

[DESCRIPTION]

[Title of Invention] LIGHTING CONTROL DEVICE, LIGHTING CONTROL SYSTEM, AND LIGHTING CONTROL METHOD

[Technical Field]

5 The present disclosure relates to a lighting control device, a lighting control system, and a lighting control method.

[Background Art]

 Conventionally, there is disclosed a lighting control device that includes a human body detector that detects the presence of a human body within a
10 detection area using an ultrasonic sensor, etc., and a controller that controls the light emission states of a plurality of lighting loads based on detection information from the human body detector (for example, see Patent Literature
1). This lighting control device is capable of providing an appropriate lighting environment according to the time period for which a person is present in the
15 detection area.

[Citation List]

[Patent Literature]

[PTL 1]

 Japanese Unexamined Patent Application Publication No. H10-125477

20 [Summary of Invention]

[Technical Problem]

 When a conventional lighting control device is applied to a lighting apparatus that restores biorhythm by irradiating a person's body with light, the user is irradiated with high output light which tends to dazzle the user.
25 Consequently, the user tends to forego treatment using light that restores biorhythm.

 In view of this, the present disclosure provides a lighting control device,

a lighting control system, and a lighting control method which are capable of reducing glare when a user undergoes treatment using light.

[Solution to Problem]

In order to achieve the above-described object, a lighting control device
5 according to an aspect of the present disclosure is a lighting control device that controls a light source according to a surrounding light amount detected by a light detector, and includes: a controller that determines, according to the surrounding light amount, an initial output value for output of light emitted by the light source, and a required time period to be taken for the output to rise
10 from the initial output value and reach a target output value greater than the initial output value, and controls power to be supplied to the light source to cause the output to rise from the initial output value and reach the target output value over the required time period. The controller: sets the initial output value higher when the surrounding light amount is a second light
15 amount than when the surrounding light amount is a first light amount, the second light amount being greater than the first light amount; and sets the required time period shorter when the surrounding light amount is the second light amount than when the surrounding light amount is the first light amount.

Furthermore, a lighting control system according to an aspect of the
20 present disclosure includes a light source that emits light, a light detector that detects a surrounding light amount, and the above-described lighting control device.

Furthermore, a lighting control method according to an aspect of the present disclosure is a lighting control method of controlling a light source
25 according to a surrounding light amount that is detected, and includes: determining, according to the surrounding light amount, an initial output value for output of light emitted by the light source, and a required time period to be

taken for the output to rise from the initial output value and reach a target output value greater than the initial output value, and controlling power to be supplied to the light source to cause the output to rise from the initial output value and reach the target output value over the required time period; setting
5 the initial output value higher when the surrounding light amount is a second light amount than when the surrounding light amount is a first light amount, the second light amount being greater than the first light amount; and setting the required time period shorter when the surrounding light amount is the second light amount than when the surrounding light amount is the first light
10 amount.

[Advantageous Effects of Invention]

According to the present disclosure, it is possible to reduce glare when a user undergoes treatment using light.

[Brief Description of Drawings]

15 FIG. 1 is a block diagram illustrating a lighting apparatus including a lighting control device according to Embodiment 1;

FIG. 2 is a graph illustrating the relationship between brightness and object luminance as adaptation luminance;

20 FIG. 3 is a graph illustrating the relationship between adaptation luminance and brightness;

FIG. 4 is a graph illustrating the relationship between output of light emitted by a light-emitting module and a required time period;

FIG. 5 is a diagram illustrating a positional relationship between an observer and a lighting apparatus;

25 FIG. 6 is a table indicating UGRs for indirect illuminance;

FIG. 7 is a diagram illustrating the relationship between environmental illuminance and the required time period;

FIG. 8 is a diagram illustrating the relationship between the brightness of light emitted by the lighting apparatus and a time period;

FIG. 9 is a graph illustrating the relationship between the brightness of light emitted by the lighting apparatus and the time period;

5 FIG. 10 is a flowchart describing the operation of the lighting apparatus according to Embodiment 1; and

FIG. 11 is a flowchart describing the operation of a lighting apparatus according to Embodiment 2.

[Description of Embodiments]

10 Hereinafter, exemplary embodiments of the present disclosure will be described with reference to the drawings. It should be noted that each of the subsequently-described exemplary embodiments show a specific preferred example of the present disclosure. The numerical values, shapes, materials, structural components, the arrangement and connection of the structural
15 components, steps, the processing order of the steps, etc. shown in the following exemplary embodiments are mere examples, and are not intended to limit the scope of the present disclosure. Therefore, among the structural components in the following exemplary embodiments, components not recited in any one of the independent claims which indicate the broadest concepts of the present
20 disclosure are described as arbitrary structural components.

It should be noted that the drawings are schematic diagrams, and do not necessarily provide strictly accurate illustration. Furthermore, in the drawings, substantially identical components are assigned the same reference signs, and overlapping description is omitted or simplified.

25 Hereinafter, a lighting control device, a lighting control system, and a lighting control method according to exemplary embodiments of the present disclosure will be described.

[Embodiment 1]

[Configuration]

FIG. 1 is a block diagram illustrating lighting apparatus 1 including lighting control device 10 according to Embodiment 1.

5 As illustrated in FIG. 1, lighting apparatus 1 emits light that restores biorhythm by regulating a user's biological clock. Lighting apparatus 1 is, for example, a light exposure apparatus or a light treatment apparatus that is placed on a table top. Lighting apparatus 1 may also be a lighting control system including a plurality of devices. Lighting apparatus 1 is an example of
10 a lighting control system.

The light that restores biorhythm is, for example, blue light. Blue light is known to have the effect of improving biorhythm when a person is exposed to light including blue light during the day. In particular, it is known that exposure to at least a predetermined amount of blue light during the day
15 has the effect of increasing the secretion amount of the biological hormone melatonin and, in the change (phase) in the secretion amount for one day, the phase advances. Accordingly, it is preferable to improve biorhythm by allowing this blue light to enter the eyes.

Lighting apparatus 1 includes light-emitting module 110, light detector
20 120, and lighting control device 10.

Light-emitting module 110 is a device that emits light having an effect of restoring a person's biorhythm. Light having an effect of restoring a person's biorhythm is, in this embodiment, light including plenty of blue light or light including blue light and white light. In this embodiment,
25 light-emitting module 110 is capable of emitting only blue light or white light, and is capable of simultaneously emitting blue light and white light. Light-emitting module 110 is an example of a light source.

It should be noted that blue light here does not mean blue light in the strict sense, but refers to light that normally appears blue, for example, light having a wavelength of from 430 nm to 495 nm. Here, white light mentioned does not mean white light in the strict sense, but refers to white that normally appears white, and is light in which light of various colors of visible rays (for example, blue light (430 nm to 495 nm), green light (495 nm to 570 nm), red light (620 nm to 750 nm), etc.) are substantially uniformly mixed.

Light-emitting module 110 includes a substrate and a plurality of LED elements mounted on the substrate.

The substrate is a printed wiring board for mounting the plurality of LED elements, and is formed in a substantially rectangular shape. As a substrate, it is possible to use, for example, a resin substrate having a resin base, a metal base substrate having a metal base, or a ceramic substrate formed from ceramic.

The plurality of LED elements are mounted on the substrate. For example, the plurality of LED elements are arranged in sheet form (in rows and columns) on the substrate. For example, the plurality of LED elements are disposed at equal intervals on the substrate. The LED element may be an example of a light source.

The plurality of LED elements consists of light-emitting diode (LED) elements. The plurality of LED elements are capable of emitting white light, blue light, and red light. In this embodiment, for example, each LED element is an RGB-type LED element that emits blue light, green light, and red light. It should be noted that the LED element may be a surface-mount device (SMD) LED element or a chip-on-board (COB) LED element. The LED element is not limited to the RGB three color-type, and may be of an RGBW four color, or a BW two color (blue and white two color)-type.

Furthermore, although not illustrated in the figure, a signal line which is wiring for transmitting a control signal from lighting control device 10 and a power line which is wiring for supplying power from a power supply unit are provided on the substrate. For example, the signal line and the power line are
5 connected in series to each of the plurality of LED elements. Each of the plurality of LED elements receives supply of power from the power supply unit via the power line, and emits a predetermined light based on the control signal from the signal line.

Light detector 120 is a sensor capable of detecting the amount of light
10 in the surroundings (hereafter also referred to as “surrounding light amount”) of lighting apparatus 1. Light detector 120 is, for example, an illuminance sensor, or the like. Light detector 120 outputs, to lighting control device 10, a sensor value which is the detected surrounding light amount.

Lighting control device 10 controls light-emitting module 110 according
15 to the surrounding light amount detected by light detector 120. Lighting control device 10 includes controller 20 and input unit 30.

Controller 20 controls the power to be supplied to light-emitting module 110. Specifically, controller 20 determines, according to the surrounding light amount, an initial output value for the output of light emitted by light-emitting
20 module 110 and a required time period to be taken for the output of light emitted by light-emitting module 110 to rise from the initial output value and reach a target output value greater than the initial output value, and controls the power to be supplied to light-emitting module 110 to cause the output of light emitted by light-emitting module 110 to rise from the initial output value
25 and reach the target output value over the required time period. Specifically, controller 20 regulates the output of light emitted by light-emitting module 110, by determining the initial output value indicating the light amount of the light

initially emitted by light-emitting module 110 and the required time period to reach the target output value. The initial output value and the target output value are exemplified by illuminance (lx) here, but may be exemplified by luminous flux (lm), radiant energy (W), etc.

FIG. 2 is a graph illustrating the relationship between brightness and object luminance as adaptation luminance. FIG. 2 is shown in “Takeuchi, Tetsuji (1997) AKARUSA NO CHIKAKU, Shomei Gakkai Shi (Tetsuji Takeuchi (1997) PERCEPTION OF BRIGHTNESS, The Illuminating Engineering Institute of Japan Journal), Vol. 81 (1), pages 493 to 499”. FIG. 2 illustrates a graph in which adaptation luminances are 0 (cd/m²), 3 (cd/m²), 30 (cd/m²), 300 (cd/m²), 1000 (cd/m²), and 3000 (cd/m²).

The relationship between respective adaptation luminances and brightness when the object luminance in FIG. 2 is 102 is illustrated in FIG. 3. FIG. 3 is a graph illustrating the relationship between adaptation luminance and brightness. In FIG. 3, it is illustrated that the base at which the positive and negative directions in brightness axis reverse is a logarithmic function of 10. As illustrated in FIG. 3, it can be seen that brightness decreases together with the rise in adaptation luminance. From this, the relationship between the output of light emitted by light-emitting module 110 and the required time period is derived.

FIG. 4 is a graph illustrating the relationship between the output of light emitted by light-emitting module 110 and the required time period. As illustrated in FIG. 4, controller 20 causes the output of light emitted by light-emitting module 110 to increase with the passing of time. Specifically, controller 20 causes the power to be supplied to light-emitting module 110 to increase with the passing of time.

Controller 20 sets the initial output value higher when the surrounding

light amount is a second light amount than when the surrounding light amount is a first light amount. Here, the second light amount is greater than the first light amount. Specifically, controller 20 determines the initial output value according to the brightness of the surroundings (hereafter also referred to as “surrounding brightness”) of lighting apparatus 1. As an example, when the surroundings are dark, controller 20 sets the initial output value low so as to match the surrounding brightness; when the surroundings are bright, controller 20 sets the initial output value high so as to match the surrounding brightness. This is because, for example, if lighting apparatus 1 is bright and the surroundings of lighting apparatus 1 are dark, the difference in brightness and darkness between the brightness of lighting apparatus 1 and the surrounding brightness of lighting apparatus 1 becomes big. When the difference between this brightness and darkness is big, a person tends to feel unnecessarily dazzled by the light of lighting apparatus 1. As such, the initial output value is determined so that the brightness of the light emitted by lighting apparatus 1 matches the surrounding brightness. It should be noted that, since a person gets used to the brightness when a predetermined period of time passes, the person does not feel unnecessarily dazzled even when the light emitted by lighting apparatus 1 is brightened.

The initial output value is a value that is determined depending on the surrounding brightness of lighting apparatus 1, and includes 0. The initial output value is set to such a value that, relative to the surrounding environment of lighting apparatus 1, a user does not feel or hardly feels dazzled.

The method of setting the initial output value will be described in detail.

FIG. 5 is a diagram illustrating a positional relationship between an

observer and a lighting apparatus.

The Glare Index Method which is a method that accurately evaluates discomfort glare using a formula which has, as variables, the luminance of the lighting apparatus, the size of the lighting apparatus, the position of the lighting apparatus, the surrounding brightness that become the background of the light emission surface of the lighting apparatus such as the ceiling surface and the wall surface, which influence the degree of discomfort glare, as illustrated in FIG. 5, is known. This is described, for example, in the URL “<http://www2.panasonic.biz/es/lighting/plam/knowledge/document/0105.html>”
a-puanchor_8”.

Here, unified glare rating (UGR), which is a method that unifies discomfort glare, is taken into consideration. The UGR is calculated from background luminance L_b (cd/m^2), lighting apparatus light emission surface luminance L (cd/m^2), lighting apparatus light emission surface size ω (sr), and the subsequently-described position index ρ , using Equation 1.,

[Math. 1]

$$UGR = 8 \ln \left(\frac{0.25}{L_b} \right) \sum \frac{L^2 \omega}{\rho^2} \quad (\text{Equation 1})$$

Here, background luminance L_b is normally calculated from indirect illuminance E_i (lx) at the position of the observer’s eyes, using Equation 2.

The observer is the user in this embodiment.

[Math. 2]

$$L_b = \frac{E_i}{\pi} \quad (\text{Equation 2})$$

Lighting apparatus light emission surface luminance L can be calculated from luminous intensity I (cd) of the lighting apparatus in the

direction of the observer and lighting apparatus projection area A_p (m²), using Equation 3.

[Math. 3]

$$L = \frac{I}{A_p} \quad (\text{Equation 3})$$

5 The lighting apparatus light emission surface size, since it is expressed by solid angle ω , is calculated from lighting apparatus projection area A_p (m²) and distance r (m) from the observer to the lighting apparatus, using Equation 4.

[Math. 4]

$$\omega = \frac{A_p}{r^2} \quad (\text{Equation 4})$$

Position index ρ is an index determined according to the position of the lighting apparatus when seen from the observer. The method for calculating the value of position index ρ will be described using the lighting space in FIG. 5 as an example. As illustrated in FIG. 5, the positional relationship between the observer and lighting apparatus is expressed by distance H in the height direction from the center of the visual field to the lighting apparatus, distance L in the lateral direction from the center of the visual field to the lighting apparatus, and distance R from the observer to the fixation point. Next, L/R and H/R is calculated from H , L , and R . Subsequently, based on the calculated L/R and H/R , position index ρ is read from a predetermined position index calculation table. Since the value of the UGR and the degree of discomfort glare have a fixed relationship, discomfort glare is evaluated based on this relationship.

In the JIS lighting of indoor workplace standard (JIS Z9125:2007), it is preferable that the degree of discomfort glare does not exceed the UGR value.

If the UGR value is exceeded, the glare imparts a feeling of discomfort to the user. In the JIS lighting of indoor workplace standard, when it is assumed that the lighting apparatus in this embodiment is to be used in a canteen or a lounge, for example, the UGR value is set at 22.

5 Based on this, from H, L, R, etc., the UGR when the indirect (background) illuminance at the position of the observer's eyes is 350 lx, 500 lx, 650 lx, and 800 lx is 22, and the illuminance of the lighting apparatus at the position of the observer is shown in FIG. 6. FIG. 6 is a table indicating the UGR for indirect illuminance.

10 As illustrated in FIG. 6, H/R, L/R, and position index ρ are calculated, where distance H in the height direction from the center of the visual field to the lighting apparatus is 1, distance L in the lateral direction from the center of the visual field to the lighting apparatus is 0.5, and distance R from the observer to the fixation point is 2.

15 From the results in FIG. 6, in the case where the brightness of light-emitting module 110 has the rate of change that increases in stages with the passing of time in (d) in FIG. 8, the illuminance of the lighting apparatus at the observer's position with which UGR is 22 is calculated to be 900 lx, when indirect illuminance is, for example, 350 lx. As such, it is possible that by
20 setting the initial output value such that the illuminance of the lighting apparatus at the observer's position is less than or equal to 900 lx, discomfort glare does not occur. By performing these calculations, the initial output value can be set to such a value that, relative to the surrounding environment of the lighting apparatus, a user does not feel or hardly feels dazzled.

25 FIG. 7 is a diagram illustrating the relationship between required time period t and environmental illuminance E . In FIG. 7, required time period t is indicated by the vertical axis, and environmental illuminance E is indicated by

the horizontal axis.

Here, (a) in FIG. 7 illustrates a step form in which required time period t decreases following an increase in brightness, (b) in FIG.7 illustrates an inverse proportional curve form in which required time period t decreases following an increase in brightness, (c) in FIG.7 illustrates a step form in which required time period t decreases in stages following an increase in brightness, and (d) in FIG. 7 illustrates a linear form in which required time period t decreases following an increase in brightness.

Controller 20 sets the required time period shorter when the surrounding light amount is the second light amount than when the surrounding light amount is the first light amount. Specifically, when the surrounding light amount is the first light amount, controller 20 sets the required time period longer than when the surrounding light amount is the second light amount; and when the surrounding light amount is the second light amount, controller 20 sets the required time period shorter than when the surrounding light amount is the second light amount.

As illustrated in (a) through (d) in FIG. 7, each relationship between required time period t and environmental illuminance E is indicated by a monotonically nonincreasing function. It should be noted that the relationship between required time period t and environmental illuminance E is not limited to the relationships illustrated in (a) through (d) in FIG. 7.

FIG. 8 is a diagram illustrating the relationship between brightness $g(t)$ of light emitted by light-emitting module 110 and required time period t . In FIG. 8, environmental illuminance E is indicated by the vertical axis, and required time period t is indicated by the horizontal axis.

Here, (a) in FIG. 8 illustrates a linear form in which brightness $g(t)$ of light emitted by light-emitting module 110 increases with the passing of time,

(b) in FIG. 8 illustrates a plurality of straight lines in which brightness $g(t)$ of light emitted by light-emitting module 110 increases with the passing of time, (c) in FIG. 8 illustrates a curved form in which brightness $g(t)$ of light emitted by light-emitting module 110 increases exponentially with the passing of time, and (d) in FIG. 8 illustrates a step form in which brightness $g(t)$ of light emitted by light-emitting module 110 increases in stages with the passing of time.

It should be noted that in (b) in FIG. 8, with regard to the straight lines in which $g(t)$ increases, the slope of the straight lines also increases with the increase in brightness and the passing of time. In (d) in FIG. 8, with regard to the step portions forming the step form in which $g(t)$ increases, the amount of increase in brightness increases with the increase in brightness and the passing of time.

Controller 20 causes the amount of change in the output of light emitted by light-emitting module 110 to increase with the passing of time. More specifically, controller 20 causes the amount of change in the output of light emitted by light-emitting module 110 to increase with the passing of time, using an exponential function. In other words, controller 20 causes the amount of change in the output of light emitted by light-emitting module 110 to increase according to a monotonically nondecreasing function. For example, using (c) in FIG. 8 as an example, when controller 20 uses an exponential function, the function of brightness indicated by the exponential function is divided into a first region from 0 to a_1 and a second region from a_1 to a_2 which is brighter than the first region. In the first region, the increase/decrease in brightness indicated by the function is gentle, and thus a first required time period, which is the time period for which light-emitting module 110 emits light, becomes long. In the second region, the increase/decrease in brightness indicated by the function is steep compared to the first region, the second

required time period becomes short. The second region is a region that exists after the first region, that is, a region coming after the elapse of the first required time period from when light-emitting module 110 is turned ON. The time period for which light-emitting module 110 emits light in the second
5 region is the second required time period. As such, a time period obtained by adding the second required time period to the first required time period is the required time period.

As illustrated in (a) through (d) in FIG. 8, each relationship between brightness $g(t)$ of light emitted by light-emitting module 110 and required time
10 period t is indicated by a monotonically nondecreasing function. It should be noted that the relationship between brightness $g(t)$ of light emitted by light-emitting module 110 and required time period t is not limited to the relationships illustrated in (a) through (d) in FIG. 8.

An example in which the initial output value and the required time
15 period are determined in such lighting apparatus 1 will be described.

FIG. 9 is a graph illustrating the relationship between the brightness of light emitted by lighting apparatus 1 and time.

As illustrated in FIG. 9, for example, where the brightness of peripheral light is 352 lx, a time of 6:55 is set as a reference, and the target output value is
20 2445 lx, a linear monotonically nondecreasing function as in (a) in FIG. 8 is used. Under this condition, controller 20 calculates the initial output value as 352 lx and calculates the required time period up to the target output value as 5 minutes. In this case, when the surrounding brightness is 0 lx, controller 20 calculates the turn ON start time as 6:54 which is a time that is 1 minute
25 earlier than 6:55. In other words, the required time period is 6 minutes. Furthermore, when the surrounding brightness is 1000 lx, controller 20 calculates the turn ON start time as 6:56:30 which is 1 minute and 30 seconds

later than 6:55.

As illustrated in FIG. 1, controller 20 determines whether surrounding brightness E (for example, the environmental illuminance described earlier) indicated by a sensor value is less than threshold value E1. This is performed
5 in order to determine (set) an initial output value according to the surrounding environment of lighting apparatus 1 by determining whether the surroundings of lighting apparatus 1 is a bright environment or a dark environment.

When controller 20 determines that surrounding brightness E is less than threshold value E1, controller 20 calculates required time period T1a that
10 is required when raising output from the initial output value to the target output value. In contrast, when controller 20 determines that surrounding brightness E is greater than or equal to threshold value E1, controller 20 calculates required time period T2a that is shorter than required time period T1a and required when raising output from the initial output value to the
15 target output value. Specifically, when the surrounding brightness of lighting apparatus 1 is dark, controller 20 lengthens the required time period that is required when the output is raised from the initial output value to the target output value. In contrast, when controller 20 determines that the surrounding brightness of lighting apparatus 1 is bright, controller 20 shortens
20 the required time period that is required when the output is raised from the initial output value to the target output value.

Furthermore, controller 20 determines whether integrated value p between brightness (illuminance) and a usable time period for which the user uses lighting apparatus 1 is greater than or equal to required light exposure
25 amount Q. For example, a daily required light exposure amount Q required to regulate the circadian rhythm of an elderly person is said to be 5000 lx·hour (A Wirz-Justice et al. (2013), Chronotherapeutics for Affective Disorders,

KARGER). Based on this, since the daily required light exposure amount is satisfied when integrated value p is greater than or equal to required light exposure amount Q , controller 20 controls the power to be supplied to light-emitting module 110 for required time period T1a or required time period T2a. Furthermore, since the daily required light exposure amount is not satisfied when integrated value p is less than required light exposure amount Q , controller 20 controls the power to be supplied to light-emitting module 110 for required time period T1b which is a time period shorter than required time period T1a, or for required time period T2b which is a time period shorter than required time period T2a. It should be noted that the usable time period for which the user uses lighting apparatus 1 is the time period in which the user undergoes light exposure. Furthermore, there are cases where required time period T2b may be longer, shorter, or the same as required time period T1b. Integrated value p is equivalent to the light exposure amount to which the user has been exposed to light.

To describe using the example illustrated in FIG. 9, assuming that, in the case where the surrounding brightness of lighting apparatus 1 is 0 lx, the region indicated by slanted lines from 6:54 to time t_a is required light exposure amount Q , the usable time period for which the user uses lighting apparatus 1 is t_0 , and the function is $g(t)$. Required light exposure amount Q is indicated by the integrated value of time and brightness, that is, the area of the slanted line region. The relational expression in this case is expressed by Equation 5. [Math. 5]

$$\int_0^{t_0} g(t) dt \geq \int_0^{t_a} g(t) dt \quad (\text{Equation 5})$$

In this case, the daily required light exposure amount is sufficient.

Furthermore, to describe using another example, assuming that, in the case where the surrounding brightness of lighting device 1 is 0 lx, the region

indicated by slanted lines from 6:54 to time t_a is required light exposure amount Q , and the usable time period for which the user uses lighting apparatus 1 is t_1 . The relational expression in this case is expressed by Equation 6.

5 [Math. 6]

$$\int_0^{t_1} g(t) dt < \int_0^{t_a} g(t) dt \quad (\text{Equation 6})$$

In this case, the daily required light exposure amount is insufficient.

From this, when the usable time period for which the user uses lighting apparatus 1 is long, controller 20 calculates required time periods T_{1a} and T_{2a} which are longer than required time periods T_{1b} and T_{2b} . When the usable time period for which the user uses lighting apparatus 1 is short, controller 20 calculates required time periods T_{1b} and T_{2b} which are shorter than required time periods T_{1a} and T_{2a} . In this manner, controller 20 regulates the required time period so that the user satisfies the required light exposure amount.

Input unit 30 can receive, by way of an input operation by the user, input of the usable time period for which the user uses lighting control device 10. Input unit 30 is an interface that outputs the inputted usable time period to controller 20, and is, for example, a display unit including push-down buttons, a touch panel, etc. It should be noted that input unit 30 need not be provided in lighting control device 10, and need only to be provided in lighting apparatus 1. Furthermore, input unit 30 may be an input terminal such as a smartphone that is capable of radio communication with lighting apparatus 1.

[Operation]

25 Next, the operation of lighting control device 10, lighting apparatus 1, and the lighting control method will be described with reference to FIG. 10.

FIG. 10 is a flowchart describing the operation of lighting apparatus 1 according to Embodiment 1.

As illustrated in FIG. 10, first, the user inputs the usable time period for which the user uses lighting apparatus 1 (S1). The usable time period may
5 be inputted from input unit 30. Furthermore, another input unit may be connected to controller 20, and the inputting may be performed via the other input unit.

Next, light detecting unit 120 of lighting apparatus 1 detects the surrounding brightness of lighting apparatus 1, generates a sensor value, and
10 outputs the sensor value to controller 20 of lighting control device 10. When controller 20 obtains the sensor value, controller 20 determines (sets) the initial output value according to the sensor value (S2).

Next, controller 20 determines whether surrounding brightness E of lighting apparatus 1 indicated by the sensor value is less than threshold $E1$
15 (S3).

When controller 20 determines that surrounding brightness E of lighting apparatus 1 is less than threshold value $E1$ (Yes in S3), controller 20 calculates required time period $T1a$ that is required when raising output from the initial output value to the target output value (S4). Calculation of
20 required time period $T1a$ is calculation based on the description with reference to FIG. 5 and FIG. 6.

Next, controller 20 determines whether integrated value p of the light exposure amount is greater than or equal to required light exposure amount Q (S5).

25 When controller 20 determines that integrated value p is greater than or equal to required light exposure amount Q (Yes in S5), controller 20 controls the power to be supplied to light-emitting module 110 for required time period

T1a (S6). Specifically, controller 20 controls the power to be supplied to light emitting module 110 to cause the output of light emitted by light-emitting module 110 to rise from the initial output value and reach the target output value over required time period T1a. Then, the process ends.

5 In contrast, when controller 20 determines that integrated value p is less than required light exposure amount Q (No in S5), controller 20 controls the power to be supplied to light-emitting module 110 for required time period T1b (S7). Specifically, controller 20 controls the power to be supplied to light emitting module 110 to cause the output of light emitted by light-emitting
10 module 110 to rise from the initial output value and reach the target output value over required time period T1b. Required time period T1b is a value obtained by correcting required time period T1a, and has a value less than the value of required time period T1a. The reason required time period T1b is less than required time period T1a is that, when integrated value p is less than
15 required light exposure amount Q , the daily required light exposure amount Q required to regulate the circadian rhythm of a person is insufficient. As such, setting required time period T1b shorter than required time period T1a causes integrated value p of the light exposure amount to increase. Then, the process ends.

20 In contrast, when controller 20 determines that surrounding brightness E is greater than or equal to threshold value $E1$ (No in S3), controller 20 calculates required time period T2a that is required when raising the output from the initial output value to the target output value (S11).

Next, controller 20 determines whether integrated value p of the light
25 exposure amount is greater than or equal to required light exposure amount Q (S12).

When controller 20 determines that integrated value p is greater than

or equal to required light exposure amount Q (Yes in S12), controller 20 controls the power to be supplied to light-emitting module 110 for required time period $T2a$ (S13). Specifically, controller 20 controls the power to be supplied to light emitting module 110 to cause the output of light emitted by light-emitting module 110 to rise from the initial output value and reach the target output value over required time period $T2a$. Then, this process ends.

In contrast, when controller 20 determines that integrated value p is less than required light exposure amount Q (No in S12), controller 20 controls the power to be supplied to light-emitting module 110 for required time period $T2b$ (S14). Specifically, controller 20 controls the power to be supplied to light emitting module 110 to cause the output of light emitted by light-emitting module 110 to rise from the initial output value and reach the target output value over required time period $T2b$. Then, this process ends. Required time period $T2b$ is a value obtained by correcting required time $T2a$, and has a value smaller than the value of required time period $T2a$. The reason that required time period $T2b$ is less than required time period $T2a$ is the same as the reason that required time period $T1b$ is less than required time period $T1a$.

[Effects]

Next, the effects produced by lighting control device 10, lighting apparatus 1, and the lighting control method according to this embodiment will be described.

As described above, lighting control device 10 according to this embodiment controls light-emitting module 110 according to the surrounding light amount detected by light detector 120. Lighting control device 10 includes controller 20 that determines, according to the surrounding light amount, an initial output value for output of light emitted by light-emitting module 110, and a required time period to be taken for the output to rise from

the initial output value and reach a target output value greater than the initial output value, and controls power to be supplied to light-emitting module 110 to cause the output to rise from the initial output value and reach the target output value over the required time period. Furthermore, controller 20 sets
5 the initial output value higher when the surrounding light amount is a second light amount than when the surrounding light amount is a first light amount. Here, the second light amount is greater than the first light amount. In addition, controller 20 sets the required time period shorter when the surrounding light amount is the second light amount than when the
10 surrounding light amount is the first light amount.

Accordingly, controller 20 determined the initial output value and the required time period, according to the light amount in the surroundings (surrounding light amount) of lighting apparatus 1. Furthermore, controller 20 controls the power to be supplied to light emitting module 110 to cause the
15 output of light emitted by light-emitting module 110 to rise from the initial output value and reach the target output value over the required time period. In this manner, from the turn ON time, the brightness of the light emitted from light-emitting module 110 of lighting apparatus 1 increases gradually with the passing of time and reaches the target brightness. Accordingly, since lighting
20 apparatus 1 lights up according to the surrounding light amount, the user is not dazzled when lighting apparatus 1 is turned ON. Furthermore, since the light amount of the light emitted by lighting apparatus 1 increases over the required time period from the turn ON time, the user can get used to the brightness even when looking directly at the light emitted by lighting
25 apparatus 1.

Therefore, it is possible to reduce glare when a user undergoes treatment using light.

Furthermore, a lighting control system according to this embodiment includes light-emitting module 110 that emits light, light detector 120 that detects a surrounding light amount, and lighting control device 10.

Furthermore, the lighting control method according to this embodiment
5 is a lighting control method of controlling light-emitting module 110 according to a surrounding light amount that is detected. The lighting control method includes: determining, according to the surrounding light amount, an initial output value for output of light emitted by light-emitting module 110, and a required time period to be taken for the output to rise from the initial output
10 value and reach a target output value greater than the initial output value, and controlling power to be supplied to light-emitting module 110 to cause the output to rise from the initial output value and reach the target output value over the required time period;

Even in these cases, the same effects as described above are produced.

15 Furthermore, in lighting control device 10 according to this embodiment, controller 20 causes the amount of change in the output of light emitted by light-emitting module 110 to increase over time.

Accordingly, the time period for which controller 20 controls the power to be supplied to light-emitting module 110 does not tend to become lengthy.
20 Accordingly, since the user can be exposed to as much light as possible even during the required time period, the user's treatment time does not tend to become lengthy.

Furthermore, in lighting control device 10 according to this embodiment, controller 20 causes the amount of change in the output of light
25 emitted by light-emitting module 110 to increase over time, using an exponential function.

Accordingly, for example, in a first region of an exponential function,

the increase/decrease in brightness indicated by the function is gentle, and thus the first required time period becomes long. As such, the light emitted by light-emitting module 110 gently brightens in the period from when light-emitting module 110 emits light to when the first required time period passes. Accordingly, since the light brightens gently, the user's eyes get used to the brightness.

Furthermore, for example, in the second region of an exponential function, the rate of increase of brightness indicated by the function is steep compared to that in the first region, the required time period becomes short. Since the second region exists after passing through the first region, the eyes have gotten used to the brightness to some extent. In other words, since the first required period of time has passed from the emission of light, even if the light emitted by light-emitting module 110 suddenly becomes bright, the user does not tend to be dazzled even when looking directly at the light emitted by lighting apparatus 1.

Furthermore, in lighting control device 10 according to this embodiment, when the light emitted by light-emitting module 110 has a unified glare rating (UGR) of 22, an indirect illuminance at a position of eyes of an observer is less than or equal to 900 lx.

Furthermore, in lighting control device 10 according to this embodiment, the surrounding light amount and the required time period have a relationship indicated by a monotonically non-increasing function.

Furthermore, in lighting control device 10 according to this embodiment, when a light exposure amount which is an amount of light a user is exposed to does not satisfy a daily required light exposure amount, controller 20 sets the required time period shorter as a difference between the light exposure amount and the daily required light exposure amount is bigger.

Furthermore, lighting control device 10 controls light-emitting module 110 according to the surrounding light amount detected by light detector 120. Furthermore, lighting control device 10 includes controller 20 that determines, according to the surrounding light amount, an initial output value for output of light emitted by light-emitting module 110, and a required time period to be taken for the output to rise from the initial output value and reach a target output value greater than the initial output value, and controls power to be supplied to light-emitting module 110 to cause the output to rise from the initial output value and reach the target output value over the required time period. In addition, controller 20 sets the initial output value higher and the required time period shorter as the surrounding light amount is bigger.

(Embodiment 2)

Lighting control device 10, lighting apparatus 1, and the lighting control method according to this embodiment will be described.

[Configuration]

In Embodiment 1, controller 20 has a first mode equivalent to Embodiment 1, whereas controller 20 in this embodiment is different from Embodiment 1 in having a second mode, aside from the first mode. The structural components of lighting control device 10 and lighting apparatus 1 in this embodiment are the same as in Embodiment 1 in the case where no particular description is made, and the same structural components are assigned the same reference signs and detailed description thereof shall be omitted.

As illustrated in FIG. 1, controller 20 has a first mode and a second mode.

In the first mode, the initial output value and the required time period are determined according to the surrounding light amount of lighting

apparatus 1 detected by light detector 120. In the first mode, when controller 20 obtains a sensor value from light detector 120, controller 20 outputs the initial output value and the required time period based on the obtained sensor value.

5 In the second mode, the initial output value, the required time period, and the usable time period are selectively determined according to (i.e., set to) the values inputted by way of the input operation by the user via input unit 30. In the second mode, controller 20 controls the power to be supplied to light-emitting module 110 according to options inputted from input unit 30, to
10 cause the output of light emitted by light-emitting module 110 to rise from the initial output value and reach the target output value over the required time period.

The switching between the first mode and the second mode is executed by way of the user performing input operation on a mode switching screen
15 displayed on input unit 30. It should be noted that the first mode and the second mode may operate at the same time. In this case, controller 20, for example, may prioritize the input output value and the required time period that are inputted in the second mode over the initial output value and the required time period that are determined in the first mode.

20 Input unit 30 can receive, by way of an input operation by the user, input of at least one of the initial output value, the required time period, and the usable time period. Input unit 30 is an interface that outputs the inputted initial output value, required time period, and usable time period to controller 20.

25 In the case of the second mode, input unit 30 can receive input of an option selected from among options in which the brightness of the surroundings is divided into a plurality of levels. The “options in which the brightness of the

surroundings is divided into a plurality of levels” may be options obtained by dividing the brightness into three levels such as “bright”, “normal”, “dark”, or may be options for five levels, 1 to 5, in which the higher number indicates a higher level of aversion to glare. In this case, controller 20 may perform
5 corrections to set a longer required time period, etc., as the aversion lever is higher. It should be noted that the options are not limited to three, and the options are not limited to the above. Input unit 30 outputs the inputted option to controller 20.

[Operation]

10 Next, the operation of lighting control device 10, lighting apparatus 1, and the lighting control method will be described with reference to FIG. 11.

FIG. 11 is a flowchart describing the operation of lighting apparatus 1 according to Embodiment 2. FIG. 11 illustrates processes in the case where the brightness of the surroundings is determined by the user selecting from
15 among options obtained by dividing the brightness of the surroundings into a plurality of levels.

As illustrated in FIG. 11, controller 20 causes input unit 30 to display a plurality of options (S101). Specifically, input unit 30 displays options obtained by dividing the brightness of the surroundings into a plurality of
20 levels.

Next, the user selects one option from among the plurality of options (S102). Controller 20 determines that the selected brightness to be the brightness of the surroundings. With this, the initial output value is determined according to (i.e., set to) the option inputted by the user.
25 Hereinafter, step S1 onward is the same as in FIG. 10, and thus description will be omitted.

It should be noted that, in the case where the user determines the

required time period, step S4 and step S11 are omitted.

[Effects]

Next, the effects produced by lighting control device 10, lighting apparatus 1, and the lighting control method according to this embodiment will
5 be described.

As described above, lighting control device 10 according to this embodiment further includes input unit 30 that receives, by way of an input operation by a user, input of at least one of the initial output value, the required time period, and a useable time period for which the user uses the
10 lighting control device. Furthermore, controller 20 has a first mode in which the initial output value and the required time period are determined according to the surrounding light amount detected by light detector 120, and a second mode in which the initial output value, the required time period, and the usable time period are selectively determined according to an initial output value, a
15 required time period, and a usable time period inputted, by way of the input operation by the user, via input unit 30.

In this manner, in the first mode, controller 20 automatically determines the initial output value and the required time period, according to the surrounding light amount detected by light detector 120. Furthermore, in
20 the second mode, the initial output value, the required time period, and the usable time period are selectively determined according to (i.e., set to) values inputted by way of input operation by the user via input unit 30. Accordingly, the initial output value and the target output value can be determined automatically in the first mode, and the initial output value, the required time
25 period, and the usable time period are determined selectively according to the preference of the user in the second mode. As such, when lighting control device 10 is applied to lighting apparatus 1, user-friendliness is improved.

Furthermore, in lighting control device 10 according to this embodiment, in the second mode, input unit 30 further receives an option selected from among a plurality of options obtained by dividing surrounding brightness into a plurality of levels. Furthermore, controller 20 controls the power to be supplied to light-emitting module 110 according to the option inputted via input unit 30, to cause the output to rise from the initial output value and reach the target output value over the required time period.

Accordingly, in the case of the second mode, input unit 30 receives input of an option selected from among options obtained by dividing the brightness of the surroundings into a plurality of levels. Accordingly, the brightness of the surroundings of lighting apparatus 1 can be inputted via input unit 30 according to the preference of the user, without using light detector 120. Furthermore, since there are cases where glare is disliked depending on the user, the initial output value, the required time period, and the usable time period can be determined according to the user's preference. As such, when lighting control device 10 is applied to lighting apparatus 1, user-friendliness is improved.

The other effects of produced by this embodiment are the same as those in Embodiment 1.

(Other variations, etc.)

Although the present disclosure is described above based on exemplary embodiments, the present disclosure is not limited to the foregoing exemplary embodiments.

For example, in the foregoing exemplary embodiments, the lighting control method may also be a program executed by a computer.

Furthermore, in the lighting control device, the lighting control system, and the lighting control method according to the foregoing exemplary

embodiments, the controller may have a notification function of notifying the user that the treatment time period is insufficient in the case where the integrated value p of the light exposure amount is less than required light exposure amount Q . For example, the controller may cause a display unit to
5 display “Extend treatment time period” to the user.

Furthermore, in the lighting control device, the lighting control system, and the lighting control method according to the foregoing exemplary embodiments, the process in step S1 in FIG. 10 and FIG. 11 is not limited to the process sequence in FIG. 10 and FIG. 11. For example, the process in step S1
10 in FIG. 10 and FIG. 11 may be executed before or after step S4.

Furthermore, in the lighting control device, the lighting control system, and the lighting control method according to the foregoing exemplary embodiments, the determination in step S3, step S5, and step S12 in FIG. 10 and FIG. 11 are performed by the controller but may be performed by a
15 determining unit different from the controller. In this case, the controller may be a drive control circuit that controls the power to be supplied to the light-emitting module.

Furthermore, in the lighting control device, the lighting control system, and the lighting control method according to the foregoing exemplary
20 embodiments, the target output value may be corrected by assuming the user’s facial illuminance according to the posture of the user. Specifically, since the user’s facial illuminance is considered to be one third of the illuminance of a table surface, the target output value may simply be corrected three-fold. Furthermore, with regard to the posture of the user, options indicating
25 postures may be provided to the input unit.

Furthermore, the respective processing units which are included in the lighting control device and the lighting control system or which realize the

lighting control method according to the foregoing exemplary embodiments are typically implemented as an LSI which is a integrated circuit. These processing units may be implemented as separate individual chips, or as a single chip to include all or a part thereof.

5 Furthermore, the means for circuit integration is not limited to an LSI, and implantation with a dedicated circuit or a general-purpose processor is also available. A field programmable gate array (FPGA) that is programmable after the LSI has been manufactured or a reconfigurable processor in which connections and settings of circuit cells are reconfigurable may be used.

10 It should be noted that in each of the foregoing exemplary embodiments, the respective structural components may be configured using dedicated hardware, or may be implemented by executing software programs suitable for the respective structural components. The respective structural components may be implemented by a program execution unit such as a CPU or a processor
15 reading out and executing a software program recorded on a recording medium such as a hard disk or a semiconductor memory, etc.

 Furthermore, the numerical figures used above, are all given as examples in order to specifically describe the present disclosure, and thus the exemplary embodiments of the present disclosure are not limited to the
20 numerical figures given as examples.

 Furthermore, the partitioning of the function blocks in the block diagrams are examples, and a plurality of function blocks may be implemented as a single function block, a single function block may be divided into a plurality of function blocks, and part of a function may be transferred to
25 another function block. Furthermore, the functions of a plurality of blocks having similar functions may be processed in parallel or through time division by a single hardware or software.

Furthermore, the sequence in which the respective steps are executed in the flow charts are given as an example in order specifically describe the present disclosure, and other sequences are possible. Furthermore, part of the foregoing steps may be executed simultaneously with (in parallel to) another
5 step.

Aside from the above, forms obtained by various modifications to the exemplary embodiment that can be conceived by a person of skill in the art as well as forms realized by arbitrarily combining structural components and functions in the exemplary embodiment which are within the scope of the
10 essence of the present disclosure are included in the present disclosure.

[Reference Signs List]

- 1 lighting apparatus (lighting control system)
- 10 lighting control device
- 20 controller
- 15 30 input unit
- 110 light source (light-emitting module)
- 120 light detector

[CLAIMS]

[Claim 1]

A lighting control device that controls a light source according to a surrounding light amount detected by a light detector, the lighting control
5 device comprising:

a controller that determines, according to the surrounding light amount, an initial output value for output of light emitted by the light source, and a required time period to be taken for the output to rise from the initial output value and reach a target output value greater than the initial output value, and
10 controls power to be supplied to the light source to cause the output to rise from the initial output value and reach the target output value over the required time period, wherein

the controller:

sets the initial output value higher when the surrounding light
15 amount is a second light amount than when the surrounding light amount is a first light amount, the second light amount being greater than the first light amount; and

sets the required time period shorter when the surrounding light amount is the second light amount than when the surrounding light
20 amount is the first light amount.

2. The lighting control device according to claim 1, wherein

the controller causes an amount of change in the output to increase over
time.

3. The lighting control device according to claim 2, wherein

the controller causes the amount of change in the output to increase

over time, using an exponential function.

4. The lighting control device according to any one of claims 1 to 3, further comprising:

5 an input unit that receives, by way of an input operation by a user, input of at least one of the initial output value, the required time period, and a useable time period for which the user uses the lighting control device, wherein the controller has a first mode in which the initial output value and the required time period are determined according to the surrounding light amount
10 detected by the light detector, and a second mode in which the initial output value, the required time period, and the usable time period are selectively determined according to an initial output value, a required time period, and a usable time period inputted, by way of the input operation by the user, via the input unit.

15 5. The lighting control device according to claim 4, wherein in the second mode, the input unit further receives an option selected from among a plurality of options obtained by dividing surrounding brightness into a plurality of levels, and

20 the controller controls the power to be supplied to the light source according to the option inputted via the input unit, to cause the output to rise from the initial output value and reach the target output value over the required time period.

25 6. The lighting control device according to any one of claims 1 to 5, wherein

when the light emitted by the light source has a unified glare rating

(UGR) of 22, an indirect illuminance at a position of eyes of an observer is less than or equal to 900 lx.

7. The lighting control device according to any one of claims 1 to 6,
5 wherein

the surrounding light amount and the required time period have a relationship indicated by a monotonically non-increasing function.

8. The lighting control device according to any one of claims 1 to 7,
10 wherein

when a light exposure amount which is an amount of light a user is exposed to does not satisfy a daily required light exposure amount, the controller sets the required time period shorter as a difference between the light exposure amount and the daily required light exposure amount is bigger.

15

9. A lighting control device that controls a light source according to a surrounding light amount detected by a light detector, the lighting control device comprising:

a controller that determines, according to the surrounding light amount,
20 an initial output value for output of light emitted by the light source, and a required time period to be taken for the output to rise from the initial output value and reach a target output value greater than the initial output value, and controls power to be supplied to the light source to cause the output to rise from the initial output value and reach the target output value over the required
25 time period, wherein

the controller sets the initial output value higher and the required time period shorter as the surrounding light amount is bigger.

10. A lighting control system, comprising:

a light source that emits light;

a light detector that detects a surrounding light amount; and

5 the lighting control device according to any one of claims 1 to 9.

11. A lighting control method of controlling a light source according to a surrounding light amount that is detected, the lighting control method comprising:

10 determining, according to the surrounding light amount, an initial output value for output of light emitted by the light source, and a required time period to be taken for the output to rise from the initial output value and reach a target output value greater than the initial output value, and controlling power to be supplied to the light source to cause the output to rise from the
15 initial output value and reach the target output value over the required time period;

setting the initial output value higher when the surrounding light amount is a second light amount than when the surrounding light amount is a first light amount, the second light amount being greater than the first light
20 amount; and

setting the required time period shorter when the surrounding light amount is the second light amount than when the surrounding light amount is the first light amount.