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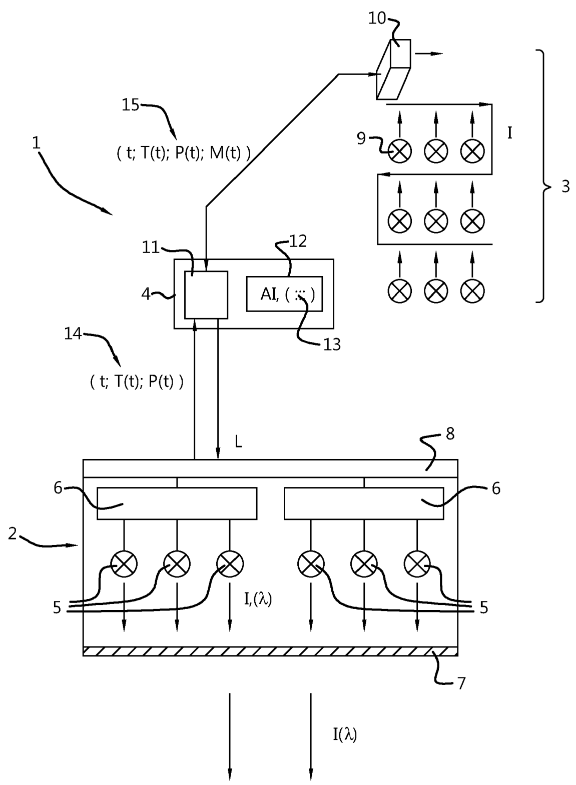
(54) **CONTROL UNIT FOR A LIGHTING SYSTEM**

(57) The invention relates to a control unit for a lighting system, which lighting system comprises a drive unit and at least one light sources with said lighting system functionally coupled to said at least one light sources, wherein the control unit is functionally coupled to said lighting system and comprises a communication device for retrieving data remotely from the lighting system and a data processor and a computer program product for generating said local control settings.

Fig. 1



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Description

FIELD OF THE INVENTION

[0001] The present invention relates to a control unit for a lighting system, a computer program product for generating control settings for a lighting system, a lighting system, and a method for operating a lighting system.

BACKGROUND OF THE INVENTION

[0002] Already in 2000, US6441558 in its abstract states "An LED luminary system for providing power to LED light sources to generate a desired light color comprises a power supply stage configured to provide a DC current signal. A light mixing circuit is coupled to said power supply stage and includes a plurality of LED light sources with red, green and blue colors to produce various desired lights with desired color temperatures. A controller system is coupled to the power supply stage and is configured to provide control signals to the power supply stage so as to maintain the DC current signal at a desired level for maintaining the desired light output. The controller system is further configured to estimate lumen output fractions associated with the LED light sources based on junction temperature of the LED light sources and chromaticity coordinates of the desired light to be generated at the light mixing circuit. The light mixing circuit further comprises a temperature sensor for measuring the temperature associated with the LED) light sources and a light detector for measuring lumen output level of light generated by the LED light sources. Based on the temperatures measured, the controller system determines the amount of output lumen that each of the LED light sources need to generate in order to achieve the desired mixed light output, and the light detector in conjunction with a feedback loop maintains the required lumen output for each of the LED light sources."

[0003] And 15 years later, WO2015/200615 in its abstract states "Illumination devices and methods are provided for calibrating and controlling individual LEDs in the illumination device, for obtaining a desired luminous flux and chromaticity of the device over changes in drive current, temperature, and over time as the LEDs age. In some embodiments, the illumination device may include a phosphor converted LED, configured for emitting illumination for the illumination device, wherein a spectrum of the illumination emitted from the phosphor converted LED comprises a first portion having a first peak emission wavelength and a second portion having a second peak emission wavelength, which differs from the first peak emission wavelength. In such embodiments, methods are provided for calibrating and controlling each portion of the phosphor converted LED spectrum, as if the phosphor converted LED were two separate LEDs. An illumination device is also provided herein comprising one or more emitter modules having improved thermal and electrical characteristics".

[0004] Thus in semiconductor-based lighting elements, such as LEDs, the color spectrum and the brightness (intensity) change. In addition, LEDs are also affected by a dispersion of their technical properties with regard to brightness and color during manufacture. This can be compensated for by the manufacturer using so-called "binning," in which semiconductor elements are sorted according to a predetermined dispersion.

[0005] There are thus several applications in which a desired light color is generated from three LED light sources with red, green and blue color spectra. The light emitted by the three LEDs can be detected by a three-section filter, and the measured RGB value can be converted to the so-called CIE XYZ color space (CIE=Commission Internationale de l'Eclairage [International Commission on Illumination]). The measured value vector is compared with an XYZ target value in a control unit which functions as a P controller and which, depending on the error, acts upon a drive unit such that the drive unit is made to supply electrical power to the light sources accordingly. By carrying out the actions as mentioned and using the control unit and other means, compensation for changes in the brightness and color of the light emitted by the LED light sources can be provided.

[0006] However, a disadvantage in this respect is that the sensor has to be adjusted to the frequency spectra of the LEDs for the control unit to function sufficiently. Furthermore, with this system, a lighting device with more than three light sources having different color spectra can no longer be controlled, because the result of an algorithm of said control unit is no longer unequivocal in view of the fact that several lumen settings of at least four light sources can generate the same color impression in the XYZ color space.

[0007] There are also different applications that focus on processes for determining the light current components of individual LEDs via a v(lambda)-adapted sensor. The operationally conditioned color and brightness changes of the individual LEDs are determined by measuring the spectral component with the aid of measuring the operating temperature of the LED (board and junction temperature). These measured values are determined individually for the particular controlled LED. This has the disadvantage that only one individual light source can always be observed by the measuring method used. Even a detection of the color shift of an individual light source can be determined only indirectly with the information of the temperature. Non-temperature-dependent color changes of the light source cannot be differentiated.

SUMMARY OF THE INVENTION

[0008] It is an objective of the present invention to provide a lighting system comprising a lighting unit, an optical part and a drive unit, and also a method for operating such a lighting system, the system and method being suitable to provide optimized control of light sources with different color spectra and to enable differentiation of temperature changes and non-temperature-dependent color changes in real time.

[0009] It is an alternative of further object to handle lumen and color maintenance of at least one light source without a feedback loop, while taking into account factors that have an impact on light source depreciation. This also includes the desired user input. A user will have full control over the lights with the advantage that the light and color will be accurate throughout the lifetime of the light source.

[0010] Yet another or alternative object is to create a platform that is capable to incorporate other domains to enhance the user experience of the computer program product.

[0011] Aspects of the present invention are set out in the accompanying independent and dependent claims. Features from the dependent claims may be combined with features from the independent claim as appropriate and not merely as explicitly set out in the claims.

[0012] At least the abovementioned objective is achieved by a control unit for a lighting system, which lighting system comprises a drive unit and at least one light sources with said drive unit functionally coupled to said at least one light sources, wherein the control unit is functionally coupled to said lighting system and comprises:

- a communication device for retrieving data remotely from the lighting system;
- a data processor and a computer program product which, when running on said data processor:

    * retrieve local operating parameters from said lighting system, said local operating parameters comprises a total local operations time of the at least one light source, a representative of a temperature of the at least one light source at said local operations time, and a representative of a power drawn by the at least one light source at said local operations time;
    * generates a machine learning network;
    * retrieve reference operating parameters from a set of reference light sources which are statistically representative of the at least one light source and which are based upon a reference operations time;
    * retrieve measured reference light output parameters at said reference operations time from the set of reference light sources;
    * update a machine learning network training dataset using said retrieved reference operating parameters and reference light output parameters and said reference operations time;
    * update said machine learning network using said updated training dataset;
    * provide said local operating parameters as input to said updated machine learning network;
    * generate said local control settings using said updated machine learning network, and provide said local control settings to said lighting system.

[0013] There is further provided computer program product generating control settings for a lighting system that comprises a drive unit and at least one light source functionally coupled to said at least one light source, which computer program product, when running on a data processor:

* retrieve local operating parameters from said lighting system, said local operating parameters comprises a total local operations time of the at least one light source, a representative of a temperature of the at least one light source at said local operations time, and a representative of a power drawn by the at least one light source at said local operations time;
* generates a machine learning network;
* retrieve reference operating parameters from a set of reference light sources which are statistically representative of the at least one light source and which are based upon a reference operations time;
* retrieve measured reference light output parameters at said reference operations time from the set of reference light sources;
* update a machine learning network training dataset using said retrieved reference operating parameters and reference light output parameters and said reference operations time;
* update said machine learning network using said updated training dataset;
* provide said local operating parameters as input to said updated machine learning network;
* generate said local control settings using said updated machine learning network, and provide said local control settings to said lighting system.

[0014] There is further provided a lighting system, comprising:

- a lighting unit which comprises at least two of said light sources having different color spectra;
- a drive unit which is functionally coupled to the lighting unit and which is configured to control power to at least one of the light sources of the lighting unit;
- at least one sensor which is configured to detect a representative of a temperature each of the at least two light sources, and
- the control unit described above, functionally coupled to the drive unit.

[0015] Reference is made to light sources in general. Currently, most used light sources are light sources based upon solid state components. Most know of these are light emitting diodes, LEDs. These are well known in the art and require drive units that regulate power. Current developments for light sources relates to quantum dots.

[0016] In general, lumen and color maintenance were found to be two complementary problems since LED light sources are based on mixing different channels (colors) by controlling their intensity. Depreciation can be forecasted and taken into account so that the light output is compensated by adding more contribution on the depreciated channels. Limited amount of data will be recorded and model predictions will have to apply generalizations for unseen data. Note that in the context of this software, SPD prediction is done together with Yxy prediction to get a better representation of light, however their functions may be overlapping (for example, light control).

[0017] Other definitions that may be used in the current application:

SPD - Spectral power distribution of a light source in visible range

MacAdam steps - A measure that determines which chromaticity points are indistinguishable by a naked eye from from a given target chromaticity.

Chromaticity, (..xy), (..uv) - A 2-dimensional representation of color,

Luminous flux, Lumen, PHIv - "intensity" of light.

COB - Chip On Board. Had multiple smd's on it that emit red, green and blue light.

LM80 - An LED depreciation report standard.

Contribution values - are values in range of 0 to 1 that indicate the intensity of each channel of a COB. In this respect, 1 means that the channel is emitting the maximum amount of light possible. This is done by adjusting the PWM/PDM duty cycles.

Total on-time of a channel: Total on-time is calculated by integrating the used contribution values over the lifetime of the COB. a channel on half contribution has half on-time compared to another channel on a full contribution, on a same COB.

Operating temperature - temperature under which a COB operates when each channel contributes at a particular intensity. The heat is caused because of emission of light.

[0018] In the current context, a reference light source which is statistically representative of a (local) light source in an embodiment is a light source of the same type as the (local) light source. Usually is has the same specified emission spectrum. Often, it is one selected from the same production batch. In case light sources are produced in a continuous production process, the statistically representative of the light source can be light sources that are produced at/in predetermined time ranges. These time ranges are selected such that the light sources that are selected are statistically representative. This requires insight in the production process and the variations over time. Usually, selection is such that a light source is selected as representative for at least 100 light sources. In particular, a light source is selected as representative for at least 1000 light sources. More in particular, a light source is selected that is representative for at least 10.000 light sources. To be able to select a light source that is representative, at least one light source is selected out of less than 100.000. For example, suppose that 1000 light sources are produced in an hour and the production process provides light sources that vary significantly over a time interval of 5 hours, then in an example three statistically representative light sources are selected in an interval of 5 hours. Thus, the three selected light sources statistically represent 5000 light sources and possibly even the variation in this time range of 5 hours. These three light sources are measures very accurately during operation time. The number of selected light sources to statistically represent the local light sources also depends on the fluctuation in production, the required accuracy and requirement on the local light sources, and the measurement accuracy of local operating parameters, of reference operating parameters and of reference light output parameters. These statistical relations determine the ration and number of reference light sources to local light sources. Using the statistically representative light sources, a dataset with various parameters against operating time can be measured, for instance selected from temperature, power supplied, voltage, current, flux, emission spectrum, luminescence, spectral irradiance, and a combination thereof.

[0019] Machine learning techniques (mainly deep learning) are to design and train a model given an input of the same type (RGB image, infrared, etc.) as the system perceives. The model is trained on a large amount of annotated data, a training dataset. In the current case, measured data from reference light sources. In the case of deep learning, a detection framework such as Faster-RCNN, SSD, R-FCN, Mask-RCNN, or one of their derivatives can be used. A base model structure can be VGG, AlexNet, ResNet, GoogLeNet, adapted from the previous, or a new one. A model can be initialized with weights and trained similar tasks to improve and speedup the training. Optimizing the weights of a model, in case of deep learning, can be done with the help of deep learning frameworks such as Tensorflow, Caffe, or MXNET. To train a model, optimization methods such as Adam or RMSProb can be used. Classification loss functions such Hinge Loss or Softmax Loss can be used. Other approaches which utilize handcrafted features (such as LBP, SIFT, or HOG) and conventional classification methods (such as SVM or Random Forest) can be used.

[0020] On the basis of a set of training data with measurements one or more machine learning algorithms and statistical classification algorithms can be applied. Example algorithms may include linear classifiers (e.g. Fisher's linear discriminant, logistic regression, naive Bayes, and perceptron), support vector machines (e.g. least squares support vector machines), clustering algorithms (e.g. k-means clustering), quadratic classifiers, multi-class classifiers, kernel estimation (e.g. k-nearest neighbor), boosting, decision trees (e.g. random forests), neural networks, Gene Expression Programming, Bayesian networks, hidden Markov models, binary classifiers, and learning vector quantization. Other example classification algorithms are also possible.

[0021] The process of categorization may involve the computing device determining, based on the output of the comparison of the one or more subsets with the one or more predetermined sets of scene types, a probability distribution (e.g. a Gaussian distribution) associated with the one or more subsets. Those skilled in the art will be aware that such a probability distribution may take the form of a discrete probability distribution, continuous probability distribution, and/or mixed continuous-discrete distributions. Other types of probability distributions are possible as well.

[0022] A current computer program product and/or method will use machine learning techniques (mainly deep learning) to design and train a model using a training dataset. The model is trained on a large amount of measured data.

[0023] The lighting unit may include at least four light sources, and the control unit is arranged for using an optimization algorithm which, as a main condition, optimizes a value of color consistency of each of the light sources, such as the color rendering index (CRI), which can be calculated from the predetermined primary data and the instantaneous secondary data.

[0024] The reference operating parameters may include previously measured data for each of the reference light sources and/or a reference optical part and/or a reference drive unit. Said measured data may be provided as a specification from the manufacturers of at least one of the reference light sources, the reference optical part and the reference drive unit. The measured data for the reference light sources may include color spectrum, peak wavelength, dominant wavelength, and beam angle in full width and half maximum for each one of the reference light sources.

[0025] The control unit is configured to use the optimization algorithm which may result in controlling values of the individual light source. The optimization algorithm may compensate any influences on the color and brightness change, in particular since a redundancy in determination regarding the color impression is generated by using the at least two light sources as compensation source. Additionally, color adaptation can also take place under reduction of the total brightness of the light in that the optimization is carried out in an XYZ color space affected by brightness.

[0026] The control unit is configured to carry out the setting of the lighting unit, by means of the drive unit, and by using the optimization algorithm that includes two or more optimization criteria. The optimization goal is to optimize the color consistency of the light sources and/or to maximize the life time of each of the light sources, wherein the optimization settings are calculated from local operating parameters and reference operating parameters. This data that include predetermined measured values for the individual light sources, the optical part and the drive unit, and local operating parameters that include the junction temperature of the light sources and/or the temperature of the optical part measured by the sensor.

[0027] The sensor may be configured to detect the junction temperature of the light sources in the connection area. The sensor may be located near to each of the light sources as close as possible to the drive unit. The number of sensors can be chosen according to the number of the light sources that are used in the system. The temperature difference depends for each connection area on the thermal power to be dissipated from the respective connection area. Since brightness of each of the light sources defined with different wavelength depends on the junction temperature, the measured characteristic lines of the brightness as function of the junction temperature may show a powerdependent curve shape.

[0028] The control unit may provide temperature-dependent color correction onto the drive unit.

[0029] The optimization goal of the control unit may further be optimizing the color spectrum of the light sources. From the reference operating parameters in respect of the reference light sources and for instance the measured junction temperature and the temperature of the optical part, an associated spectrum may be calculated, which is added to the calculated spectra of the other light sources to form a jointly calculated "predetermined" total spectrum. From this calculated total spectrum, the CRI value Ra is calculated in the usual manner, as in the case of measured spectral values. It is preferred for this calculation to occur in the CIE system.

[0030] For at least two light sources, there are unlimited possibilities or possibilities only limited by the resolution of the control to adjust a desired chromaticity coordinate of color by mixing the used primary colors. Depending on the mixing ratio, it can be optimized towards different parameters like lumen efficiency or color consistency. The desired chromaticity coordinate color may also be optimized towards the color reproductions properties of the optical part. When the optimization is done, desired chromaticity coordinates x/y may be adjusted.

[0031] The control unit may define an ecosystem using an Artificial Intelligence method that gets feedback/input from the light sources, the optical part and the drive unit. Said ecosystem is configured to control the drive unit. Therefore, the system is not bound by a specific drive unit. The Artificial Intelligence method may be combined with and/or comprise machine learning and/or the use of artificial neural networks and training and/or trained artificial neural networks. In a specific embodiment, the control unit comprises the computer program product which in addition updates a trained artificial neural network using an update of reference operating parameters and corresponding updated reference light output parameters.

[0032] Said ecosystem is configured to use a communication protocol depending on the predetermined specifications of the drive unit. Said communication protocol may be the DMX protocol. The DMX protocol may allow a setting of the drive unit current for each light source with a precision of 8 bit (that is 256 different values). Instead of the DMX protocol, other protocols may also be used, for example, protocols with higher precision. It is preferable to provide a control reserve of, for example, one additional bit, in order to appropriately take into consideration the decrease in brightness occurring as a result of aging processes.

[0033] In an embodiment of the system according to the invention, the predetermined primary data include a preset target lumen value.

[0034] In an embodiment of the system according to the invention, the predetermined primary data include a preset target correlated color temperature.

[0035] The system may be configured to be adjustable by the choice of the light sources and may be controlled with the optimization algorithm that includes, e.g., adjusting the junction temperature to a desired color temperature, brightness and the like. For achieving a solution in real time, when the said temperature is found to be above a limit value, the control unit compensates the temperature changes in that area.

[0036] The predetermined (target) correlated color temperature and the preset target lumen value of the lighting unit as well as the optical part may be compensated with the optimization algorithm of the control unit in dependency on the junction temperature of the light sources and/or the temperature of the optical part, depreciation in lumen of the light sources, color rendering index and mixed-light capability with the optical part. Accordingly, the control unit may be configured to set control values for the target parameters.

[0037] In an embodiment the control unit is configured to control a lumen value of each of the light sources during operation of the lighting system.

[0038] In an embodiment, at least one light source is a solid state light source, in particular a LED light source, and/or said at least one light source comprises at least two light sources each having a different emission spectrum, in particular at least three light sources with each light source having a different emission spectrum. In many practical implementations, at least three LED light sources are combined in creating an emission resembling for instance CIE standard daylight D65, or for instance Illuminants A, and other spectral power distributions.

[0039] In an embodiment, the control unit is configured to optimize a value of color consistency of each of the at least two light sources, in particular a ratio of each of the at least two light sources in order to generate a set light emission. A set spectral power distribution, for instance D65, or any other, may be input into the control unit via the communication device. In an embodiment, a user input can be received. Using the updated machine learning network or updated trained artificial neural network, local control settings can be generated end provided to the drive unit. For instance, the updated trained neural network may be used to predict spectral emission and the computer program product uses the predicted spectral emission in calculating local control settings.

[0040] In an embodiment, the control unit is configured to maximize a life time of each of the at least two light sources. In fact, in an embodiment, the trained updated machine learning network or updated trained artificial neural network provides parameters for maximizing the life time.

[0041] In an embodiment, the control unit further comprises a second communication device for communicating data to the lighting system, in particular the communication device using a second communication protocol different from the communication protocol of the communication device, wherein the computer program product, when running on said data processor, controls the second communication device for transmitting the local control settings to said lighting system.

[0042] In an embodiment, the computer program product transmits data to lighting system at least once a day, in particular functionally real time, in particular real time. It allows continuous adjustment of the drive unit for attaining a set emission spectrum.

[0043] In an embodiment, the computer program product is set to receiving reference operating parameters at least a daily base, in particular at least once every hour. In this way, the training dataset can be updated, the artificial neural network can be re-trained. Usually, the reference light sources already have an operations time that is longer than the local light sources. Thus, in fact, the training dataset already is in time advance of ahead of the local light sources.

[0044] In an embodiment each of the light sources comprises a semiconductor-based light source.

[0045] The lighting system may comprise on calibration unit comprising reference light sources, one or more measurement devices for measuring reference operating parameters and reference light output parameters. The calibration unit may be coupled to a series of control units. Each control unit may be coupled to a series of drive units each coupled to one or more light sources. For instance, one central calibration unit may comprise hundreds of reference light sources that are continuously measured. For instance. Reference light sources are measured each minute, each hour, depending also on changes in the light emission measured. A building or a house may comprise one control unit. The control unit is coupled to a series of light elements each comprising several light sources coupled to one drive unit.

[0046] In an embodiment, at least a portion of the semiconductor-based light source includes a light emitting diode (LED).

[0047] The lighting system may be implemented to any desired light source, particularly any type of light emitting diode, including organic light emitting diodes (OLED). It is also possible to use light sources of different type together, in particular LEDs and incandescent light bulbs.

[0048] In an embodiment the optimization algorithm is implementable in a CIE standardized X, Y, Z color space.

[0049] In an embodiment the optimization algorithm is configured to realize a value of the color consistency lower than 10 Kelvin.

[0050] In an embodiment, the control unit is configured to dim each of the light sources during operation of the lighting system.

[0051] The predetermined (target) correlated color temperature and the preset target lumen value of the lighting unit as well as the optical part may be compensated with the optimization algorithm of the control unit in dependency on the junction temperature of the light sources, depreciation in lumen of the light sources, color rendering index and mixed-light capability with the optical part. Accordingly, the control unit may be configured to set lumen values for the target parameters.

[0052] It can be understood that the embodiments of the method according to the invention may include a lighting system having any of the features or combinations of features that are disclosed herein in connection with discussions of the lighting system according to the invention. Accordingly, the entireties of the earlier discussions of the lighting system are hereby incorporated into this discussion of the examples of the method.

[0053] The invention further applies to an apparatus or device comprising one or more of the characterizing features described in the description and/or shown in the attached drawings. The invention further pertains to a method or process comprising one or more of the characterizing features described in the description and/or shown in the attached drawings.

[0054] The various aspects discussed in this patent can be combined in order to provide additional advantages. Furthermore, some of the features can form the basis for one or more divisional applications.

BRIEF DESCRIPTION OF THE DRAWINGS

[0055] Further features and advantages of the invention will become apparent from the description of the invention by way of exemplary and non-limiting embodiments of a lighting system.

[0056] The person skilled in the art will appreciate that the described embodiments of the system according to the present invention are exemplary in nature only and not to be construed as limiting the scope of protection in any way. The person skilled in the art will realize that alternatives and equivalent embodiments of the object can be conceived and reduced to practice without departing from the scope of protection of the present invention.

[0057] Reference will be made to the figures on the accompanying drawing sheets. The figures are schematic in nature and therefore not necessarily drawn to scale. Further, equal reference numerals denote equal or similar parts. On the attached drawing sheets,

figure 1 illustrates a schematic block diagram of a lighting system in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF EMBODIMENTS

[0058] Figure 1 is a block diagram illustrating an exemplary lighting system 1. The current lighting system 1 comprises a lighting unit 2, a calibration system 3, and a control unit 4. Each of these parts will be discussed in more detail below. Several of the lighting unit 2, calibration system 3 and control unit 4 communicate with one another and exchange data. In the depicted embodiment, the calibration system 3 and the control unit 4 communicate with one another. In fact, in the depicted embodiment the calibration system 3 sends data to the control unit 4. The control unit 4 processes the received data. The control unit 4 can also sent requests for data or even instructions to the calibration system 3.

[0059] In the depicted embodiment of figure 1, the control unit 4 and the lighting unit 2 communicate with one another. In fact, the control unit 4 receives measurement data from the lighting unit 2. The control unit send local control settings 16 to the lighting unit 2.

[0060] In the way illustrated, these elements control unit 4, lighting unit 2 and calibration system 3 are functionally coupled. The coupling can be hard wired. In most embodiments, however, the elements communicate wireless. Thus, the functional coupling in such an embodiment is a wireless coupling. A skilled person will recognize that such a coupling can be via one or more means and protocols like WiFi, Bluetooth, Zigby, via optical coupling, and the like. The elements may all be coupled to the internet and communicate via internet protocols.

[0061] In the embodiment illustrated, the lighting unit 2, calibration unit 3, and control unit 4 are depicted as separate elements. In many embodiments, these elements will be physically separated from one another. These elements in many embodiments are going to be remote from one another. For instance, the calibration unit 3 can be located at or near a production facility, the control unit may be located at a corporate headquarter, and (many) lighting units 2 may be located at stores, houses, manufacturing plants, and/or office buildings all over the world. Thus, a control unit 4 may be functionally coupled to a multitude of similar lighting units 2.

[0062] In the depicted embodiment, the control unit 4 receives measurement data from one calibration system 3 measuring many light sources 9. Alternatively, a series of control units 4 can receive data from one calibration system 3. Thus, a larger calibration system 3 can be defined that is functionally coupled with a series of control units 4. In this way, complex and accurate measuring devices 10 can be used which can automatically measure many light sources 9.

[0063] The elements discussed so far (lighting unit 2, calibration system 3, control unit 4) have been discussed on a communications level, and in an abstract manner. Below, these elements are going to be discussed on a more detailed level.

[0064] First, the lighting unit 2 will be discussed in more detail, then the calibration system, and finally the control unit 4.

[0065] The lighting unit 2 can be a lighting system based upon "light emitting diodes", LEDs. These are well known in the art by now. Other solid state light sources may also be used, for instance based on quantum dots, or other light emitting devices. As is commonly known, most of these advanced light sources require driving electronics and can be combined to obtain a required emission spectrum I(λ). Many different configurations of lighting units are possible. In the embodiment depicted in figure 1, three basic light sources are coupled to one drive unit 6. Two of these drive units 6 are combined into one lighting unit 2. The lighting unit 2 depicted here comprises an optical part 7 that can combine the output (light emission) $I_1(\lambda)$ of all the light sources 5 into one emission spectrum I(λ).

[0066] In some embodiments, the lighting unit 2 comprises a lighting unit control 8 that controls the drive units 6 and for instance allows data communication. A lighting unit 2 can be a physically separate entity. Like for instance for replacing the known light bulb.

[0067] Next, the calibration system 3 is going to be discussed. In an embodiment, as discussed, a statistically representative of the at least one light source is selected. In an embodiment, the statistically representative can be a light source that is from a same production batch, in case an element is produces in a batch process. For light sources that are produces in a continuous process, such a statistically representative can be elements that are produces in a certain time window around a light source. In the batch example, suppose that light sources are produces in batches of 5000 light sources. In such a situation, one can select for instance 5 light sources random from the 5000. The other light sources will get a batch indication. In the example of line production, suppose 5000 light sources are produces in an hour. Then at 5 random production times, light sources are selected. The other 4995 light sources produced in that hours will receive an identical identifier.

[0068] Next, the statistically representatives will be placed in a measurement setup. The measuring setup is provided with one or more measurement devices, like a luminescence photometer, a temperature sensor. At predefined time intervals, the measurement devices will measure characteristics of each light source. Thus, a data set is created of several characteristics of each light source against operation time. In an embodiment as depicted in figure 1, the measurement device of devices and the objects to be measured will be circulated with respect to one another. For instance, the light sources can have fixed positions on a rail. A transport device will move the measurement devices past each of the light sources.

[0069] In this way, a data set is created of statistically representatives of the light sources.

[0070] As indicated in Figure 1, the control unit 4 is configured to act on the drive unit 6 as a function of predetermined primary data 14 relating to the light sources 5, the optical part 7 and the drive unit 6 as well as instantaneous secondary data 130 obtained real-time from the lighting unit 110, the optical part 116 and the drive unit 115 during operation of the lighting system 100.

[0071] The system 1 may include any suitable light sources 5 having different color spectrums, particularly any type of light emitting diode, including organic light emitting diodes (OLED). It is also possible to use light sources 5 of different types together, in particular LEDs and incandescent light bulbs.

[0072] Optionally, the light unit 2 may include multiple light sources 5 that may be monochromatic or polychromatic. In some embodiments, each of light sources 5 may produce a monochromatic light having a single wavelength or a narrow SPD with a single peak. In other embodiments, each of light sources 5 may produce a polychromatic light having multiple different peaks in its SPD. Furthermore, in some embodiments, each of light sources 5 may be any type of light source capable of emitting single wavelength light or light with a narrow SPD with a single peak, such as an LED, high pressure sodium lamp (HPS), fluorescent lamp (FL), or the like, or any combination thereof. Considering different kinds of light sources, it is noted that multi-package LEDs are flexible in spectral composition, and spectrum proportions of each LED are easy to control. For example, in some embodiments, by choosing different drive units 6 like in figure 1, a variety of LEDs with different spectra could be obtained.

[0073] In some embodiments, chromaticity of each light source 5 may correspond to a specific chromaticity coordinate on a chromaticity diagram, which in turn may correspond to a specific color presented on the chromaticity diagram.

[0074] For example, as shown in Figure 1, the lighting unit 2 may comprise four component light sources 5. As described above, each component light source 5 may emit light having a specific color. For example, in some embodiments, the four colors may be red, amber, green and blue. In various embodiments, any colors presented on the chromaticity diagram may be used. A polychromatic desired light having desired optical characteristics may be produced by mixing the component lights according to certain proportions. In some embodiments, proportions of the component lights may correlate with each other. Particularly, in some embodiments, proportion of one component light may assume a linear relationship with proportion of another component light. It shall be noted that the above description of the light emitting device is provided for illustration purposes, and is not intended to limit the scope of the present disclosure. For persons of ordinary skill in the art, various variations and modifications may be conducted under the teaching of the present disclosure. For example, the lighting unit 2 may have any number of component light sources 5, each light source 5 may produce a component light of any color, and a component light may be a monochromatic or polychromatic light.

The drive unit 6 may drive the light sources 5 by providing them with voltage or current at calculated levels. The drive unit 6 may receive a command from the control unit 4, and adjust driving voltage or current for individual light sources 5 accordingly. The control unit 4 may be configured to select and determine parameters for spectrum optimization based on the local operating parameters 14 and the reference operating parameters 15. For example, the control unit 4 may calculate respective proportions of multiple component lights to be combined to generate a desired light having a desirable synthesized chromaticity which is defined by a desired color consistency. In some embodiments, the local operating parameters 14 may provide the control unit 4 information regarding a working condition of the lighting system 1. As used herein, the term "working condition" broadly relates to any condition or circumstance under which a lighting solution operates, which includes but is not limited to the purpose or goal of the lighting, the target object or environment to be illuminated, the requirement or input by a system default or a user, etc. In some embodiments, information regarding the working condition relates to conditions of an ambient environment of a target object and may be acquired by a detector, transmitted from a local storage device or a remote server, or manually input by a user, or the like, or a combination thereof.

[0075] In some embodiments, the control unit 4 calculates respective proportions of component lights based on the component chromaticity and the desired chromaticity. As used herein, the term "component chromaticity" refers to the chromaticity of a component light, and the term "desired chromaticity" or "synthesized chromaticity" refers to the chromaticity of the desired light.

The control unit 4 uses an optimization algorithm which is designed to calculate control settings of the drive unit 6 on the basis of the local operating parameters 14 and reference operating parameters 15 for optimizing a value of color consistency of each of the light sources 5 and/or maximizing life time of each of the light sources 5. The local operating parameters 14 may include values of the junction temperature 131 of the light sources 5 detected by a sensor, the temperature of the optical part detected by a sensor, power supplied to the light sources in at least one of the lighting unit 2 and/or the drive unit 6, during operation of the lighting system 1.

[0076] For example, with four component light sources 5, there might be unlimited possibilities or possibilities only limited by the resolution of the control to adjust a desired chromaticity coordinate color by mixing the used primary colors. Depending on the mixing ratio, it can be optimized towards different parameters like lumen efficiency or color consistency. The color consistency may be optimized towards the color reproductions properties of the optical part 7. When the optimization is done, desired chromaticity coordinates x/y may be adjusted.

[0077] The local operating parameters 14 may include previously measured data for each one the light sources 5, the drive unit 6 and the optical part 7. Said measured data may be provided as a specification from the manufacturers of at least one of the drive unit 6, the light sources 5 and the optical part 7. The reference operating parameters for the statistically representative light sources 9 may include a predetermined color spectrum, peak wavelength, dominant wavelength, and beam angle in full width and half maximum for each one of the light sources.

[0078] The present invention can be summarized as relating to a lighting system 100 with a lighting unit 110 which comprises at least two light sources 111, 112, 113, 114 having different color spectrums, with an optical part 116 which is configured to mix the color spectrums of the light sources 111, 112, 113, 114, with a drive unit 116 which is connected to the lighting unit 110, with a sensor 117, 118 which is configured to detect at least one of the junction temperature 131 of the light sources 111, 112, 113, 114 at a position of a connection area between the drive unit 115 and the lighting unit 110 and the temperature 133 of the optical part 116, and with a control unit 140 which is configured to optimize a value of color consistency of each of the light sources 111, 112, 113, 114 and to maximize life time of each of the light sources 111, 112, 113, 114, and configured to act on the drive unit 116.

[0079] It will be clear to a person skilled in the art that the scope of the present invention is not limited to the examples discussed in the foregoing but that several amendments and modifications thereof are possible without deviating from the scope of the present invention as defined by the attached claims. In particular, combinations of specific features of various aspects of the invention may be made. An aspect of the invention may be further advantageously enhanced by adding a feature that was described in relation to another aspect of the invention. While the present invention has been illustrated and described in detail in the figures and the description, such illustration and description are to be considered illustrative or exemplary only, and not restrictive.

[0080] The present invention is not limited to the disclosed embodiments. Variations to the disclosed embodiments can be understood and effected by a person skilled in the art in practicing the claimed invention, from a study of the figures, the description and the attached claims. In the claims, the word "comprising" does not exclude other steps or elements, and the indefinite article "a" or "an" does not exclude a plurality. 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. Any reference numerals in the claims should not be construed as limiting the scope of the present invention.

REFERENCE LIST

[0081]

1 lighting system
2 lighting unit
3 calibration system

4 control unit
5 local light sources
6 drive unit
7 optical part
8 lighting unit control
9 statistically representative light sources
10 measuring system
11 control unit communication device
12 Machine learning module
13 training data set
14 local operating parameters
15 reference operating parameters
16 local control settings

t time
T(t) temperature as a function of time
P(t) power as a function of time
M(t) light source output as a function of time
L illumination instructions

Claims

1. A control unit for a lighting system, which lighting system comprises a drive unit and at least one light sources with said drive unit functionally coupled to said at least one light sources, wherein the control unit is functionally coupled to said lighting system and comprises:

- a communication device for retrieving data remotely from the lighting system;
- a data processor and a computer program product which, when running on said data processor:

* retrieve local operating parameters from said lighting system, said local operating parameters comprises a total local operations time of the at least one light source, a representative of a temperature of the at least one light source at said local operations time, and a representative of a power drawn by the at least one light source at said local operations time;
* generates a machine learning network;
* retrieve reference operating parameters from a set of reference light sources which are statistically representative of the at least one light source and which are based upon a reference operations time;
* retrieve measured reference light output parameters at said reference operations time from the set of reference light sources;
* update a machine learning network training dataset using said retrieved reference operating parameters and reference light output parameters and said reference operations time;
* update said machine learning network using said updated training dataset;
* provide said local operating parameters as input to said updated machine learning network;
* generate said local control settings using said updated machine learning network, and provide said local control settings to said lighting system.

2. The control unit of claim 1, wherein said at least one light source is a solid state light source, in particular a LED light source, and/or said at least one light source comprises at least two light sources each having a different emission spectrum, in particular at least three light sources with each light source having a different emission spectrum.

3. The control unit according to any one of the preceding claims, wherein the control unit is configured to optimize a value of color consistency of each of the at least two light sources, in particular a ratio of each of the at least two light sources in order to generate a set light emission.

4. The control unit according to any one of the preceding claims, wherein the control unit is configured to maximize a life time of each of the at least two light sources.

5. The control unit according to any one of the preceding claims, further comprising a second communication device for communicating data to the lighting system, in particular the communication device using a second communication protocol different from the communication protocol of the communication device, wherein the computer program product, when running on said data processor, controls the second communication device for transmitting the local control settings to said lighting system.

6. The control unit according to any one of the preceding claims, wherein said computer program product transmits data to lighting system at least once a day, in particular functionally real time, in particular real time.

7. The control unit according to any one of the preceding claims, wherein said computer program product is set to receiving reference operating parameters at least a daily base, in particular at least once every hour.

8. A computer program product generating control settings for a lighting system that comprises a drive unit and at least one light source functionally coupled to said at least one light source, which computer program product, when running on a data processor:

* retrieve local operating parameters from said lighting system, said local operating parameters comprises a total local operations time of the at least one light source, a representative of a temperature of the at least one light source at said local operations time, and a representative of a power drawn by the at least one light source at said local operations time;
* generates a machine learning network;
* retrieve reference operating parameters from a set of reference light sources which are statistically representative of the at least one light source and which are based upon a reference operations time;
* retrieve measured reference light output parameters at said reference operations time from the set of reference light sources;
* update a machine learning network training dataset using said retrieved reference operating parameters and reference light output parameters and said reference operations time;
* update said machine learning network using said updated training dataset;
* provide said local operating parameters as input to said updated machine learning network;
* generate said local control settings using said updated machine learning network, and provide said local control settings to said lighting system.

9. A lighting system, comprising:

- a lighting unit which comprises at least two of said light sources having different color spectra;
- a drive unit which is functionally coupled to the lighting unit and which is configured to control power to at least one of the light sources of the lighting unit;
- at least one sensor which is configured to detect a representative of a temperature each of the at least two light sources, and
- the control unit of any one of the preceding claims, functionally coupled to the drive unit.

10. The lighting system of claim 9, further comprising:

- an optical part which is configured to mix the color spectra of the light sources.

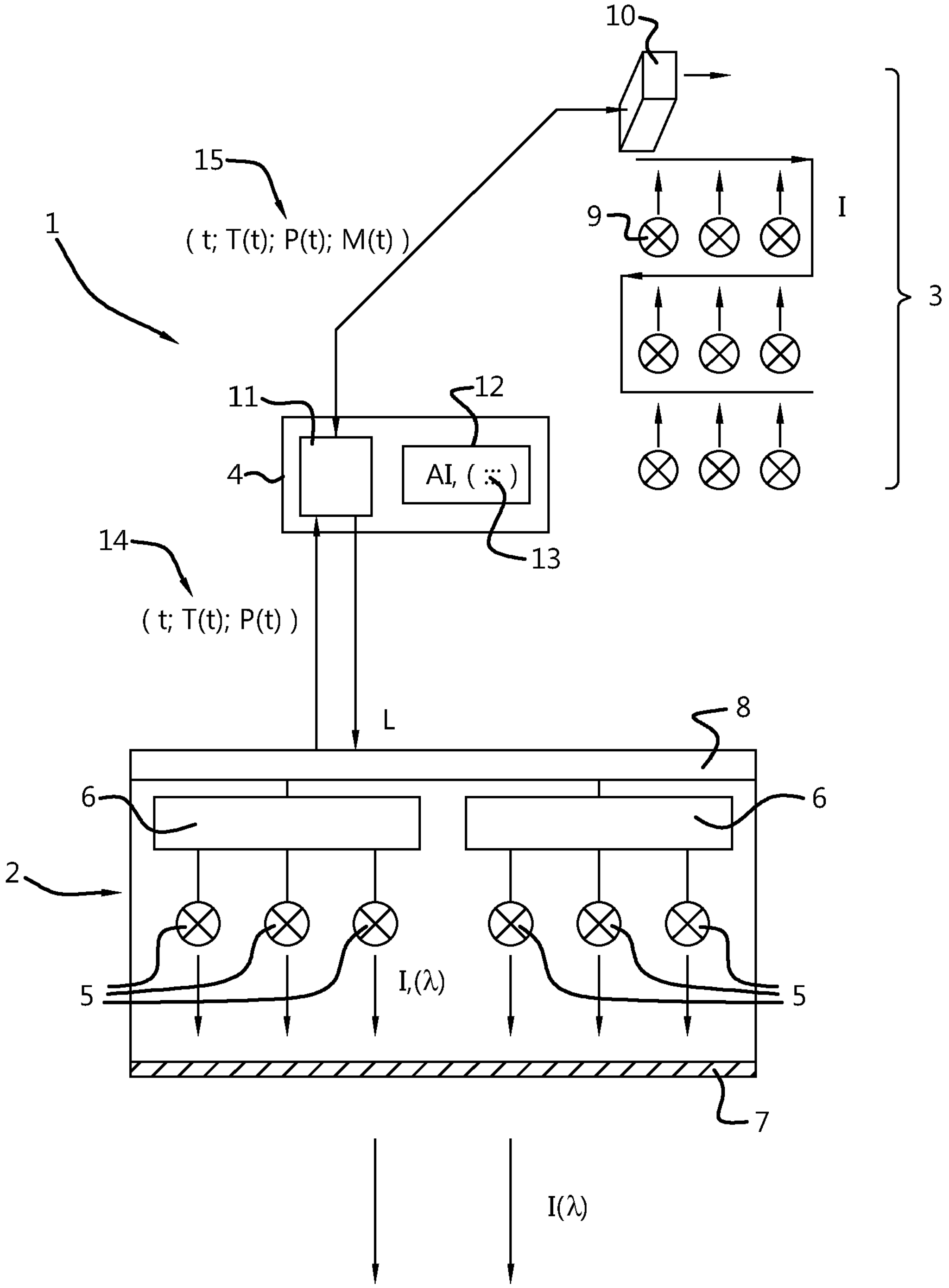
11. A method for operating a lighting system provided with the control unit of any one of the preceding claims 1-5, said lighting system comprising a lighting unit comprising at least two light sources having different color spectra, and a drive unit which is functionally coupled to the light sources and which is configured to energize the at least two light sources of the lighting unit, with at least one sensor which is configured to detect at a representative of a temperature of the light sources, and with a control unit functionally coupled to the drive unit, wherein the method comprises:

* retrieve local operating parameters from said lighting system, said local operating parameters comprises a total local operations time of the at least one light source, a representative of a temperature of the at least one light source at said local operations time, and a representative of a power drawn by the at least one light source at said local operations time;
* generates a machine learning network;
* retrieve reference operating parameters from a set of reference light sources which are statistically representative of the at least one light source and which are based upon a reference operations time;
* retrieve measured reference light output parameters at said reference operations time from the set of reference light sources;
* update a machine learning network training dataset using said retrieved reference operating parameters and reference light output parameters and said reference operations time;
* update said machine learning network using said updated training dataset;
* provide said local operating parameters as input to said updated machine learning network;
* generate said local control settings using said updated machine learning network, and provide said local control settings to said lighting system.

12. The method according to any of the preceding claims, further comprising:

- controlling a lumen value of each of the light sources during operation of the lighting system in accordance with the calculated control settings.

Fig. 1



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EUROPEAN SEARCH REPORT

Application Number
EP 21 16 6503

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	WO 2017/192566 A1 (GROWFLUX LLC [US]) 9 November 2017 (2017-11-09) * paragraphs [0102] - [0151]; figures 2, 3, 4 *	1-12	INV. H05B45/24 H05B45/28 H05B45/50
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TECHNICAL FIELDS SEARCHED (IPC)

H05B

The present search report has been drawn up for all claims

3

Place of search	Date of completion of the search	Examiner
Munich	16 September 2021	Morrish, Ian

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO. EP 21 16 6503

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16-09-2021

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