may further comprise a communication module to communicate with the lighting units 112, 114. The communication module may comprise a transmitter or a transceiver (which may comprise the input 104). The communication module may be configured to communicate lighting control instructions to the lighting units 112, 114. The lighting control instructions may be the same for each lighting unit, or be different for different lighting units. The lighting control instructions may relate to one or more light settings, which may for instance be defined as RGB/HSL/HSB color values, CIE color values, brightness values, beam angle/shape values, location values, etc. The lighting control

setting may be communicated (e.g. as a message) to the lighting units 112, 114 in order to control the lighting units 112, 114. Various wired and wireless communication protocols may be used, for example Ethernet, DMX, DALI, USB, Bluetooth, Wi-Fi, Li-Fi, 3G, 4G, 5G or ZigBee. A specific communication technology may be selected based on the communication capabilities of the lighting units 112, 114, the power consumption of the communication driver for the (wireless) communication technology and/or the communication range of the signals. If the controller 102 is comprised in a remote server, the controller 102 may be configured to control the lighting units 112, 114 via an intermediary device such as a bridge, a hub, a central (home) lighting control system, a smartphone, etc. This may depend on the system architecture of the lighting system 100.

The one or more lighting units 112, 114 may be any type of lighting units 112, 114 arranged for receiving lighting control instructions. The one or more lighting units 112, 114 may comprise inputs configured to receive lighting control instructions (which may be indicative of light settings) from the controller 102, either directly or via an intermediary device. The lighting units 112, 114 may be one or more light sources (e.g. LED/OLED light sources). The lighting units 112, 114 may be arranged for providing general lighting, task lighting, ambient lighting, atmosphere lighting, accent lighting, indoor lighting, outdoor lighting, etc. The lighting units 112, 114 may be installed in a luminaire or in a lighting fixture. The lighting units 112, 114 may be addressable light sources of a luminaire (e.g. a light source array, an LED strip, etc.). The lighting units 112, 114 may be portable lighting units (e.g. a hand-sized device, such as an LED cube, an LED sphere, an object/animal shaped lighting unit, etc.) or wearable lighting units (e.g. a light bracelet, a light necklace, etc.).

The processor 106 may be configured to analyze the set of light settings to extract one or more features of the light settings, wherein the features relate to light characteristics of the light settings, and to cluster the set of light settings into a plurality of clusters based on the extracted one or more features. The processor 106 may cluster the light settings into the plurality of clusters using machine learning algorithms.

One way to solve the problem of downscaling a set of light settings is to use machine learning algorithms. The problem of downscaling may be addressed by using unsupervised learning or representation learning. The goal for unsupervised learning is to model the underlying structure or distribution in the data in order to learn more about the data, e.g. to learn about the (important) features in the set of light settings which defines the

light settings. The unsupervised learning algorithms are left to their own devices to discover and present the structure in the data. Unsupervised learning may be broadly categorized into:

- Clustering; and
- Dimensionality reduction

- 5 When a clustering problem is to be solved, the goal is to discover inherent groupings in the data, such as grouping the set of light settings based on the extracted one or more features. Dimensionality reduction may be defined as reducing the size/number of a data set, for example, by removing the redundancy in the data and keeping only the important features.

- Machine learning clustering algorithms are known in the art, and the
 10 application/selection of a specific algorithm may depend for example on the number of light settings, the number of features of the light settings that are to be analyzed, whether the number of clusters is known or not, etc. A possible well-known clustering algorithm is k-means clustering. The advantage of this algorithm is that it requires a relatively low amount of computing power, and that it is relatively fast. For the analyzed one or more features,
 15 $(x_1, x_2, \dots, x_n)$, where each feature is a d-dimensional real vector, k-means clustering aims to partition the n features into k ($\leq n$) sets $S = \{S_1, S_2, \dots, S_k\}$; wherein k is the number of clusters. The objective of k-means clustering is to minimize the within-cluster sum of squares (WCSS) (i.e. variance). Formally, the objective is to find:

$$\operatorname{argmax}_S \sum_{i=1}^k \sum_{x \in S_i} \|x - \mu_i\|^2,$$

- 20 Wherein μ_i is the mean of points in S_i . The most common algorithm uses an iterative refinement technique. Due to its ubiquity, it is often called the k-means algorithm; it is also referred to as Lloyd's algorithm. Lloyd's algorithm is known in the art and is not further discussed. One of the key questions in k-means clustering is the selection of number of clusters k . This is often considered a disadvantage, because the optimal choice of the number
 25 of clusters typically creates a balance between maximum compression of the data using a single cluster, and maximum data representation accuracy by assigning each data point to its own cluster. The inventors have realized that for clustering light settings this does not have to be a disadvantage. The number of clusters may be determined such that the number of clusters is (substantially) equal to the number of lighting units. This may further improve
 30 downscaling of a lighting atmosphere.

Another clustering algorithm that may be used is Mean-Shift clustering, which locates center points of clusters. This type of algorithm may be beneficial when the number of clusters has not been defined, because the mean-shift automatically discovers this.

Density-Based Spatial Clustering of Applications with Noise (DBSCAN) is another alternative which, similar to mean-shift, does not require the number of clusters to be defined. Another benefit of DBSCAN is that it identifies outliers as noise (as compared to assigning them to a cluster). It should be understood that these clustering algorithms are mere examples, and that the skilled person is able to apply different clustering algorithms without departing from the scope of the appended claims.

The light characteristics of the light settings, and therewith the features, may, for example, relate to colors of the light setting. The processor 106 may be configured to cluster the light settings based on the colors. If, for example, the set of light settings comprises blue, red and green light settings, the processor 106 may generate clusters based on these colors (e.g. three clusters).

The light characteristics of the light settings, and therewith the features, may, for example, relate to brightness levels of the light setting. The processor 106 may be configured to cluster the light settings based on the brightness levels. If, for example, the set of light settings comprises light settings with different brightness levels, the processor 106 may generate clusters based on these brightness levels (e.g. four clusters comprising light settings with different brightness levels).

The light characteristics of the light settings, and therewith the features, may, for example, relate to beam shapes/angles of the light. The processor 106 may be configured to cluster the light settings based on the beam characteristics.

The light characteristics of the light settings, and therewith the features, may, for example, relate to an orientation/position of the lighting unit emitting the light setting or an orientation/position of the light effect of the emitted light. If, for example, the set of light settings originates from one or more remote lighting systems, the orientation/position of the original light units of the one or more remote lighting systems and/or the orientation/position of the light effect of the emitted light of by the light units of the one or more remote lighting systems may be features of the light settings. The processor 106 may be configured to cluster the light settings based on the orientation/position. If, for example, one or more first light settings of the set of light settings are indicative of a first position (e.g. left) and/or a first orientation (e.g. downward) relative to a reference position, and one or more second light settings of the set of light settings are indicative of a second position (e.g. right) and/or a second orientation (e.g. downward) relative to the reference position, the processor 106 may cluster the light settings based thereon.

If, for example, the set of light settings originates from one or more remote lighting systems, the light characteristics of the light settings, and therewith the features, may, for example, relate to a function of the light or a type of lighting unit by which the light has been emitted. The function of the lighting unit may relate to, for example, providing functional lighting (e.g. for reading a book), providing atmosphere lighting (e.g. for providing an ambience), providing indicator lighting (e.g. for notifying a user), etc. Examples of types of lighting units are LED bulbs, LED strips, pendant luminaires, recessed luminaires, wall washers, table lamps, etc. The processor 106 may be configured to cluster the light settings based on the function and/or the type of lighting unit. If, for example, one or more first light settings of the set of light settings are indicative of a first type (e.g. a spot light) and/or a first function (e.g. functional lighting) relative to a reference position, and one or more second light settings of the set of light settings are indicative of a second type (e.g. an LED strip) and/or a second function (e.g. ambient lighting) relative to the reference position, the processor 106 may cluster the light settings based thereon.

The light characteristics of the light settings, and therewith the features, may, for example, relate to a level of dynamics of the light. The light settings may be represented as values indicative of one or more of these characteristics. The level of dynamics may, for example, be determined (by the processor 106) by buffering a plurality of sets of subsequent light settings, analyzing the plurality of sets of subsequent light settings to determine differences in the light characteristics between the sets of subsequent light settings, and determining the level of dynamics based on the differences. Multiple subsequent sets of light settings may be (temporarily) stored and analyzed to determine differences in light characteristics between the sets of subsequent light settings. Alternatively, the levels of dynamics of the light settings may be predefined. The processor 106 may obtain data indicative of the levels of dynamics of the light settings. The data may be received when the light settings are obtained, for instance as metadata of the light settings. The processor 106 may be configured to cluster the light settings based on the level of dynamics of the light settings.

The light characteristics of the light settings, and therewith the features, may, for example, relate to a moment in time when the light setting has been activated (e.g. morning/afternoon, a specific time, etc.). The processor 106 may be configured to cluster the light settings based on the (average) moment in time the light settings have been selected. If, for example, one or more first light settings of the set of light settings are typically activated during a first period of the day (e.g. in the morning), and one or more second light settings of

the set of light settings are typically activated during a second period of the day (e.g. in the evening), the processor 106 may cluster the light settings based thereon. This may be beneficial if the set of light settings originate from a plurality of remote lighting systems.

The light characteristics of the light settings, and therewith the features, may, for example, relate to a preference value of the light setting indicative of how often the light setting has been selected relative to other light settings. The processor 106 may be configured to cluster the light settings based on the preference values. If, for example, one or more first light settings of the set of light settings are more preferred compared to one or more second light settings, the processor 106 may cluster the light settings based thereon. This may be beneficial if the set of light settings originate from a plurality of remote lighting systems, wherein the preference values are based on the preferences of users of the remote lighting systems.

The light characteristics of the light settings, and therewith the features, may, for example, relate to a frequency with which the light setting has been selected relative to other light settings. The processor 106 may be configured to cluster the light settings based on the frequency. If, for example, one or more first light settings of the set of light settings are selected more frequent (by other users) compared to one or more second light settings, the processor 106 may cluster the light settings based thereon. This may be beneficial if the set of light settings originate from a plurality of remote lighting systems, wherein the light settings are selected by users of the remote lighting systems.

The processor 106 may be further configured to analyze the set of light settings to extract a plurality of features from the light settings, and the processor 106 may cluster the set of light settings into the plurality of clusters based on the extracted plurality of features. Two or more of these features, for instance color and brightness, may be taken into account when the clusters are created. This is beneficial because the data representation accuracy of the set of light settings is improved, resulting in an improved downscaling of the lighting atmosphere. The respective features of the plurality of features may have respective feature ranking values. The processor 106 may cluster the set of light settings into the plurality of clusters further based on the feature ranking values of the plurality of features.

The feature ranking values may, for example, be predefined. The processor 106 may access a memory storing these predefined feature ranking values.

The feature ranking values may be based on user preferences. The user preferences may be defined by a user directly (e.g. via a user interface of a personal device such as a smartphone) or be inferred from historical lighting control activities of the user. If,

for example, a user is more interested in light settings with different colors , as compared to, for example, light settings with different intensities, the ‘color’ feature may be assigned a higher ranking value compared to the ‘intensity’ feature of the light settings.

The feature ranking values may, for example, be based on light rendering characteristics of the lighting units 112, 114 of the lighting system 100. If, for example, a first feature is related to the beam shape of the light, and a second feature is related to the color of the light, while the lighting units 112, 114 of the lighting system 100 have the same (non-adjustable) beams, the first feature related to the beam shape may be assigned a lower ranking value compared to the second feature related to the color.

The feature ranking values may be based on a time of day, a user’s activity, a user’s mood, based on environmental characteristics such as the temperature, a sound level, etc. Some features may be more influential on the lighting atmosphere. It may therefore be beneficial to assign features ranking values to the different types of features.

The light characteristics of the light settings, and therewith the features, may be represented as numerical values. The color/brightness of the light settings may, for example, be represented as color/brightness values, the beam width and/or angle may be represented as numerical values, the position of a light or the lighting unit emitting the light setting may be represented as coordinate values, etc. The values of the light settings may be used for clustering the light settings into the plurality of clusters. Alternatively, the light settings may be represented as semantic descriptions. Semantic descriptions are typically textual representations of light settings (or light scenes). Examples of semantic descriptions of light settings include “on”, “off”, “sunset”, “romantic”, “beach”, “office”, etc. The processor 106 may be further configured to apply a natural language processing (NLP) algorithm to analyze the semantic descriptions, and determine semantic similarities between the semantic descriptions of the light settings to cluster the light settings into the plurality of light settings.

The processor 106 may be further configured to determine respective lighting control settings for respective clusters based on the light settings of each respective cluster. The lighting control settings may be based on the analyzed features, or based on information related to the light settings. If, for example, a cluster comprises blue-colored light settings, the processor 106 may calculate an average of these light settings, for example based on the color values of the blue-colored light settings. The processor 106 may, for example, calculate an average light setting or a mean of the light settings of a respective cluster. The features used to determine the lighting control settings of the clusters may be the same features used

to create the clusters. Alternatively, the features used to determine the lighting control settings of the clusters may be different from the features used to create the clusters. For instance, the light settings may be clustered based on a first feature (e.g. positions of the light or the lighting units emitting the light settings), and the lighting control settings may be determined based on a second feature (e.g. colors of the light settings of the respective clusters).

The processor 106 may be configured to determine a lighting control setting for a cluster by selecting a random light setting from the light settings clustered in that cluster.

The processor 106 may be further configured to receive a subsequent set of light settings, and recluster the light settings of the subsequent set of light settings. The processor 106 may be configured to receive subsequent sets of light settings as a stream of sets of light settings. The sets of light settings may, for example, be received from a remote lighting system 150 (e.g. a public environment such as a concert venue, or from one or more other users' lighting systems), or from a database 180 storing multiple sets of light settings, which database may be updated periodically. Alternatively, the set of light settings may be light settings retrieved from video content, which may for example be rendered on a display located in the user's environment.

The processor 106 may be further configured to recluster the light settings if a difference between a previous and a subsequent set of light settings is above a threshold. In other words, the reclustering occurs when the differences between subsequent sets of light settings is substantial. If, for example, the set of light settings originates from a remote lighting system 150, the step of reclustering may be executed (only) when the lighting atmosphere at the remote lighting system 150 substantially changes.

The processor 106 may be configured to recluster the light settings periodically or randomly. The reclustering may be executed every time period, e.g. every minute, every hour, or at predefined moments in time (e.g. at specific times or every morning, afternoon or evening). The interval between the subsequent reclustering actions may be dependent on to what extent the lighting atmosphere is to be translated. If, for example, the original set of light settings is extracted from a video, the reclustering may be executed every 50 milliseconds by the processor 106, whereas if the original set of light settings originates from a database of current or favorite light settings of multiple other users, the reclustering may be executed every minute.

The processor 106 may be further configured to associate the created respective clusters with respective lighting units 112, 114 of the lighting system 100.

The processor 106 may determine the associations between clusters and lighting units 112, 114 based on, for example, light rendering characteristics of the lighting units 112, 114, the function of the lighting units 112, 114 and/or the types of lighting units 112, 114. The processor 106 may be configured to apply a further machine learning step to classify the clusters, wherein the input for the classification are light properties related to the lighting characteristics of the clusters, and wherein the output are the properties of the lighting units 112, 114 (e.g. the light rendering characteristics of the lighting units 112, 114, the function of the lighting units 112, 114 and/or the types of lighting units 112, 114). The learning machine may be a neural network with one or more hidden layers, that has been trained to identify a lighting unit for the light properties of a respective cluster. The output of this neural network will show the confidence level of how well these cluster fits each light source type. The light rendering characteristics may for example relate to the color, brightness, saturation, beam shape/size/angle of the light that can be rendered by the respective lighting unit. The function of the lighting unit may relate to, for example, providing functional lighting (e.g. for reading a book), providing atmosphere lighting (e.g. for providing an ambience), providing indicator lighting (e.g. for notifying a user), etc. Examples of types of lighting units are LED bulbs, LED strips, pendant luminaires, recessed luminaires, wall washers, table lamps, etc. A larger cluster may, for example, be associated with a first lighting unit (e.g. a wall washer) configured to provide a light effect with a larger area of effect, and a smaller cluster may, for example, be associated with a second lighting unit (e.g. a spot light) configured to provide a light effect with a smaller area of effect (e.g. a narrow beam). Alternatively, the processor 106 may determine the associations between clusters and lighting units 112, 114 randomly, based on the (numerical) addresses of the lighting units 112, 114, based on the locations of the lighting units 112, 114 in the environment, etc.

The processor 106 may be further configured to control the plurality of lighting units 112, 114 according to the respective lighting control settings of the respective associated clusters. The processor 106 may communicate lighting control instructions to the respective lighting units 112, 114 to control them.

Fig. 4 schematically shows a method of controlling a plurality of lighting units of a lighting system. The method may be executed by computer program code of a computer program product when the computer program product is run on a processing unit of a

computing device, such as the processor 106 of the controller 102. The method 400 comprises the steps of: obtaining 402 a set of light settings, analyzing 404 the set of light settings to extract one or more features of the light settings, wherein the features relate to light characteristics of the light settings, clustering 406 the set of light settings into a plurality of clusters based on the extracted one or more features, determining 408 respective lighting control settings for respective clusters based on the light settings of each respective cluster, associating 410 the respective clusters with respective lighting units of the lighting system, and controlling 412 the plurality of lighting units according to the respective lighting control settings of the respective associated clusters.

Fig. 5 schematically illustrates the steps of the method of Fig. 4. In the example of Fig. 5, the set of light settings 502 may be received from a remote lighting system 150, and mapped onto the lighting system 100. Alternatively, the set of light settings 502 may have been obtained from an image 504. In a first step, the processor 106 may receive 402, 402' the set of light settings 502. The processor 106 may then analyze 404 the set of light settings 502 to extract one or more features of the light settings (e.g. colors) and cluster 406 the light settings into a plurality of clusters 512, 514, 516 based on the extracted one or more features (e.g. the colors). The processor 106 may further determine 408 respective lighting control settings 522, 524, 526 for respective clusters based on the light settings of each respective cluster (e.g. an average color values of the colors of each respective cluster 512, 514, 516, or a random light setting from each cluster). The processor 106 may then map 410 the lighting control settings 522, 524, 526 onto the lighting units 532, 534, 536, 538 of the lighting system 100 by associating 410 the respective clusters 512, 514, 516 (and therewith the respective lighting control settings 522, 524, 526) with respective lighting units 532, 534, 536. In the example provided in Fig. 5, the number of lighting units (4) 532, 534, 536, 538 is higher than the number (3) of created clusters 512, 514, 516. The processor 106 may therefore associate a cluster (in this example cluster 512) with multiple lighting units (in this example lighting devices 532 and 538). More details about associating lighting control settings with multiple lighting units when the number of lighting units is higher than the number of clusters are mentioned below. The processor 106 may then control 412 the lighting units 532, 534, 536, 538 according to the lighting control settings by communicating lighting control instructions indicative thereof (e.g. color values of the colors of the respective clusters) to the respective lighting units 532, 534, 536, 538.

The processor 106 may be further configured to receive one or more signals indicative of a number of lighting units 112, 114 of the plurality of lighting units of the

lighting system 100, and determine a number of clusters based on the number of lighting units. The number of clusters may be determined such that the number of clusters is (substantially) equal to the number of lighting units 112, 114. Fig. 6 schematically illustrates the steps of the method of Fig. 4, wherein the number of clusters (4) is based on the number of lighting units (also 4). Here, the number of clusters is set equal to the number of lighting units. For many clustering algorithms, such as k-means clustering, it is required that the number of clusters (the cardinality) is provided. The processor 106 thus may determine/set number of clusters based on the number of lighting units. The processor 106 may communicate with the one or more lighting units 112, 114, or with an intermediary device, to obtain the signal indicative of a number of lighting units 112, 114.

The processor 106 may be configured to cluster the light settings into the clusters such that each cluster to be associated with a respective lighting unit comprises a number of light settings above a threshold. Created clusters that have a number of light settings below the threshold may not be associated with a lighting unit. Hence, outliers (anomalies) may not be mapped onto the lighting units 112, 114. Alternatively, the number of clusters may be determined such that each cluster to be associated with a respective lighting unit comprises a number of light settings above the threshold. If certain clusters would have a number of light settings below the threshold, outliers (anomalies) may be merged with the clusters that have the number of light settings below the threshold. Hence, outliers (anomalies) may be taken into account when the lighting control settings for respective clusters are determined.

The processor 106 may re-associate the clusters with the respective lighting units for subsequent sets of light settings. The re-association may be executed similar to the association as mentioned above.

The processor 106 may be configured to maintain the associations between the clusters and the respective lighting units for subsequent sets of light settings. Thus, if a first cluster has been associated with a first lighting unit, and a second cluster has been associated with a second lighting unit, the light settings of these clusters may be maintained in these clusters for subsequent sets of light settings. Each (initial) light setting may have been retrieved from a respective lighting unit of a remote lighting system 150, and each light setting of the subsequent set of light settings may have been retrieved from the same respective lighting unit of the remote lighting system. When the (initial) light settings of the (initial) set of light settings have been clustered into the (initial) clusters, the processor 106 may maintain these clusters and the clustered light settings retrieved from their respective

lighting units. A subsequent lighting control setting may be determined by the processor 106 for the respective clusters based on the subsequent light settings of each cluster, and the lighting units 112, 114 associated with the (initial) clusters may be controlled according to these light settings.

5 The processor 106 may be further configured to determine cluster sizes of the plurality of clusters, wherein the cluster size is indicative of a number of light settings of a respective cluster. The processor 106 may be further configured to determine/obtain light rendering characteristics of the plurality of lighting units 112, 114 of the lighting system 100, and associated of the respective clusters with the respective lighting units based on the sizes
10 of the respective clusters and the light rendering characteristics of the plurality of lighting units. The processor 106 may, for example, obtain one or more signals indicative of the light rendering characteristics of the lighting units 112, 114. The light rendering characteristics may relate to the beam shape, beam size, etc. of the lighting units. A first lighting unit 112 may, for example, be a spotlight with a narrow beam, and a second lighting unit 114 may, for
15 example, be a wall washer with a wide beam. Based on these light rendering characteristics, the processor 106 may, for example, associate a larger cluster (a cluster with more light settings) with the wall washer, and a smaller cluster to the spot light.

 Additionally or alternatively, the processor 106 may be further configured to determine spreads of the plurality of clusters, wherein the spread is indicative of volume of a
20 respective cluster. The processor 106 may be further configured to determine/obtain light rendering characteristics of the plurality of lighting units 112, 114 of the lighting system 100, and associated of the respective clusters with the respective lighting units based on the sizes of the respective clusters and the light rendering characteristics of the plurality of lighting units.

25 The processor 106 may be further configured to associate a cluster with multiple lighting units of the lighting system 100. When number of clusters is lower than number of lighting units, at least two (different) lighting control settings may be determined for a cluster, and the at least two lighting units may be controlled according to the at least two (different) lighting control settings. This has been illustrated in Fig. 5, wherein the processor
30 106 may determine that the number of clusters is lower than the number of lighting units, and associate a cluster 522 with multiple lighting units 532, 538 of the lighting system 100. If the number of clusters of light settings is lower than the number of lighting units of the lighting system 100, the processor 106 may cluster the lighting units of the lighting system 100 based on features of the lighting units. The features of the lighting units may relate to positions

and/or light rendering characteristics of the lighting units 112, 114. Referring again to Fig. 5, the processor 106 may receive signals indicative of the positions and/or the light rendering characteristics of the lighting units 532, 534, 536, 538, and determine that both lighting units 532 and 538 are pendant luminaires configured to emit downward light. Based thereon, the processor 106 may determine to associate cluster 512 with those lighting units 532, 538. The processor 106 may be further configured to determine which cluster to associate with multiple lighting units based on the cluster size of the cluster and/or the spread of the cluster. A larger cluster (e.g. a cluster with a larger size and/or larger spread) may for example be associated with more lighting units compared to a smaller cluster. Referring again to Fig. 5, wherein cluster 512 has the largest cluster size (i.e. the highest number light settings), the processor 106 may determine to associate multiple lighting units 532, 538 with that cluster.

The processor 106 may be further configured to select a subset of clusters from the plurality of clusters if the number of clusters is higher than number of lighting units 112, 114. The processor 106 may then associate the selected subset of clusters with the lighting units of the lighting system 100, and control one or more lighting units of the lighting system according to lighting control settings of the selected subset of clusters.

The processor 106 may be configured to select the subset of clusters, associate the selected subset of clusters with a lighting unit, and control that lighting unit according to the lighting control settings of the subset of clusters over a period of time. The subset of clusters, that may be associated with the (single) lighting unit, may be selected from the plurality of clusters based on the light rendering characteristics of the lighting unit, based on the distance between the clusters, etc. The processor 106 may communicate a plurality of lighting control commands of the respective clusters to the lighting unit over time, or the processor may generate a dynamic lighting control setting indicative of the lighting control settings of the subset of clusters, and communicate the dynamic lighting control setting to the lighting unit, which lighting unit then controls its light output over time according to the dynamic lighting control command.

The processor 106 may be configured to select the subset of clusters of the plurality of clusters based on the light rendering characteristics of the lighting units, and associate the subset of clusters. The processor 106 may be configured to compare the lighting control settings of the clusters with the light rendering characteristics of the lighting units 112, 114. If, for example, the lighting units in the lighting system are unable to render a certain color (e.g. turquoise), a cluster comprising this color may be excluded from the subset.

The processor 106 may be configured to select the subset of clusters of the plurality of clusters based on at least one of: time of day, a user activity and a user preference. For certain user activities or times of day certain types of illumination may be more suitable than others, and the processor 106 may select a subset of clusters based on one or more rules related to the time of day, a user activity and/or a user preference. Techniques for detecting user activities are known in the art and will therefore not be discussed in detail.

The processor 106 may be configured to select the subset of clusters based on variability values of the clusters, wherein each variability value is indicative of a level of distinctness of (one or more features of) a respective cluster with respect to (the same one or more features of) the other clusters. The processor 106 may be configured to apply principal component regression algorithms, which are known in the art, to determine the subset based on the variability values. If, for example, a cluster has a higher variability value (i.e. a higher level of distinctness with respect to other clusters), the processor 106 may exclude that cluster from the subset. Consequently, outlying clusters (anomalies) may not be associated with the lighting units.

The processor 106 may be further configured to assign cluster ranking values to the clusters, wherein the cluster ranking values are based on the number of light settings in the respective cluster, the spread (i.e. the variability between the data points (the light settings) in the respective cluster) and/or the distance (i.e. the distance of the respective cluster with respect to other clusters) and select a subset of clusters of the plurality of clusters based on the cluster ranking values.

If the number of clusters is higher than the number of lighting units of the lighting system 100, the processor 106 may be configured to group the plurality of clusters into group clusters based on linkage criteria of the plurality of clusters. When for example agglomerative hierarchical clustering algorithms are used, the linkage criteria may be determined and the plurality of clusters may be grouped into group clusters based on the linkage criteria, such that the number of groups clusters substantially matches the number of lighting devices.

It should be understood that the processor 106 may be configured to use a plurality of the above-mentioned examples for selecting a subset or reducing the number of clusters.

Alternatively, or additionally to clustering, dimensionality reduction algorithms may be used to address the problem of downscaling. Dimensionality reduction may be defined as reducing the size/number of a data set, for example, by removing the

redundancy in the data and keeping only the important features. Dimensionality reduction may be a form of unsupervised learning or may be from a supervised learning.

Dimensionality reduction may be further divided into feature selection and feature extraction.

Feature selection approaches try to find a subset of the original variables (also called features or attributes), whereas feature extraction (also called Feature projection) transforms the data in the high-dimensional space to a space of fewer dimensions. One of the ways to find the important features is to analyze the variability of the data set and consider the features which contribute most to the variance of the data set.

The processor 106 may be configured for downscaling the set of light settings by determining variability values for the light settings of the set of light settings. Here, each variability value may be indicative of a level of distinctness of one or more features of a respective light setting with respect to the same one or more features of the other light settings of the set of light settings. The processor 106 may further select one or more light settings with a variability value higher than the variability value of the other light settings, and control the lighting units 112, 114 according to the selected one or more light settings.

The variability values may be indicative of a level of distinctness of one or more features of a respective light setting with respect to the same one or more features (of the same type) of the other light settings of the set of light settings. If, for example, a certain feature (e.g. color) is considered, the variability values for the light settings are indicative of a level of distinctness of the color of a respective light setting with respect to the colors of the other light settings of the set of light settings.

The variability value may be indicative of a level of distinctness of one or more features of the respective light setting with respect to an average of the same one or more features of the other light settings. In other words, the variability value is based on an average of the features of the other light settings (of the set of light settings). Alternatively, the variability value may be indicative of a level of distinctness of one or more features of the respective light setting with respect to an average of the same one or more features of the other light settings and the respective light setting. In other words, the variability value may be based on an average of the features of the other light settings and the light setting.

The variability values may be determined using machine learning algorithms. For example, the variability values may represent how far each feature in the light settings is from the mean (of the same features) of the light settings. Alternatively, the variability values may represent the distance of each feature with respect to the median or mode (of the same features) of the light settings. If a vector of light settings is represented as a random vector

with an associated statistical distribution, e.g. uniform or gaussian, the variability values may be obtained from the variance of the distribution.

The processor 106 may be configured to associate a subset of the light settings with the plurality of lighting units 112, 114 based on the variability values of the light settings. The processor 106 may then control the lighting units 112, 114 according to these light settings. Alternatively, the processor 106 may associate the subset of light settings with user inputs of a user input device 130. This is further discussed below. The processor 106 may determine the associations between clusters and lighting units 112, 114 based on, for example, light rendering characteristics of the lighting units 112, 114, the function of the lighting units 112, 114 and/or the types of lighting units 112, 114, in a way similar to the above-mentioned examples.

The processor 106 may be further configured to receive a signal indicative of a number of lighting units 112, 114 of the lighting system 100, and determine a ratio of light settings with lower variability levels to light settings with higher variability levels to be associated with the plurality of lighting units, wherein the ratio is determined based on the number of lighting units in the lighting system. The processor may associate the light settings with the plurality of lighting units further based on the determined ratio. The number of light settings with a higher variability value to be associated with the lighting units 112, 114 may be determined by the processor 106 as a function of the number of lighting units (and/or the light rendering characteristics of the lighting units and/or the types of lighting units). Similarly, the number of light settings with a lower variability value to be associated with the lighting units may be determined as a function of the number of lighting units (and/or the light rendering characteristics of the lighting units and/or the types of lighting units). If, for example, the number of lighting units 112, 114 is higher, more light settings with higher variability levels may be selected compared to when the number of lighting units is lower 112, 114.

The processor may be further configured to select one or more light settings with a variability value higher than the variability value of the other light settings, and associate the selected one or more light settings with all the lighting units 112, 114 in the lighting system 100. In other words, only light settings with a relatively high variability value are associated with the lighting units of the lighting system. Fig. 9 illustrates an example wherein a plurality of light settings 902 originate from lighting units (a plurality of ceiling luminaires and two moving heads 152, 154) of a remote lighting system 150. The processor 106 may determine the variability values for the light settings of the set of light settings 902

based on one or more features indicative of one or more characteristics of the light settings.

A feature that may be used is the color. The processor 106 may determine that the variability value of light settings 906 is higher than the variability values of light settings 904, because the colors of the light settings 906 has more distinct from the other light settings 904. Based thereon, the processor 106 may associate light settings 906 with the lighting units 112, 114 of the lighting system 100, and control them accordingly.

The processor 106 may be configured to determine the variability values for the light settings are based on the level of dynamics of the light settings. The one or more characteristics of the light settings may relate to a level of dynamics of each light setting.

Referring to one of the above-mentioned paragraphs, the level of dynamics may be predefined or determined by the processor 106. Referring again to Fig. 9, the feature used for feature analysis may be the level of dynamics. The ceiling luminaires of the remote lighting system 150 may, for example, emit static (non-changing) light, and the moveable heads 152, 154 may emit dynamic light (i.e. light that changes over time). Hence, the level of dynamics of the moveable heads 152, 154 may be higher than the level of dynamics of the ceiling luminaires. The processor 106 may therefore associate light settings 906 with the lighting units 112, 114 of the lighting system 100, and control them accordingly.

Fig. 10 illustrates schematically a method 1000 for downscaling a set of light settings and controlling a plurality of lighting units 112, 114 of a lighting system 100 based thereon. The method may be executed by computer program code of a computer program product when the computer program product is run on a processing unit of a computing device, such as the processor 106 of the controller 102. The method may comprise: obtaining 1002 the set of light settings, analyzing 1004 the set of light settings to extract one or more features of the light settings, wherein the one or more features relate to one or more light characteristics of the light settings, determining 1006 variability values for the light settings, wherein each variability value is indicative of a level of distinctness of one or more features of a respective light setting with respect to the same one or more features of the other light settings of the set of light settings, associating 1008 the light settings with the plurality of lighting units based on the variability values of the light settings, wherein at least one lighting unit is associated with a light setting having a variability value higher than the variability value of the other light settings, and controlling 1010 the plurality of lighting units according to the lighting settings.

The processor 106 may be further configured to analyze the set of light settings to extract a plurality of features. Each variability value may be indicative of a

combined level of distinctness of the plurality of features of a respective light setting with respect to the plurality of features of the other light settings. The combined level of distinctness may be based on a plurality of features, for example color and brightness. A first feature (e.g. the color) may have first level of distinctness (e.g. a first level of distinctness with respect to the other colors of the other light settings), and a second feature (e.g. the brightness level) of the same light setting may have second level of distinctness (e.g. a second level of distinctness with respect to the other brightness levels of the other light settings). The combined level of distinctness, which may also be referred to as a combined variability level, may be a combination of these levels of distinctness. The features of the plurality of features may have been assigned weight values, wherein each variability value indicative of the combined level of distinctness is further based on the weight values of the features. A first feature (e.g. the color) may have first weight value higher than a second feature (e.g. the brightness level) of the same light setting, resulting in that the first feature influences the (combined) variability level to a larger extent compared to the second feature.

It may occur that the set of light settings is substantially larger than the number of lighting units 112, 114 of the lighting system 100. The processor 106 may be configured to cluster the set of light settings into a plurality of clusters based on the extracted one or more features, before the variability values are determined. The variability values may then be determined for the clusters, wherein each variability value is indicative of a level of distinctness of one or more features of a respective cluster with respect to the same one or more features of the other clusters. The processor 106 may then determine respective lighting control settings for respective clusters based on the light settings of each respective cluster, and associate the respective clusters with respective lighting units of the lighting system based on the variability values of the clusters (or with inputs of a user input device).

The lighting system 100 may further comprise a user input device 130. This has been illustrated in Figs. 7a and 7b. The user input device 130 may be configured to receive a plurality of user inputs from a user. The user input device 130 may comprise a communication module configured to communicate with one or more lighting units 112, for example via any of the above-mentioned communication protocols. The user input device 130 may communicate lighting control instructions to the one or more lighting units 112, 114. The user input device 130 may be comprised in a lighting device 112. Alternatively, the user input device 130 may be configured to communicate signals indicative of lighting control instructions to an intermediary device, such as a bridge, a hub, the controller 102,

etc., which in turn may communicate lighting control instructions to the one or more lighting units 112. This may depend on the system architecture of the lighting system 100.

Different inputs that can be received by the user input device 130 may be associated with different lighting control settings, such that when an input is received by the user input device 130, one or more lighting units 112, 114 are controlled according to the associated lighting control setting. The inputs that can be received by the user input device 130 are indicative of user inputs. For example, an input may be indicative of an actuation (e.g. touching, pressing, rotating) of a button, a gesture input, a voice input, etc.

The user input device 130 may be a light switch configured to receive sequential user inputs, a rotary light switch, a light switch comprising multiple buttons, a personal user device (e.g. a smartphone, a smartwatch, etc.), a voice assistant comprising a sound sensor configured to receive voice inputs, a motion sensor configured to detect gestures (e.g. a camera, an ultrasound transceiver, a distance sensor, etc.), etc. It should be understood that these user input devices are mere examples of user input devices 130, and that the skilled person is able to design different types of user input devices 130 without departing from the scope of the appended claims.

The processor 106 may be configured to associate respective lighting control settings with respective inputs of the plurality of inputs, such that when the respective inputs are received by the user input device 130, the one or more lighting units 112, 114 are controlled according to the associated lighting control settings. This may be based on created clusters, which may have been created via any of the above-mentioned clustering examples. Alternatively, this may be based on variability values of light settings of the plurality of light settings, which may have been created via any of the above-mentioned downscaling examples.

The processor 106 may, for example, calculate an average light setting or a mean of the light settings of a respective cluster. The features used to determine the lighting control settings of the clusters may be the same features used to create the clusters. The processor 106 may be configured to determine a lighting control setting for a cluster by selecting a random light setting from the light settings clustered in that cluster. The processor 106 may be further configured to associate a different random light setting from the cluster each time a subsequent user input has been received via an input (e.g. a button) of the user input device 130.

Fig. 8 schematically shows a method 800 for assigning lighting control settings to a user input device 130, wherein the user input device 130 is configured to receive

a plurality of inputs indicative of user inputs. The method 800 comprises the steps of obtaining 802 a set of light settings, analyzing 804 the set of light settings to extract one or more features of the light settings, wherein the features relate to light characteristics of the light settings, clustering 806 the set of light settings into a plurality of clusters based on the extracted one or more features, determining 808 respective lighting control settings for respective clusters based on the light settings of each respective cluster, and associating 810 respective lighting control settings with respective inputs of the plurality of user inputs, such that when the respective inputs are received by the user input device 130, one or more lighting units 112, 114 are controlled according to the associated lighting control settings.

10 The processor 106 of the controller 102 may be configured to execute these steps (which has been further illustrated in Figs. 7a and 7b). Thus, the lighting units 112, 114 are not directly controlled based on the lighting control settings of the plurality of clusters, but when a user has provided the respective input via one or more user input elements of the user input device 130.

15 The system 100 of Fig. 7a illustrates the controller 102, a memory 180 from which the light settings may be obtained, and a user input device 130 comprising an input element 132 configured to receive a plurality of sequential user inputs. The user input element 132 may be a single button configured to receive the sequential inputs, enabling a user to press the button multiple times to cycle through the light settings. In another example,

20 the user input element may be a rotary switch, enabling a user to rotate the rotary switch to cycle through and select multiple light settings. The processor 106 may be configured to associate light settings with respective sequential inputs by clustering 806 the set of light settings into a plurality of clusters based on extracted one or more features of the light settings, determining 808 respective lighting control settings for respective clusters based on the light settings of each respective cluster, and associating 810 respective lighting control settings with respective inputs of the plurality of sequential inputs. After the association, a

25 user can cycle through the lighting control settings associated with the user input element 132.

The system 100 of Fig. 7b illustrates the controller 102, a memory 180 from which the light settings may be obtained, and a user input device 130 comprising a first input element 134 configured to receive a first user input and a second input element 136 configured to receive a second user input. In this example, the user input elements 134, 136 may be press/touch buttons, enabling a user to press/touch the buttons to select light settings associated with those buttons. The processor 106 may be configured to associate light

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settings with respective inputs that can be received via the user input elements 134, 136 by clustering 806 the set of light settings into a plurality of clusters based on extracted one or more features of the light settings, determining 808 respective lighting control settings for respective clusters based on the light settings of each respective cluster, and associating 810
5 respective lighting control settings with respective inputs. After the association, a user can select a first lighting control setting associated with the first input element 134, and select a second lighting control setting associated with the second input element 136.

The processor 106 may be further configured to associate clusters with inputs of the user input device based on light properties related to characteristics of the clusters (e.g.
10 the cluster size or lighting characteristics of the clusters). For example, the user input device 130 may comprise three inputs (e.g. three buttons), and the processor 106 may be configured to associate a first cluster (e.g. the largest cluster, or a cluster comprising most frequently used light settings) with a first input (e.g. a first (center) button), and associate two other clusters with the second and the third input (e.g. a second and a third button).

Referring to the example of Fig. 7a, wherein the user input device 130
15 comprises an input element 132 configured to receive a plurality of sequential user inputs, the processor 106 may be further configured to determine a sequence for the plurality of lighting control settings based on the cluster sizes of the plurality of clusters. The processor 106 may be further configured to associate the lighting control settings with the user input element
20 according to the sequence. The processor 106 may, for example, determine the sequence based on properties of the clusters (e.g. the cluster size, cluster spread, the variability levels of the clusters, etc.). A first lighting control setting associated with a larger cluster may for example precede a second lighting control setting associated with a smaller cluster in the sequence of sequential inputs that can be received via the (single) user input element 132.

The processor 106 may be further configured to receive one or more signals
25 indicative of a number of inputs that can be received at the user input device, and determine a number of clusters based on the number of inputs, and cluster the set of light settings into the determined number of clusters. The number of clusters may be determined such that the number of clusters is (substantially) equal to the number of inputs (e.g. a number of user
30 input elements or a number of sequential user inputs that can be received via a (single) user input element).

The processor 106 may be configured to cluster the light settings into the clusters such that each cluster to be associated with a user input comprises a number of light settings above a threshold. Created clusters that have a number of light settings below the

threshold may not be associated with a user input. Hence, outliers (anomalies) may not be mapped onto the inputs. Alternatively, the number of clusters may be determined such that each cluster to be associated with a respective input comprises a number of light settings above the threshold. If certain clusters would have a number of light settings below the threshold, outliers (anomalies) may be merged with the clusters that have the number of light settings. Hence, outliers (anomalies) may be taken into account when the lighting control settings for respective clusters are determined.

The processor 106 may be further configured to select a subset of clusters from the plurality of clusters if the number of clusters is higher than number of inputs that can be received by the user input device 130. The processor 106 may select the subset according to any of the above-mentioned examples wherein the processor 106 selects a subset of clusters if the number of clusters is higher than the number of lighting units.

It should be noted that the above-mentioned embodiments illustrate rather than limit the invention, and that those skilled in the art will be able to design many alternative embodiments without departing from the scope of the appended claims.

In the claims, any reference signs placed between parentheses shall not be construed as limiting the claim. Use of the verb "comprise" and its conjugations does not exclude the presence of elements or steps other than those stated in a claim. The article "a" or "an" preceding an element does not exclude the presence of a plurality of such elements. The invention may be implemented by means of hardware comprising several distinct elements, and by means of a suitably programmed computer or processing unit. In the device claim enumerating several means, several of these means may be embodied by one and the same item of hardware. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

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 or even the 'cloud'.

Storage media suitable for storing computer program instructions include all forms of nonvolatile memory, including but not limited to EPROM, EEPROM and flash memory devices, magnetic disks such as the internal and external hard disk drives, removable disks and CD-ROM disks. The computer program product may be distributed on such a storage medium, or may be offered for download through HTTP, FTP, email or through a server connected to a network such as the Internet.

CLAIMS:

1. A computer implemented method (400) for controlling a plurality of lighting units (112, 114) of a lighting system (100) to downscale a number of light settings onto a smaller number of lighting units, the method (400) comprising:

- obtaining (402) a set of light settings,
- 5 - analyzing (404) the set of light settings to extract one or more features of the light settings, wherein the features relate to light characteristics of the light settings,
- clustering (406) the set of light settings into a plurality of clusters based on the extracted one or more features,
- determining (408) respective lighting control settings for respective clusters
- 10 based on the light settings of each respective cluster,
- associating (410) the respective clusters with respective lighting units (112, 114) of the lighting system (100), and
- controlling (412) the plurality of lighting units (112, 114) according to the respective lighting control settings of the respective associated clusters

15 wherein the method further comprising the steps of:

- receiving one or more signals indicative of a number of lighting units (112, 114) of the plurality of lighting units (112, 114) of the lighting system (100),
- determining a number of clusters based on the number of lighting units (112, 114), and
- 20 - clustering the set of light settings into the determined number of clusters.

2. The method (400) of any preceding claim, wherein the light settings are clustered into the clusters such that each cluster to be associated with a respective lighting unit comprises a number of light settings above a threshold.

3. The method (400) of claim 1, wherein a plurality of features is extracted from the set of light settings; and wherein the respective features have respective feature ranking values, and wherein the step of clustering the set of light settings into the plurality of clusters

based on the extracted plurality of features is further based on the feature ranking values of the plurality of features.

4. The method (400) of any preceding claim, wherein the method comprises:

- receiving a subsequent set of light settings, and
- recluster the light settings of the subsequent set of light settings.

5. The method (400) of claim 4, wherein the step of recluster is executed if a difference between a previous and the subsequent set of light settings is above a threshold.

6. The method (400) of any one of claims 1 to 3, further comprising the step of:
- maintaining the associations between the clusters and the respective lighting units for subsequent sets of light settings.

7. The method (400) of any preceding claim, wherein the step of determining respective lighting control settings for respective clusters based on the light settings of each respective cluster comprises:

- determining average light settings for the respective clusters based on the features of one or more light settings of each respective cluster.

8. The method (400) of any preceding claim, wherein the clusters are associated with the respective lighting units of the lighting system based on at least one of: light rendering characteristics of the lighting units, the function of the lighting units and the types of lighting units.

9. The method (400) of any preceding claim, further comprising the steps of:

- determining cluster sizes of the plurality of clusters, wherein a cluster size is indicative of a number of light settings of a respective cluster,
- determining light rendering characteristics of the plurality of lighting units of the lighting system,

wherein the association of the respective clusters with the respective lighting units is further based on the sizes of the respective clusters and the light rendering characteristics of the plurality of lighting units.

10. The method (400) of any one of claims 1-9, wherein the set of light settings are light settings obtained from an image or a video.

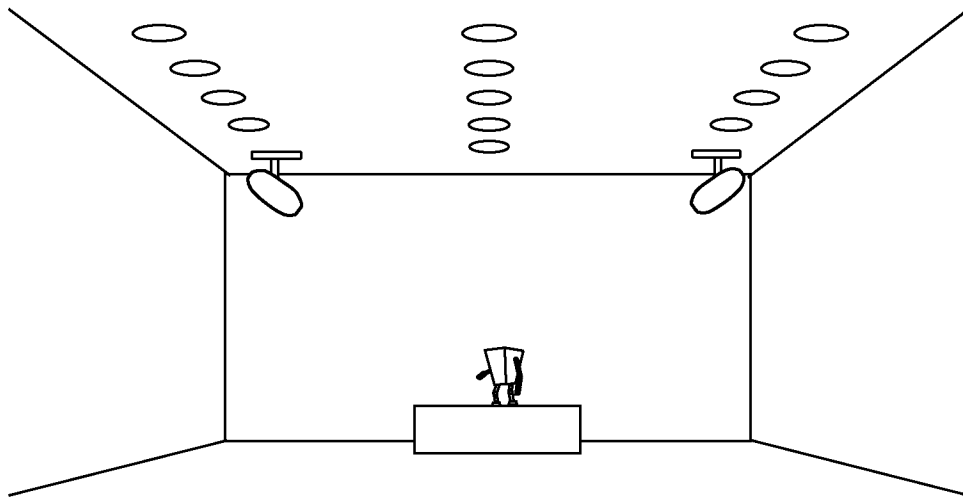
11. The method (400) of any one of claims 1-9, wherein the set of light settings are light settings obtained from a remote database or from one or more remote lighting systems.

12. A computer program product for a computing device, the computer program product comprising computer program code to perform the method (400) of any preceding claim when the computer program product is run on a processing unit of the computing device.

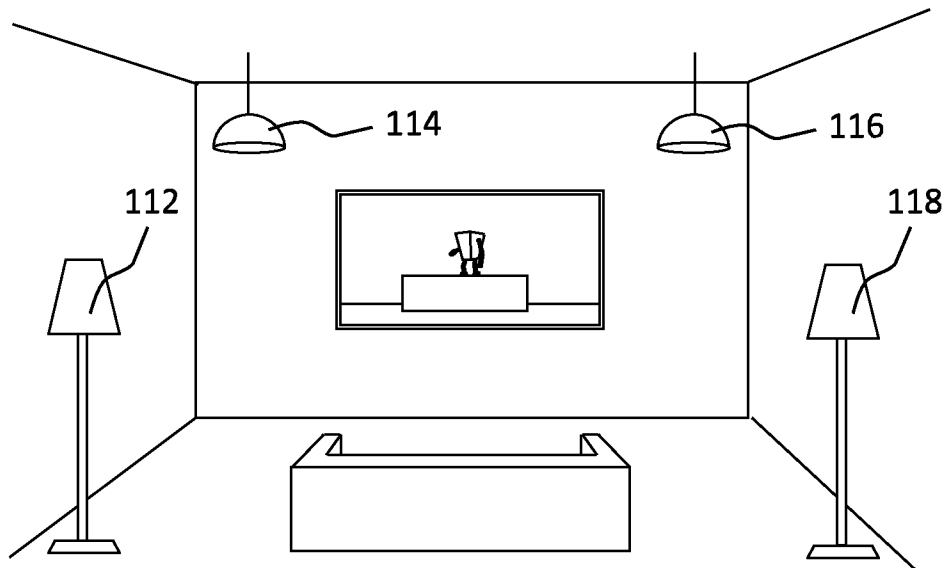
13. A controller (102) for controlling a plurality of lighting units (112, 114) of a lighting system (100), the controller (102) comprising:

- an input (104) configured to obtain a set of light settings,
- a processor (106) configured to analyze the set of light settings to extract one or more features of the light settings, wherein the features relate to light characteristics of the light settings, cluster the set of light settings into a plurality of clusters based on the extracted one or more features, determine respective lighting control settings for respective clusters based on the light settings of each respective cluster, associating the respective clusters with respective lighting units (112, 114) of the lighting system (100), and controlling the plurality of lighting units (112, 114) according to the respective lighting control settings of the respective associated clusters, wherein the processor is further configured to receive one or more signals indicative of a number of lighting units (112, 114) of the plurality of lighting units (112, 114) of the lighting system (100), determine a number of clusters based on the number of lighting units (112, 114), and cluster the set of light settings into the determined number of clusters.

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150

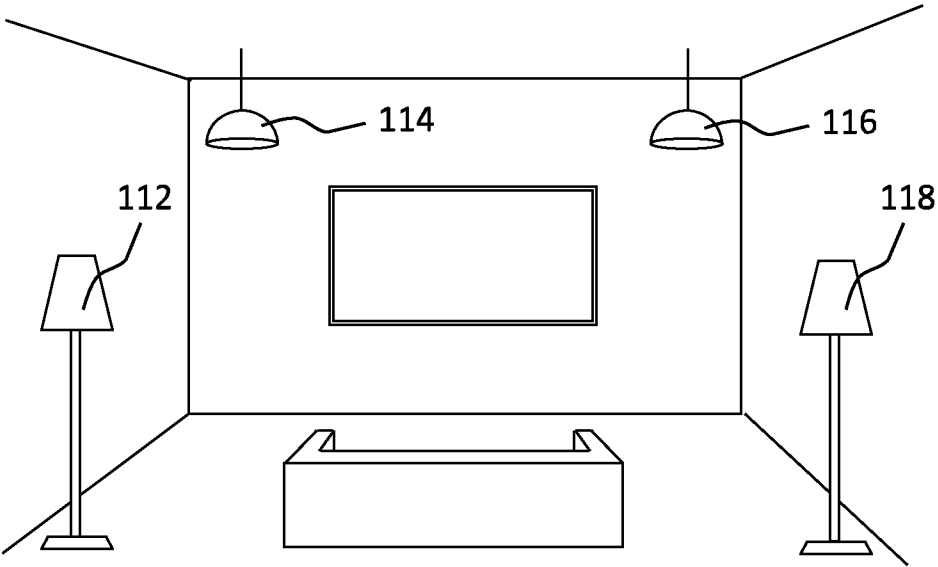


100

Fig. 1



170



100

Fig. 2

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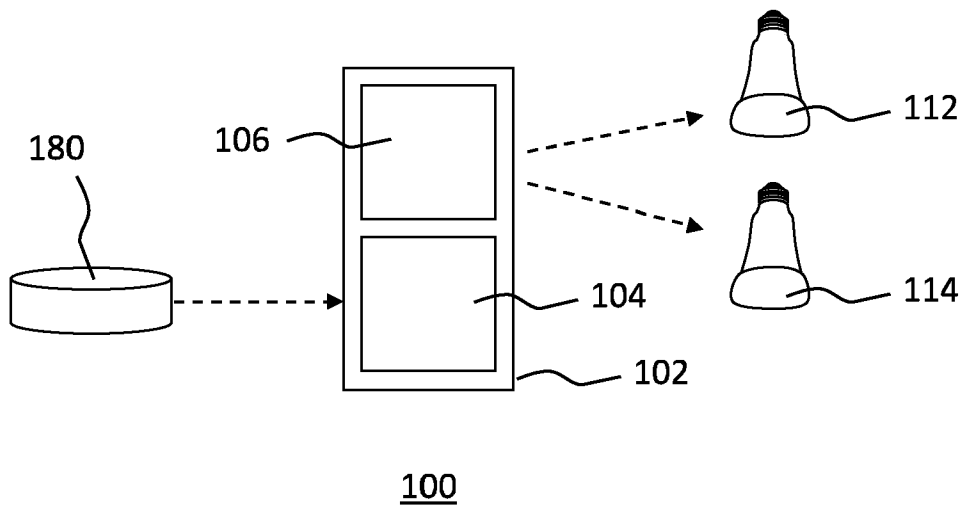


Fig. 3a

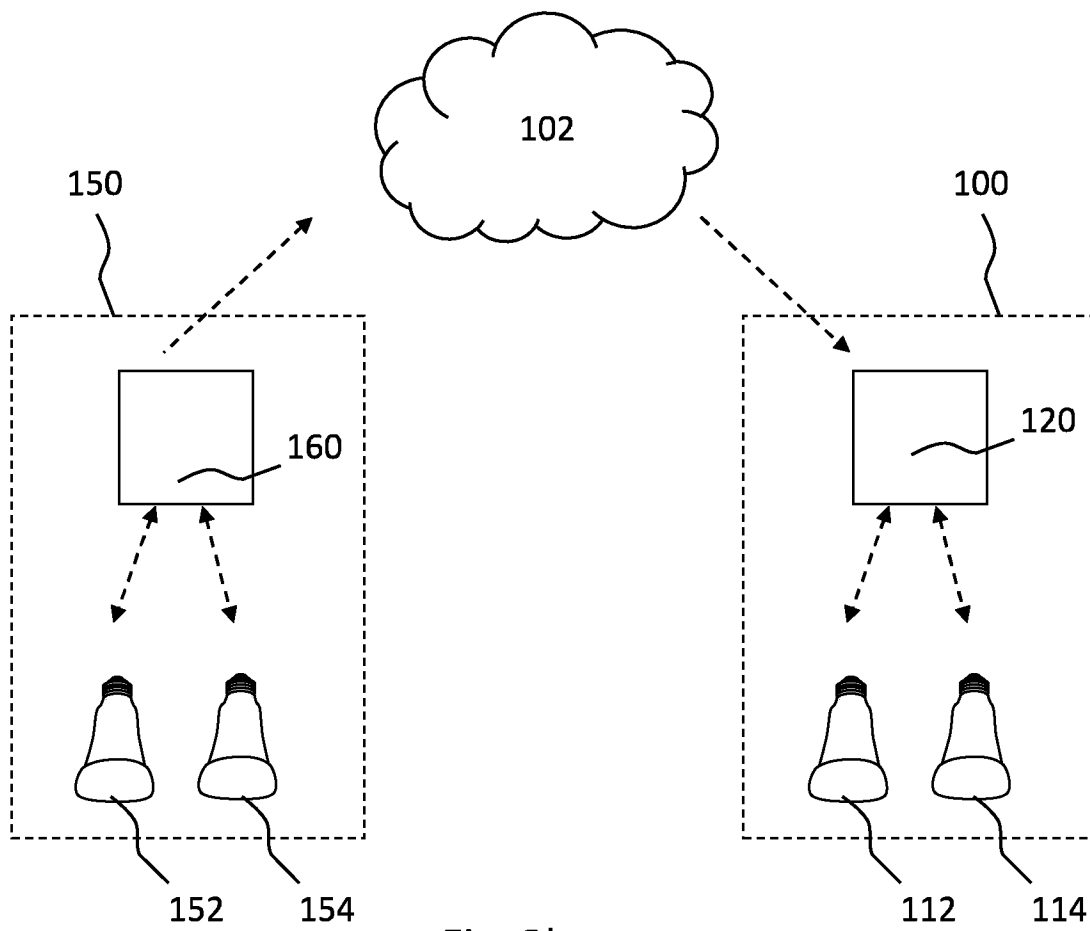


Fig. 3b

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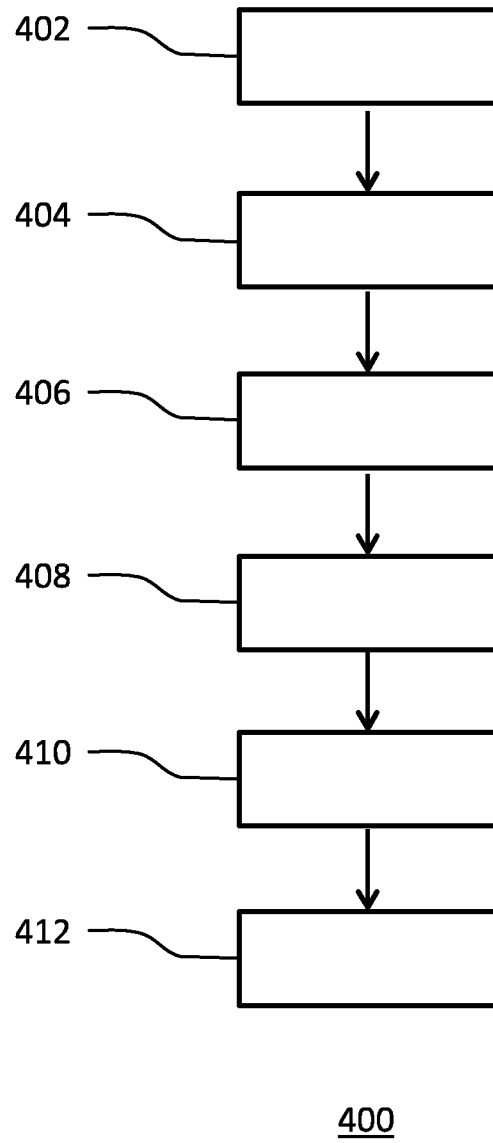


Fig. 4

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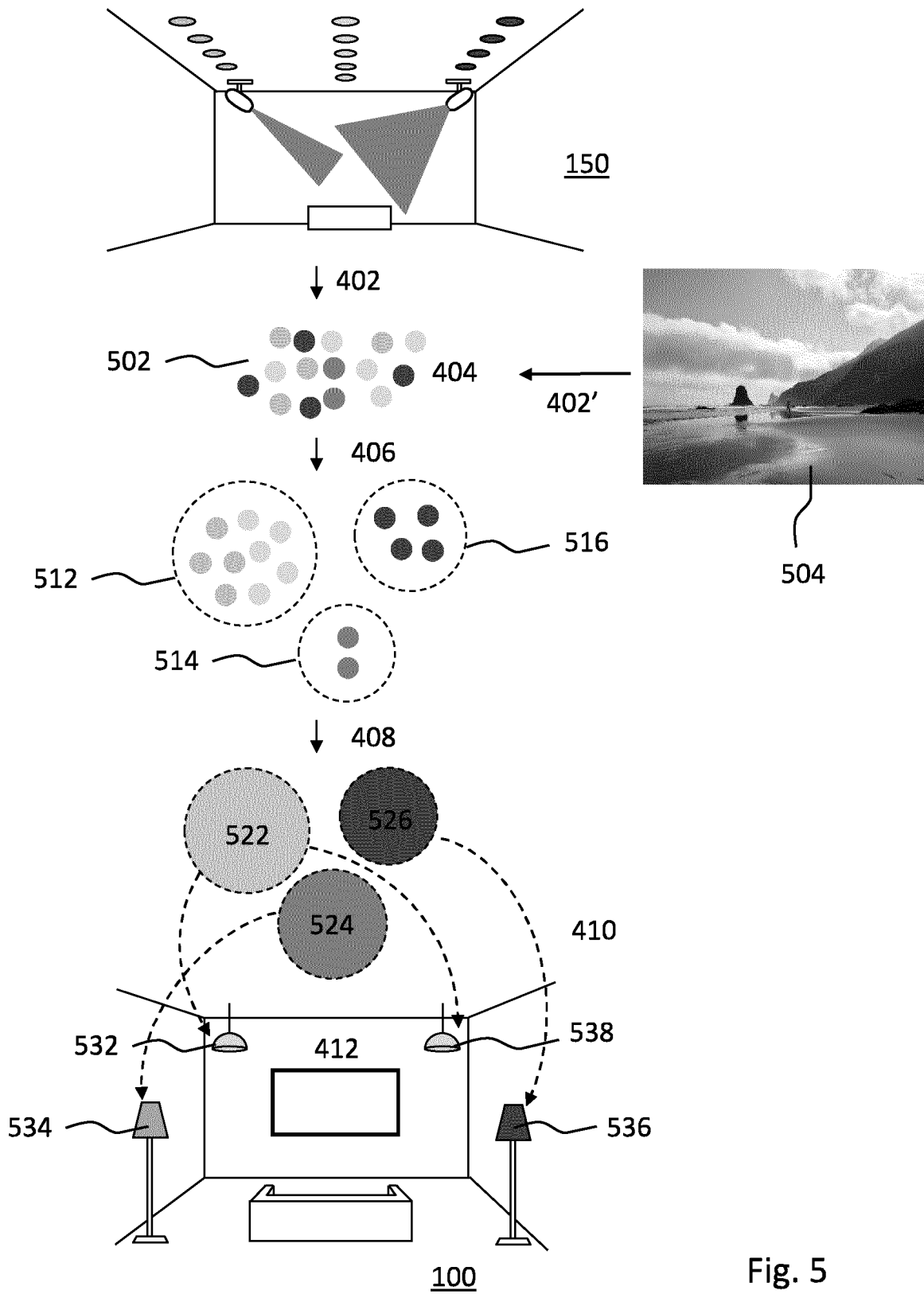


Fig. 5

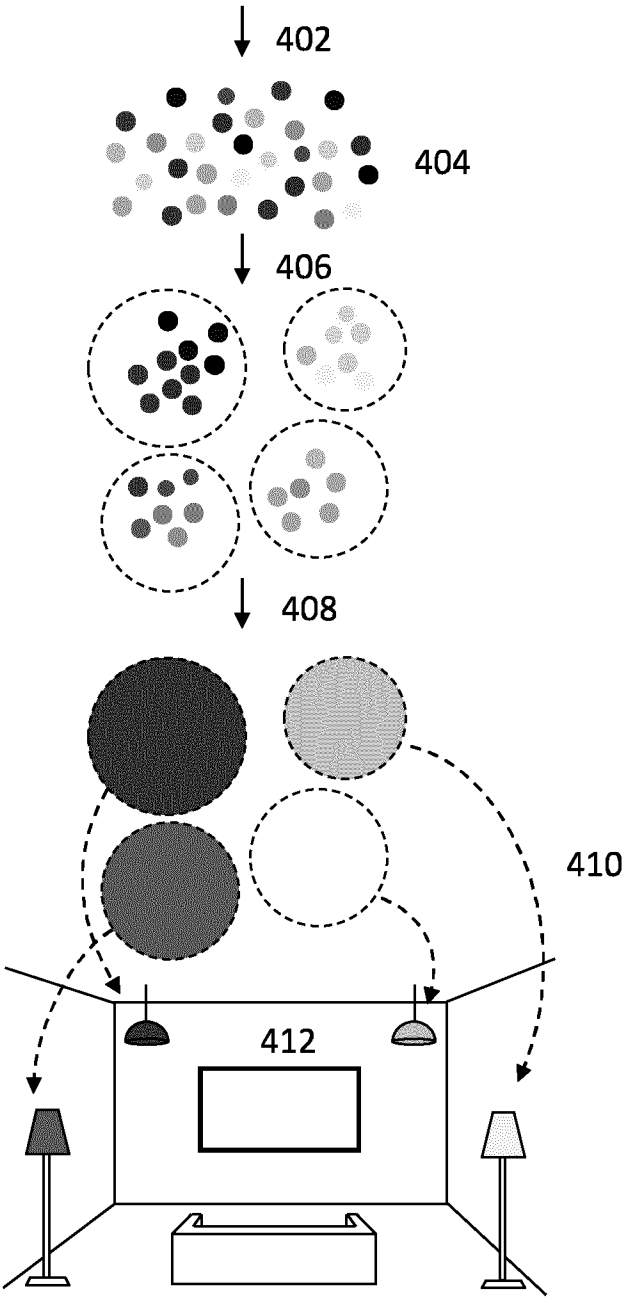


Fig. 6

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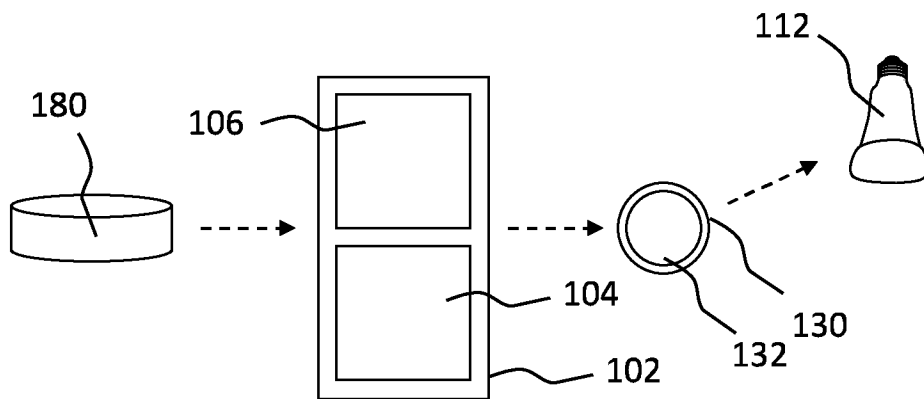


Fig. 7a

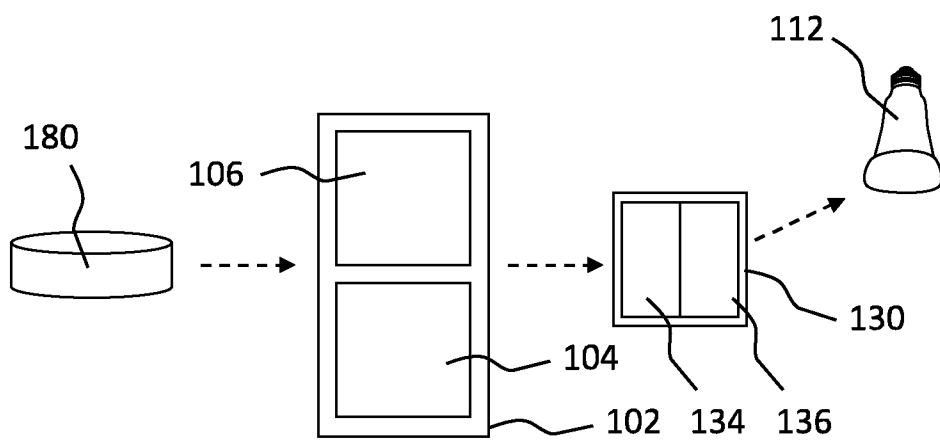


Fig. 7b

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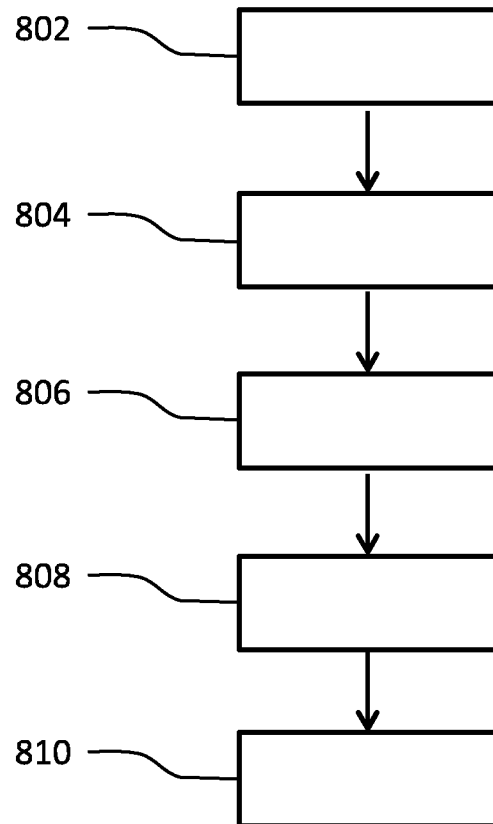
800

Fig. 8

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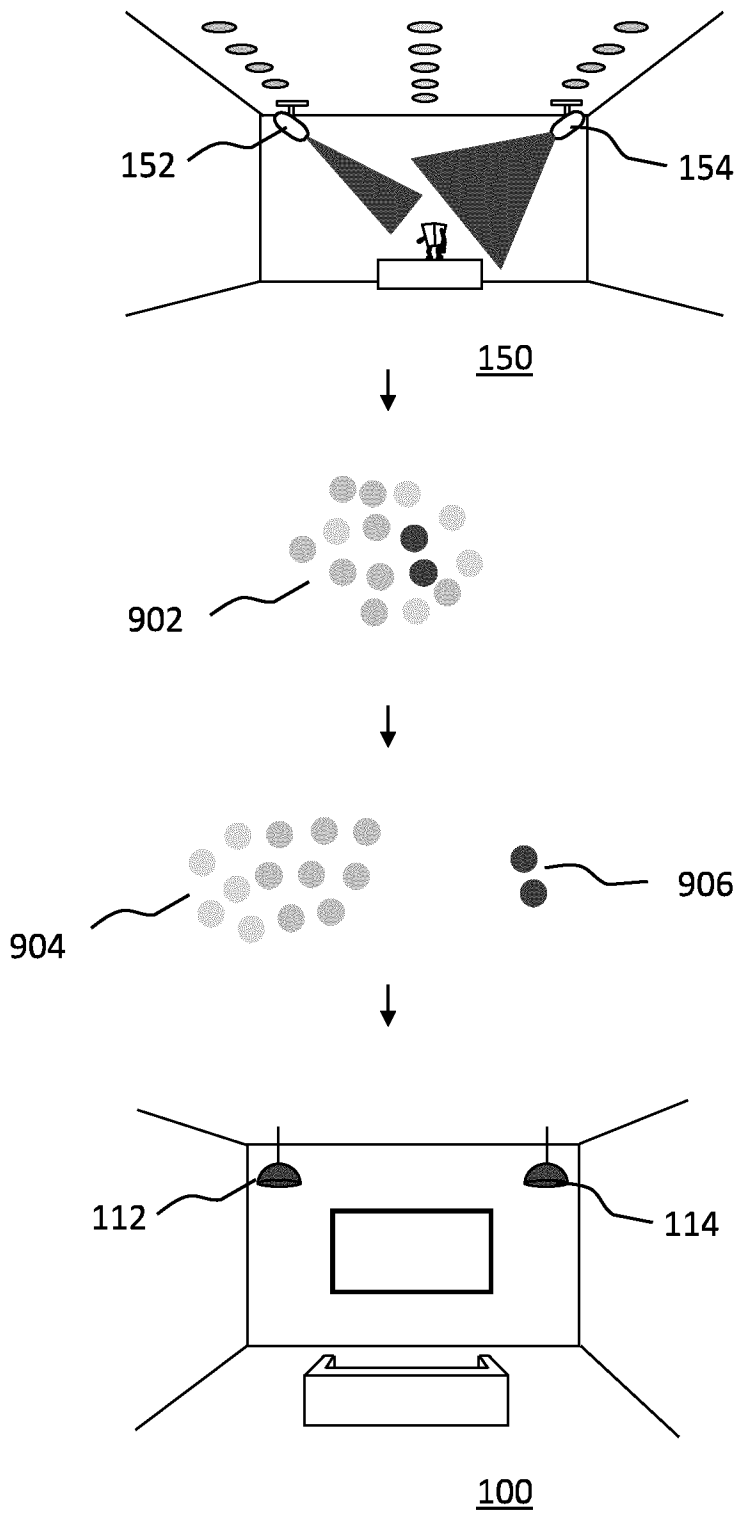


Fig. 9

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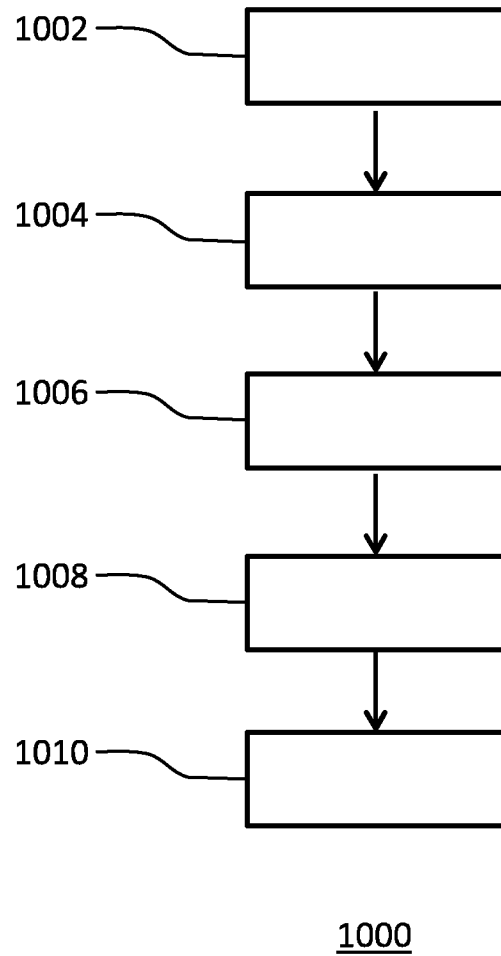


Fig. 10

INTERNATIONAL SEARCH REPORT

International application No
PCT/EP2020/065783

A. CLASSIFICATION OF SUBJECT MATTER

INV. H05B47/155 H05B47/105 H05B47/175
ADD. G06K9/62

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

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
H05B G06K

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 2018/160501 A1 (MAGIELSE REMCO [NL]) 7 June 2018 (2018-06-07) paragraphs [0040] - [0137]; claims 1-14; figures 1-9	1-13
X	US 2018/279446 A1 (VAN DE SLUIS BARTEL MARINUS [NL] ET AL) 27 September 2018 (2018-09-27) paragraphs [0036] - [0061]; figures 1-4	1-13



Further documents are listed in the continuation of Box C.



See patent family annex.

* Special categories of cited documents :

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

"E" earlier application or patent but published on or after the international filing date

"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)

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

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

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

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

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

"&" document member of the same patent family

Date of the actual completion of the international search

26 August 2020

Date of mailing of the international search report

04/09/2020

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Authorized officer

Ferla, Monica

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No

PCT/EP2020/065783

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
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