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(54) **INFORMATION PROCESSING APPARATUS,  
NON-TRANSITORY COMPUTER READABLE  
MEDIUM, AND INFORMATION  
PROCESSING METHOD**

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(57) **ABSTRACT**

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An information processing apparatus includes a processor configured to: acquire information on main illumination from an illumination intensity distribution of an image that results from imaging an actual space; and control an expression of a thing using an illumination intensity distribution that is corrected with the information on the main illumination.

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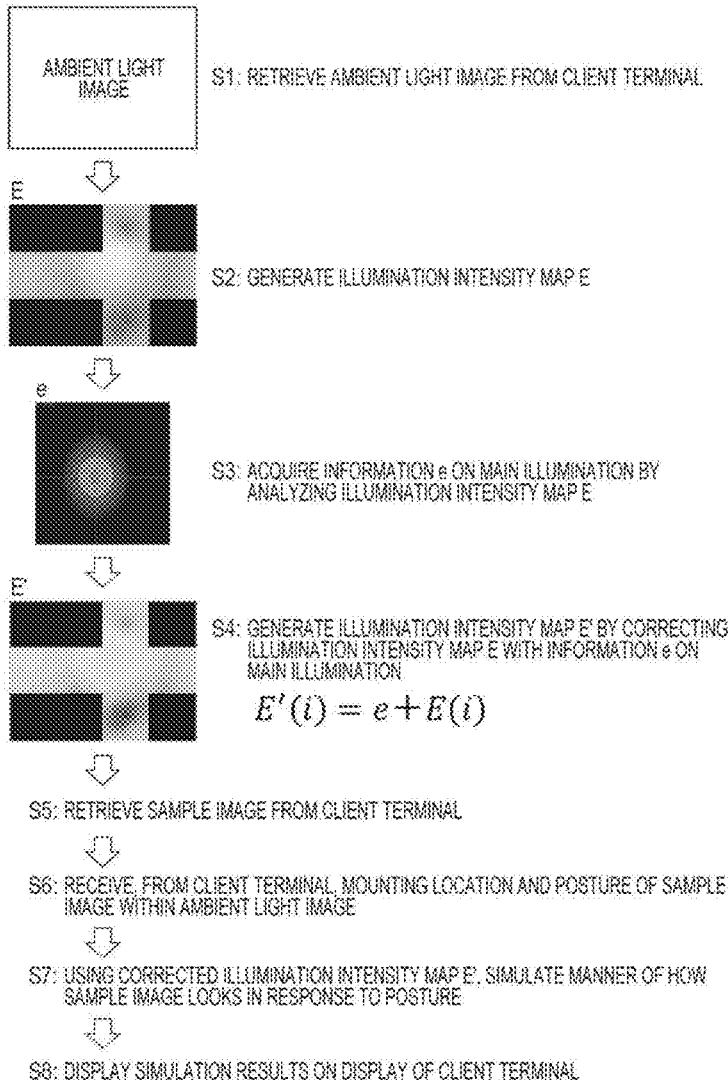


FIG. 1

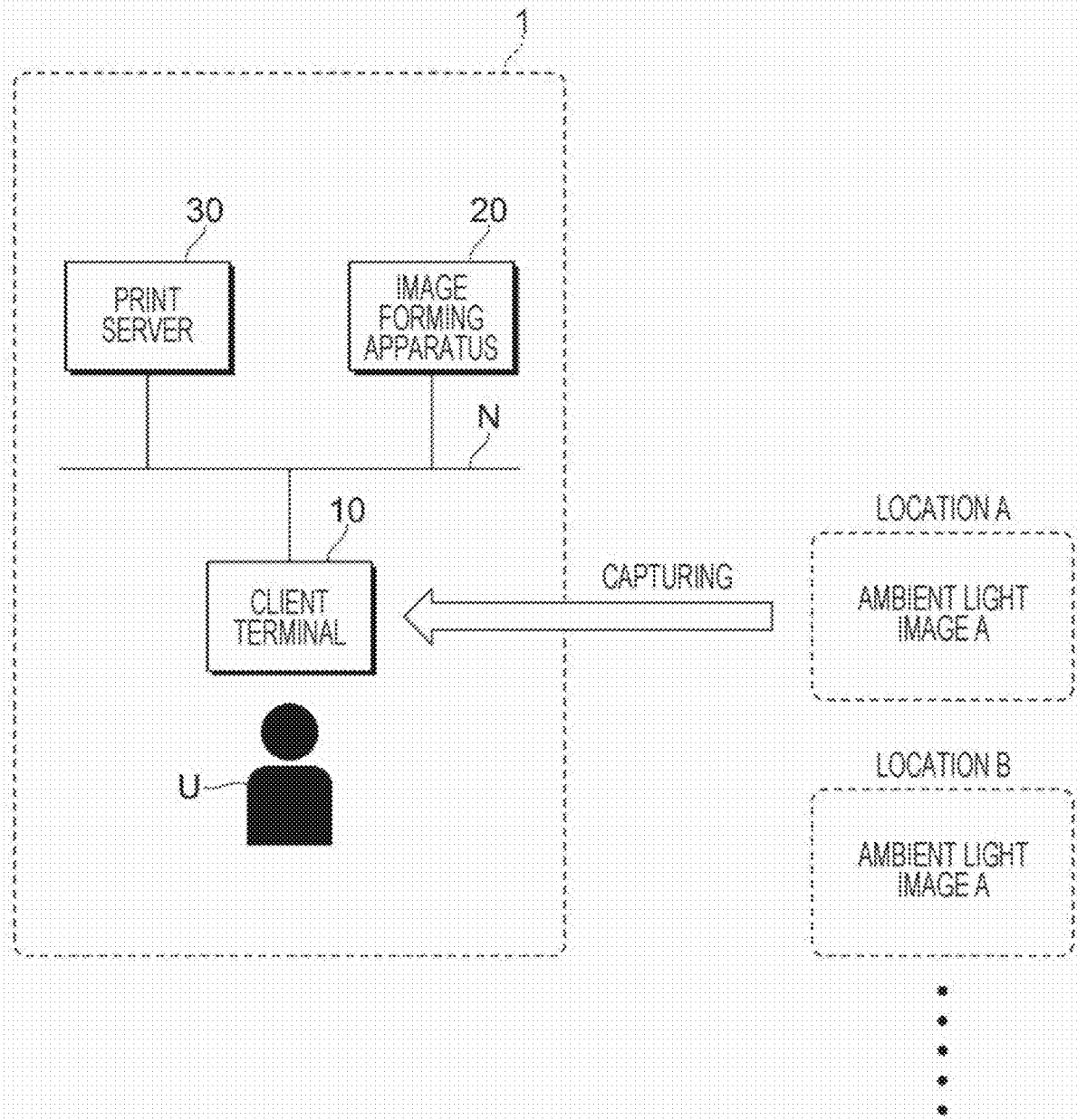


FIG. 2

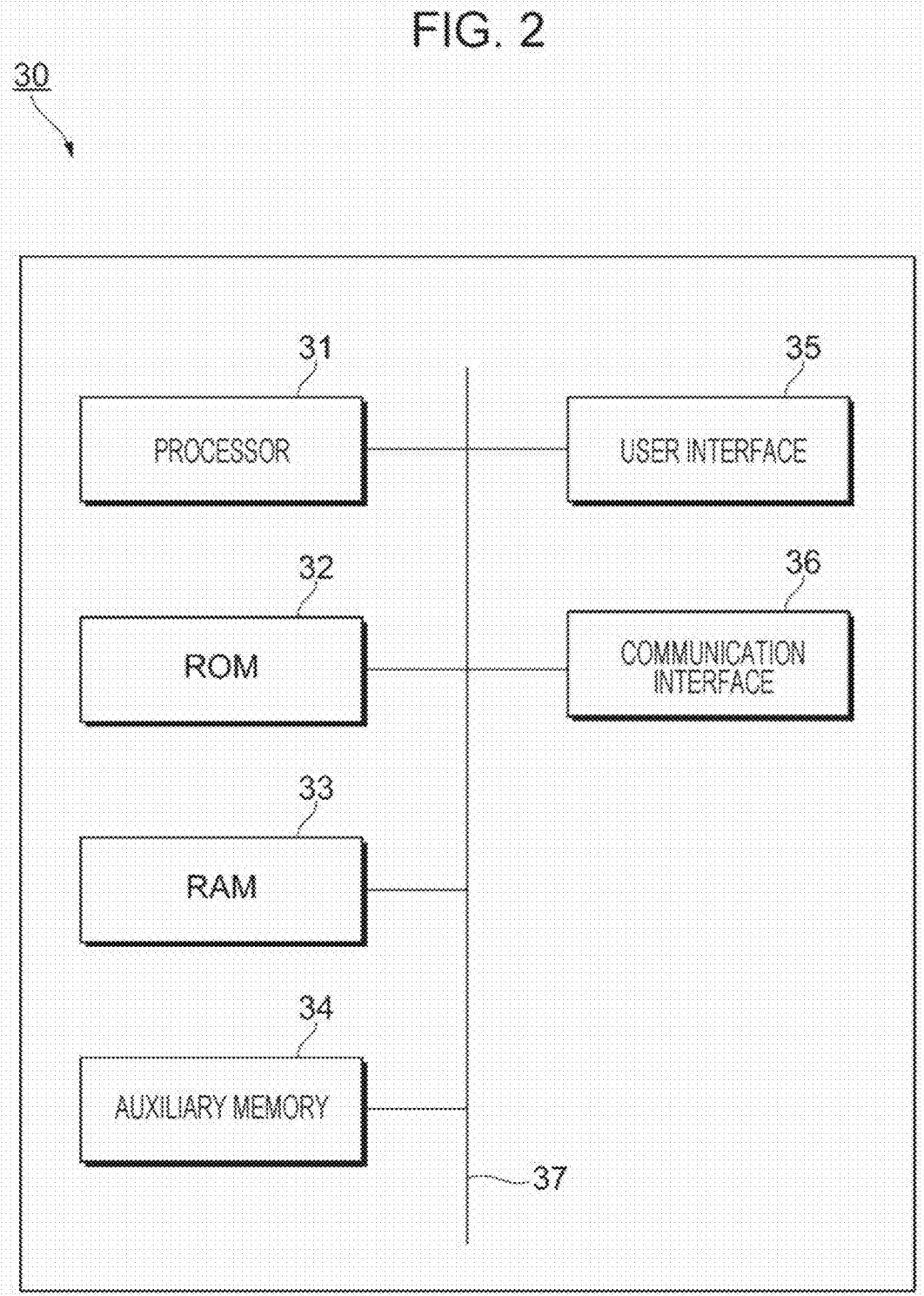


FIG. 3

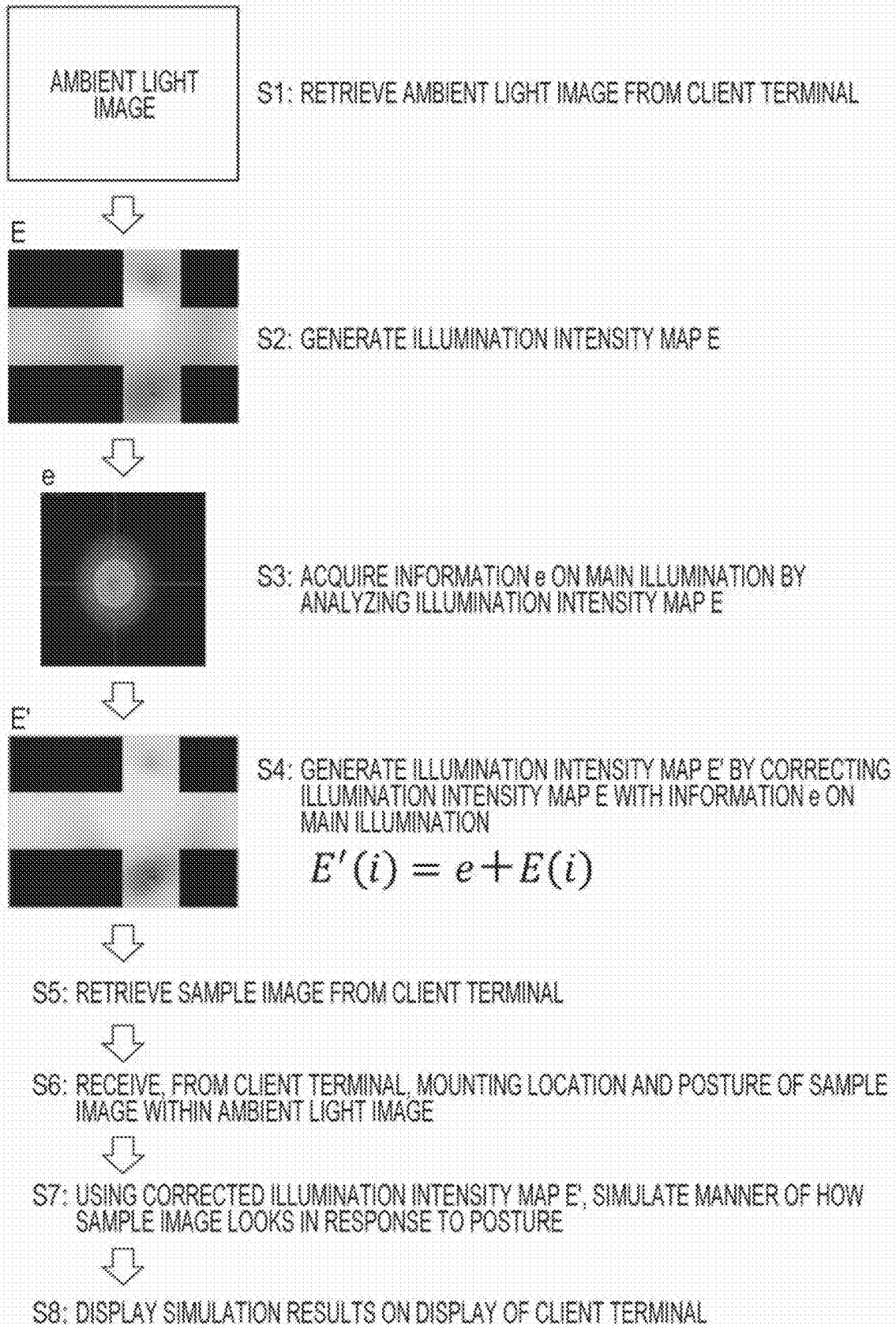
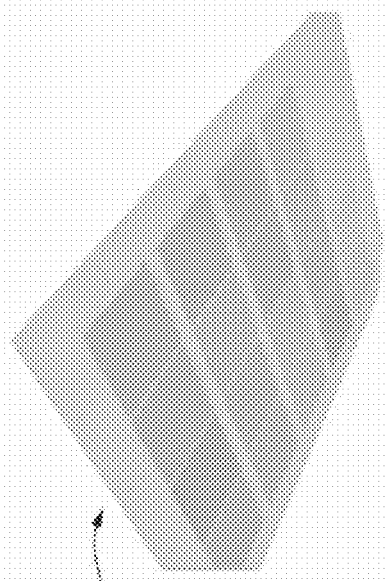


FIG. 4

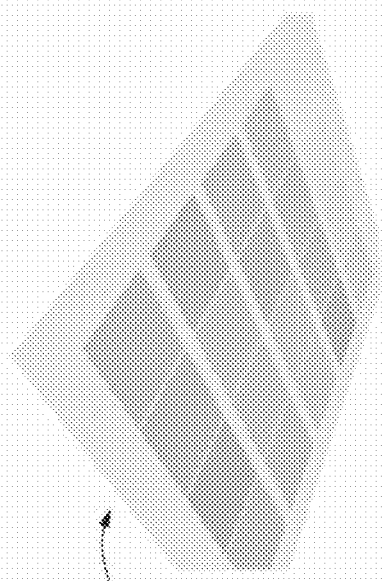
AMBIENT LIGHT IMAGE: BLUE SKY  
NOT CORRECTED WITH INFORMATION  
ON MAIN ILLUMINATION



101



AMBIENT LIGHT IMAGE: BLUE SKY  
CORRECTED WITH INFORMATION  
ON MAIN ILLUMINATION



102

FIG. 5

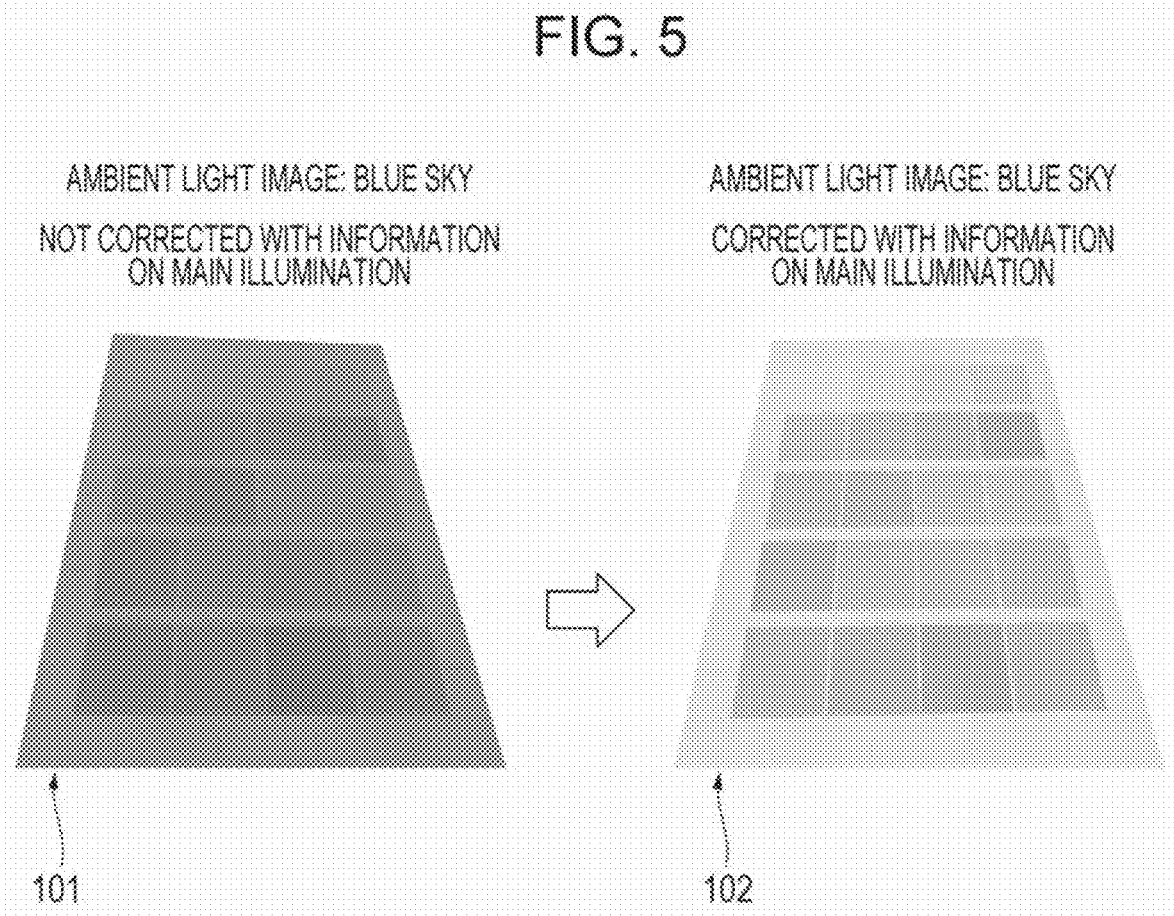


FIG. 6

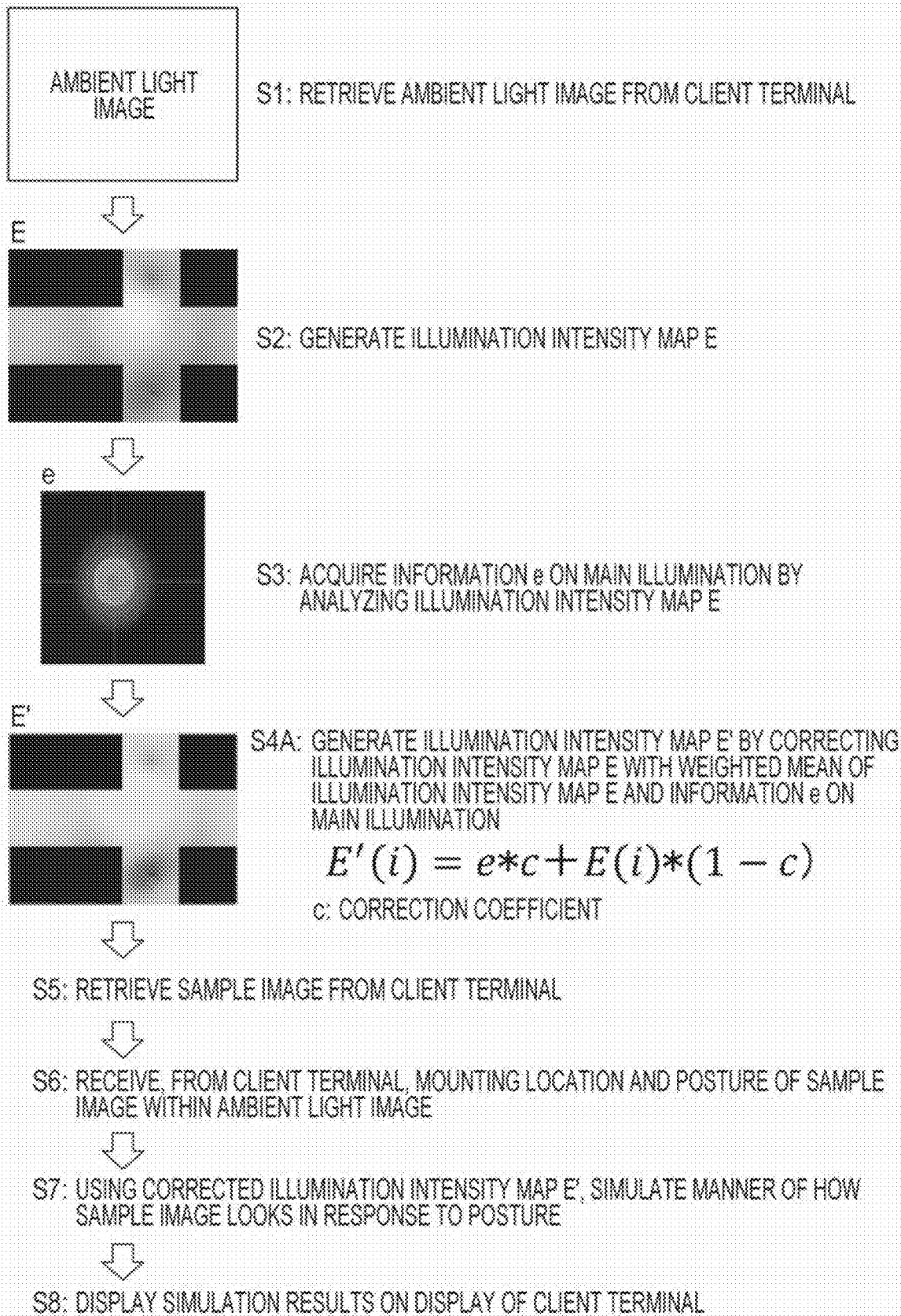


FIG. 7

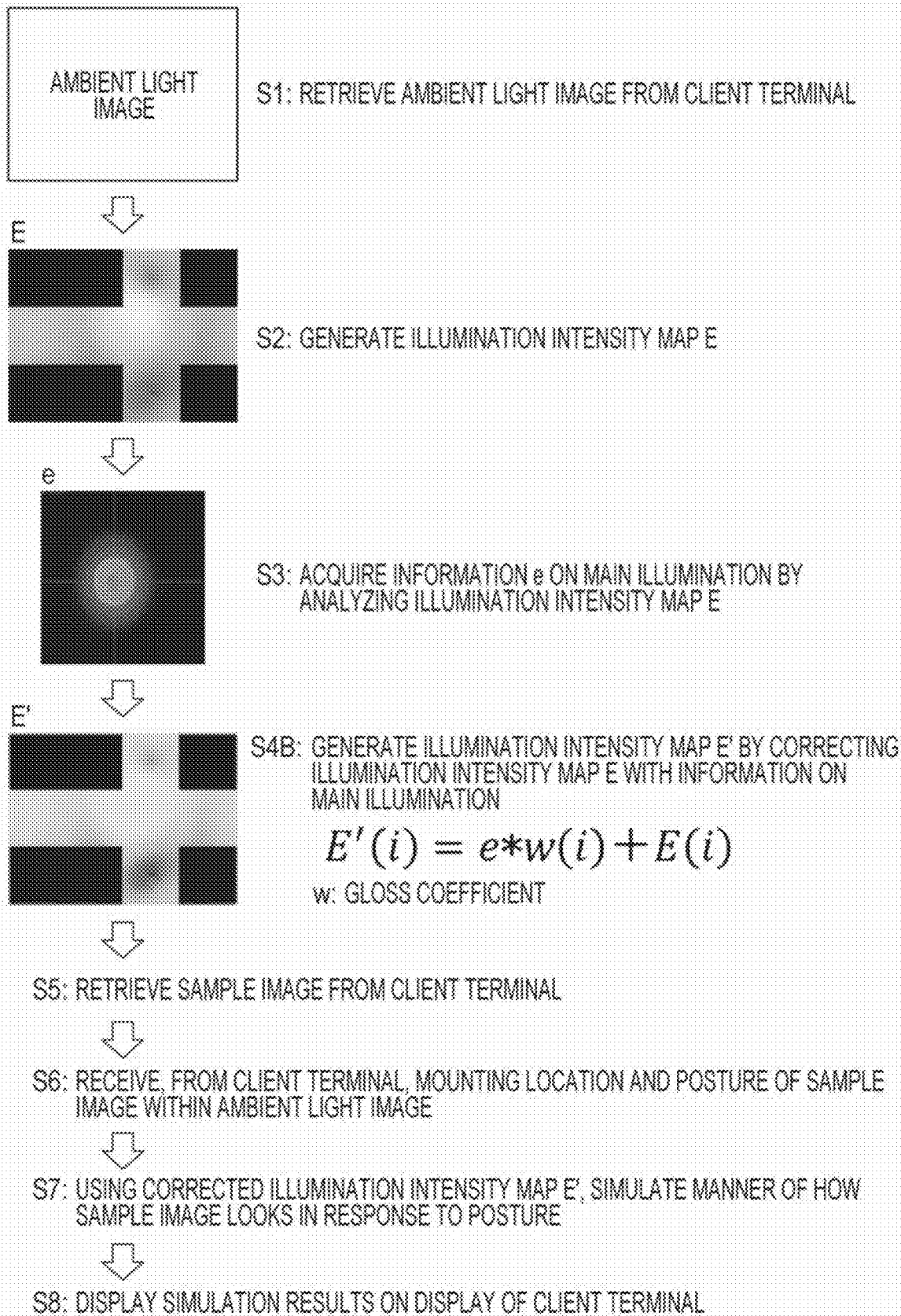




FIG. 8A

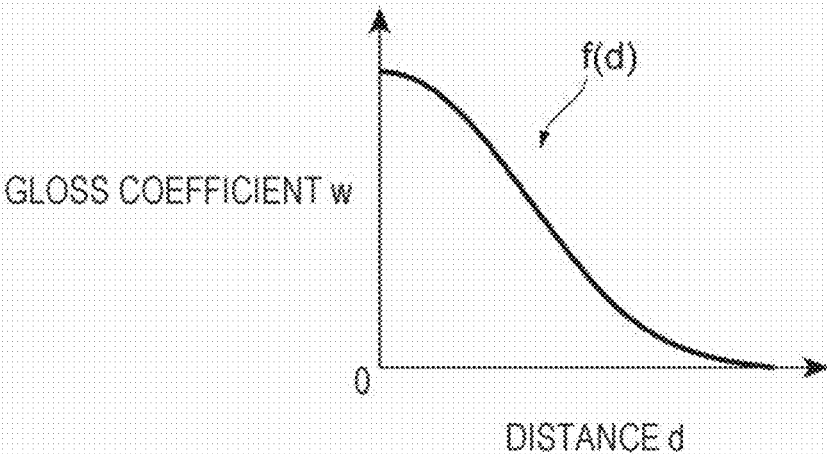


FIG. 8B

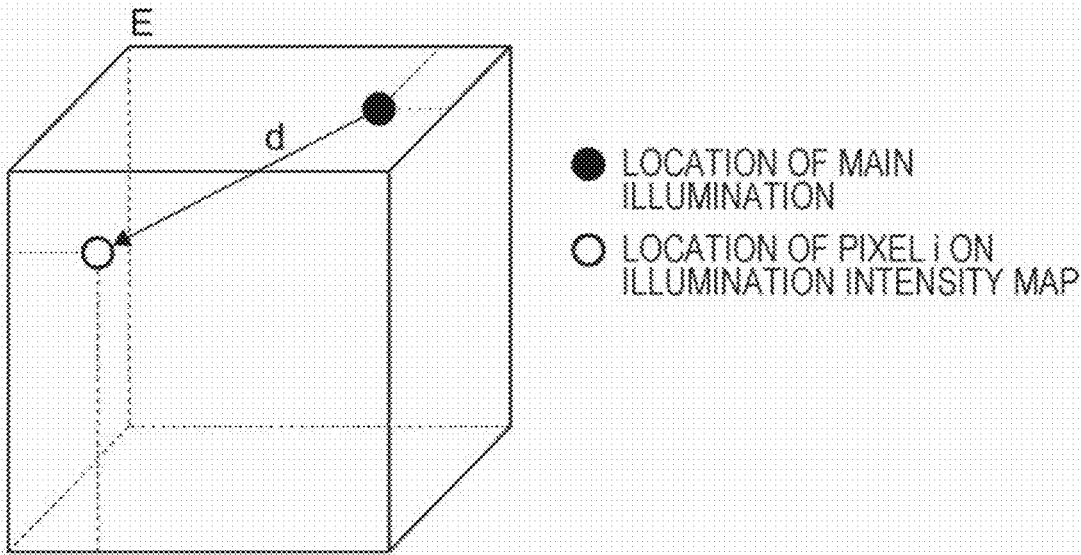


FIG. 9A

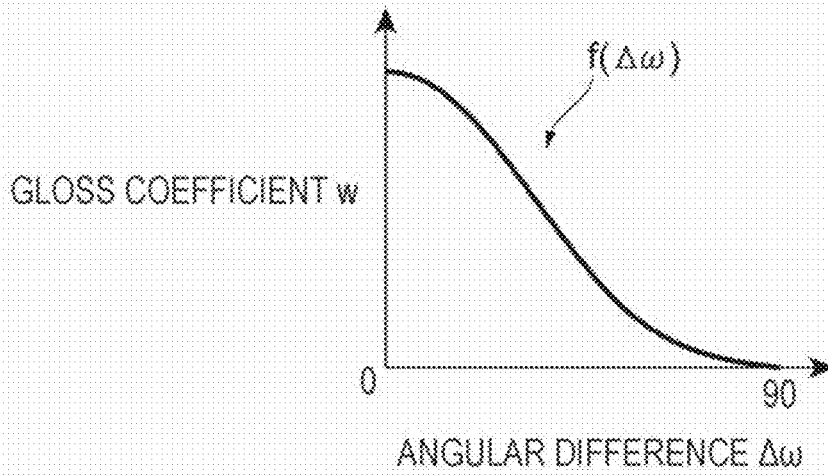


FIG. 9B

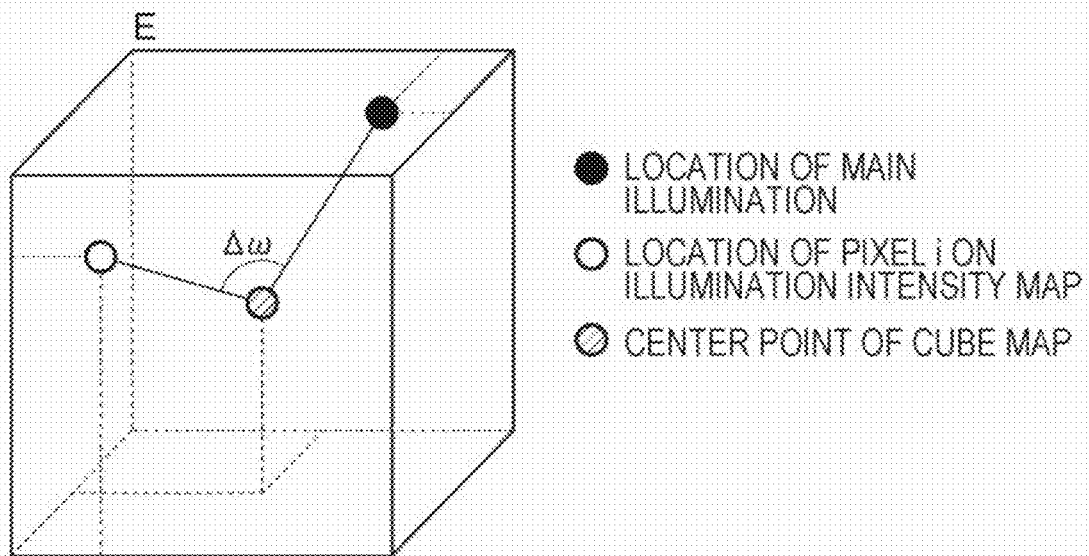
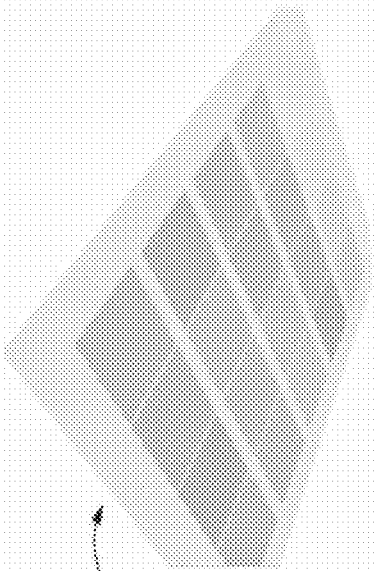
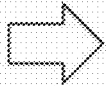


FIG. 10

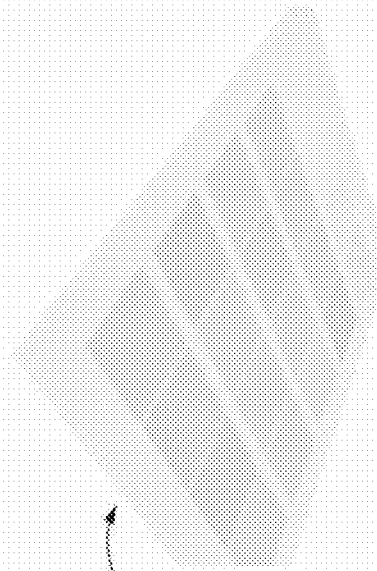
AMBIENT LIGHT IMAGE: BLUE SKY  
CORRECTED WITH INFORMATION  
ON MAIN ILLUMINATION



102



AMBIENT LIGHT IMAGE: BLUE SKY  
GLOSS CORRECTED



103

FIG. 11

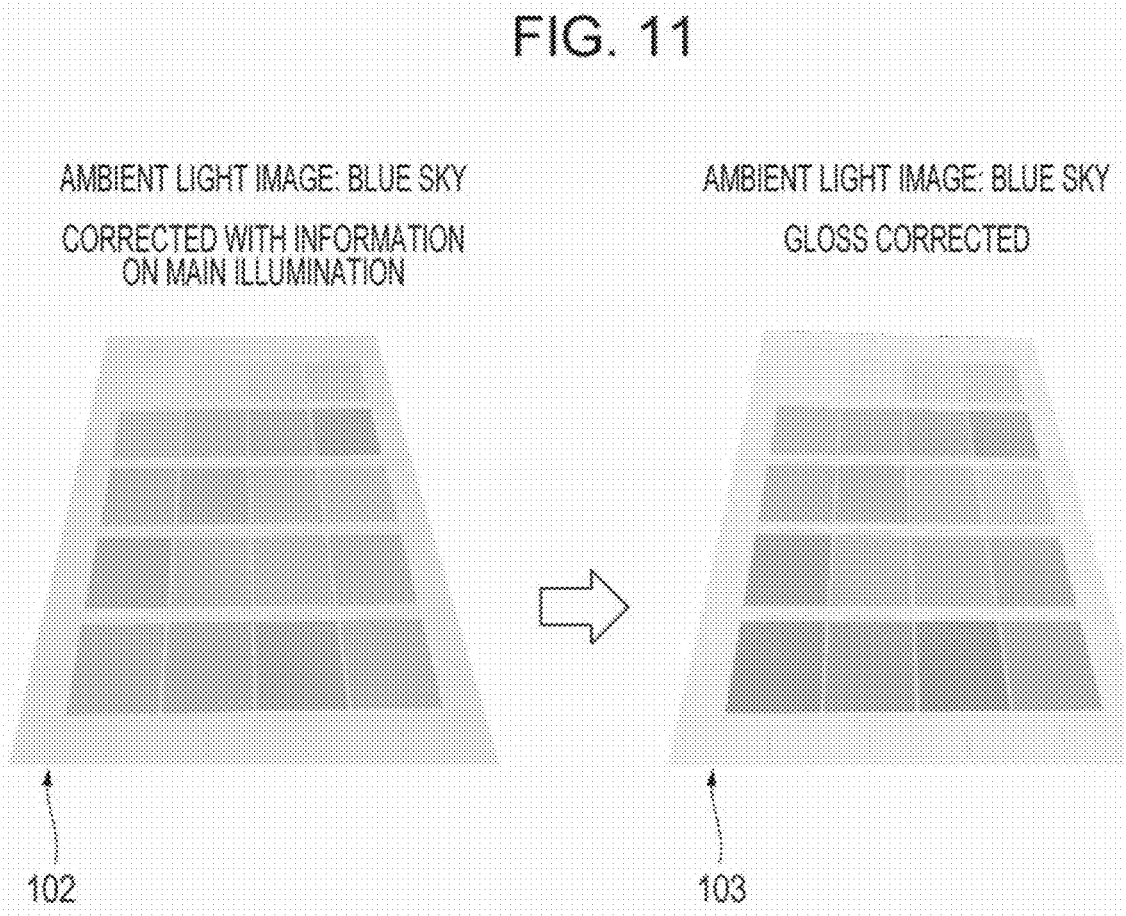


FIG. 12

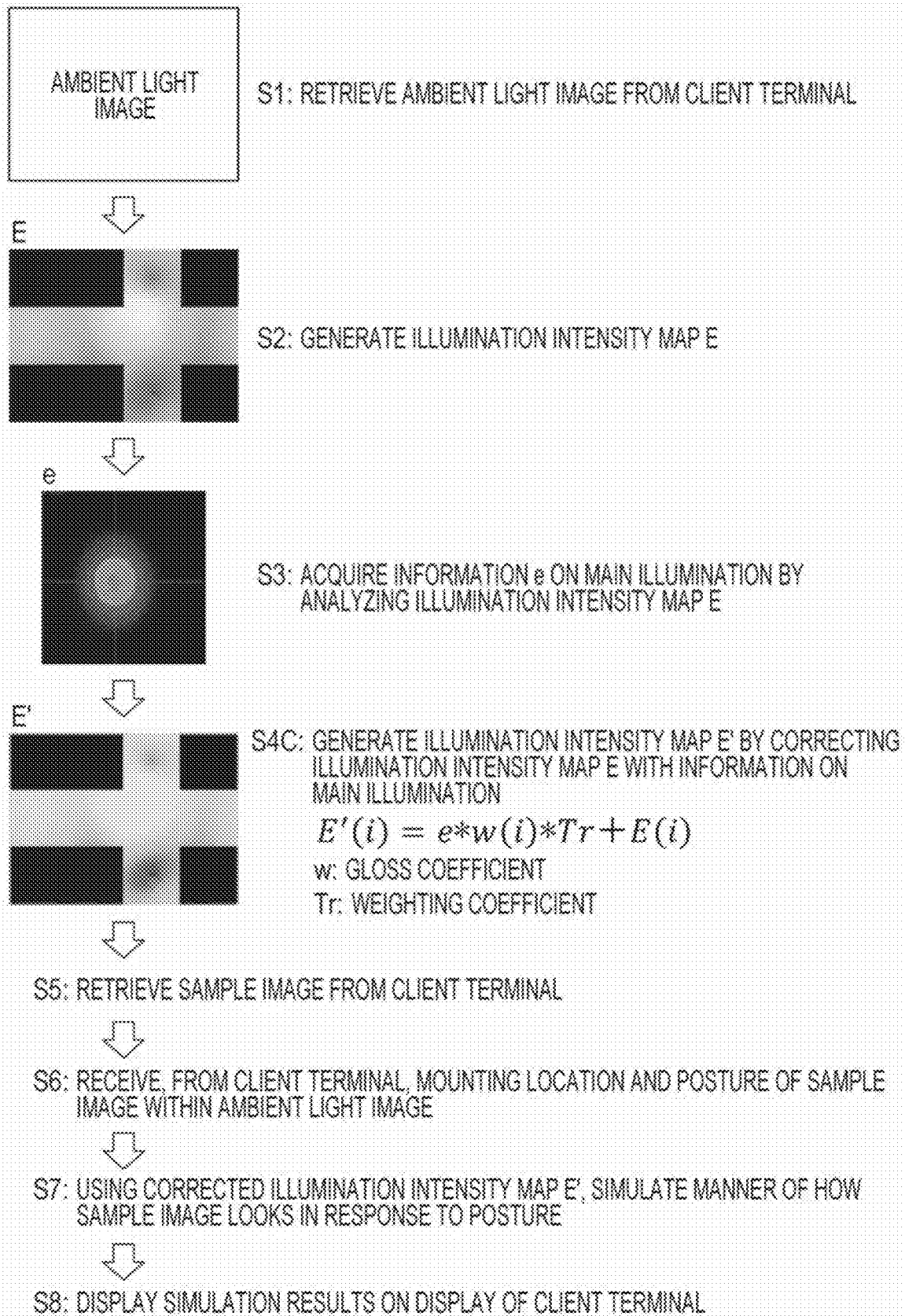


FIG. 13A

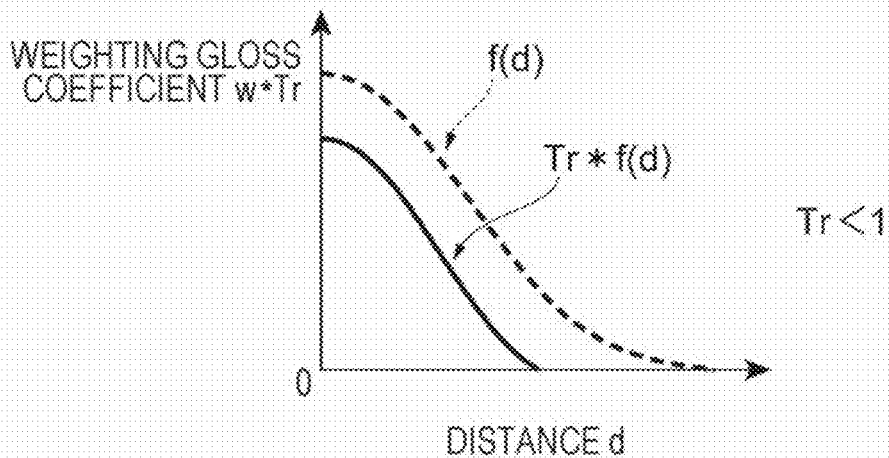


FIG. 13B

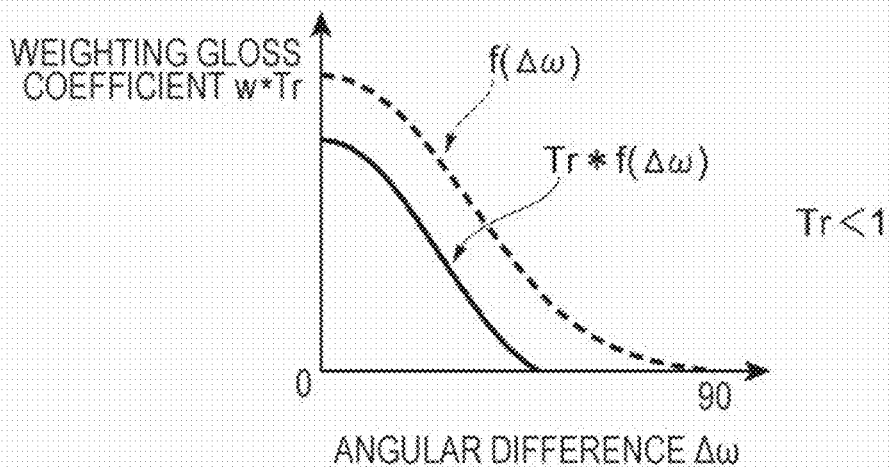


FIG. 14

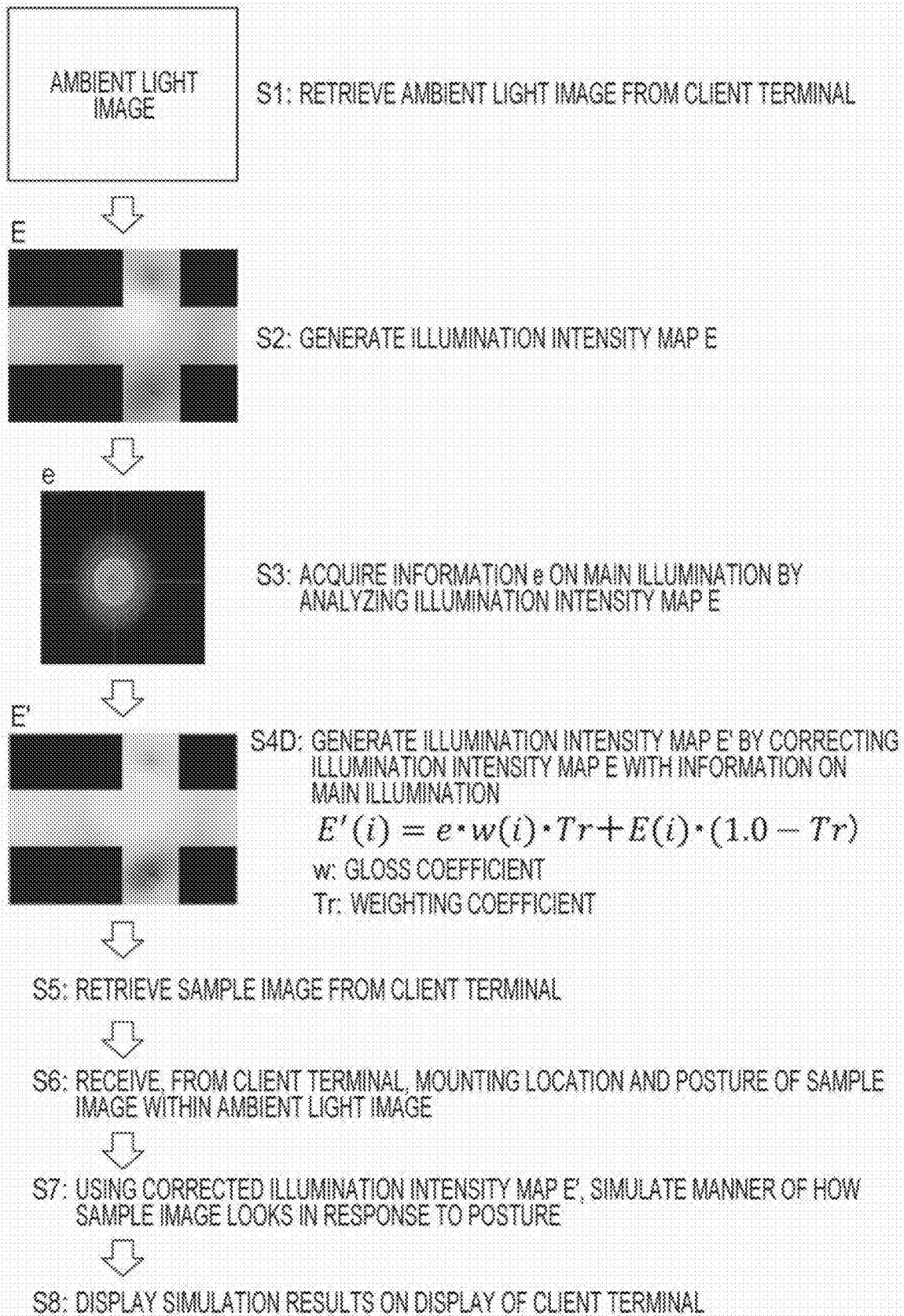
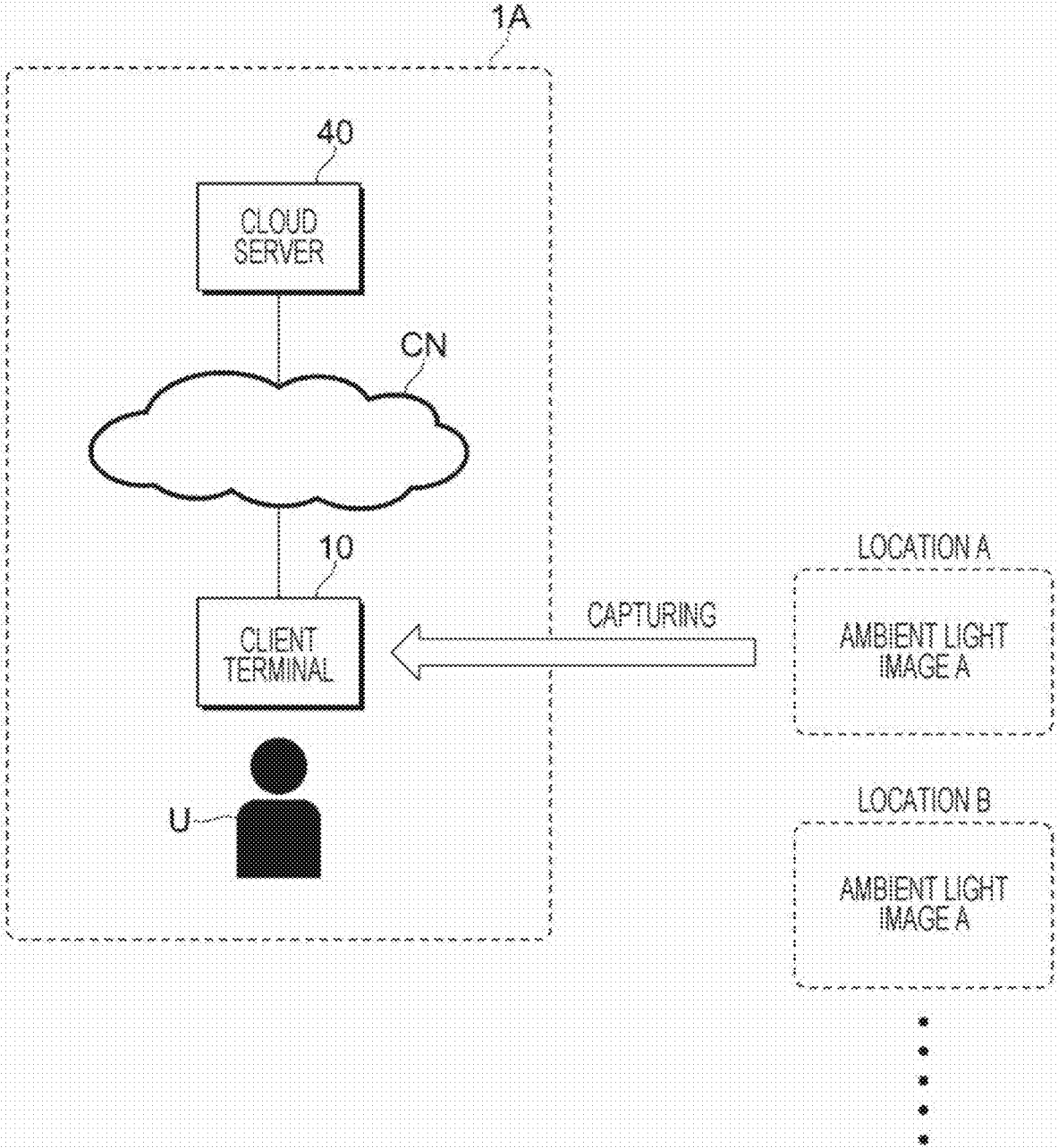


FIG. 15





**INFORMATION PROCESSING APPARATUS,  
NON-TRANSITORY COMPUTER READABLE  
MEDIUM, AND INFORMATION  
PROCESSING METHOD**

CROSS-REFERENCE TO RELATED  
APPLICATIONS

[0001] This application is based on and claims priority under 35 USC 119 from Japanese Patent Application No. 2022-129310 filed Aug. 15, 2022.

BACKGROUND

(i) Technical Field

[0002] The present disclosure relates to an information processing apparatus, a non-transitory computer readable medium, and an information processing method.

(ii) Related Art

[0003] Physically-based rendering is available as one of techniques that reproduce using a computer technique how a thing looks in terms hue and gloss. However, the physically-based rendering involves higher computation costs and is not so beneficial in terms of real-time simulation. A technique of reducing computation costs to reproduce an illumination intensity distribution is available. According to the technique, the illumination intensity distribution is calculated in all normal directions of the thing.

[0004] Reference is made to Japanese Unexamined Patent Application Publication No. 2002-236938 for related art techniques.

[0005] Cameras capable of imaging all directions from an imaging point are commercially available. This type of camera is referred to a spherical camera and an image imaged by the spherical camera is referred to as a 360-degree panoramic image (spherical image). The spherical image includes information on ambient light (“luminance information”) at the imaging point. The use of the spherical image enables the appearance of hue and gloss of an object at any point to be simulated. The spherical image (hereinafter referred to as an “ambient light image”) is an example of image resulting from imaging an actual space.

[0006] On the other hand, the luminance information acquired from the spherical image may be different from the color and illumination intensity of main illumination in the actual space. For example, when the appearance of a white paper sheet placed in the clear sky condition is simulated, the paper sheet may be blue-tinted or illumination intensity may be reproduced at a lower level.

SUMMARY

[0007] Aspects of non-limiting embodiments of the present disclosure relate to causing simulation results to look more real than when the appearance of a subject is simulated using an image captured in an actual space.

[0008] Aspects of certain non-limiting embodiments of the present disclosure address the above advantages and/or other advantages not described above. However, aspects of the non-limiting embodiments are not required to address the advantages described above, and aspects of the non-limiting embodiments of the present disclosure may not address advantages described above.

[0009] According to an aspect of the present disclosure, there is provided an information processing apparatus including a processor configured to: acquire information on main illumination from an illumination intensity distribution of an image that results from imaging an actual space; and control an expression of a thing using an illumination intensity distribution that is corrected with the information on the main illumination.

BRIEF DESCRIPTION OF THE DRAWINGS

[0010] Exemplary embodiments of the present disclosure will be described in detail based on the following figures, wherein:

[0011] FIG. 1 illustrates a configuration of a print system of a first exemplary embodiment;

[0012] FIG. 2 illustrates a hardware configuration of an information processing apparatus;

[0013] FIG. 3 illustrates a first simulation example performed by a processor;

[0014] FIG. 4 illustrates an example of simulation results displayed on a display;

[0015] FIG. 5 illustrates another example of the simulation results displayed on the display;

[0016] FIG. 6 illustrates a second simulation example performed by the processor;

[0017] FIG. 7 illustrates a third simulation example performed by the processor;

[0018] FIGS. 8A and 8B illustrate a gloss coefficient that is defined by a distance between main illumination and each pixel;

[0019] FIGS. 9A and 9B illustrate the gloss coefficient that is defined by an angular difference between the main illumination and each pixel;

[0020] FIG. 10 illustrates another example of simulation results displayed on the display;

[0021] FIG. 11 illustrates another example of simulation results displayed on the display;

[0022] FIG. 12 illustrates a fourth simulation example performed by the processor;

[0023] FIG. 13A illustrates a weighting gloss coefficient that is provided by a function of distance and FIG. 13B illustrates a weighting gloss coefficient that is provided by a function of angular difference;

[0024] FIG. 14 illustrates a fifth simulation example performed by the processor; and

[0025] FIG. 15 illustrates a configuration of an information processing system used in a second exemplary embodiment.

DETAILED DESCRIPTION

[0026] Exemplary embodiments of the disclosure are described with reference to the drawings.

First Exemplary Embodiment

System Configuration

[0027] FIG. 1 illustrates a configuration of a print system 1 used in a first exemplary embodiment. The print system 1 includes a client terminal 10, image forming apparatus 20, and print server 30. These apparatuses are communicably interconnected to each other via a network N. The client terminal 10 and print server 30 are examples of an information processing apparatus.

[0028] Each of the client terminal **10** and print server **30** basically includes a computer. The image forming apparatus **20** and print server **30** may be connected to each other via an exclusive line.

[0029] The image forming apparatus **20** forms an image on a paper sheet, such as a recording medium. A recording material used to record the image may be toner or ink. Colors of recording materials include fundamental colors, such as yellow (Y), magenta (M), cyan (C), and black (K), and special colors, such as metallic color or fluorescent color.

[0030] The client terminal **10** may be a desktop computer, laptop, tablet computer, smart phone, or wearable computer. According to the first exemplary embodiment, the client terminal **10** is typically used as an input and output device.

[0031] The image forming apparatus **20** of the first exemplary embodiment may be a production printer, printer used in office, or printer used at home. The image forming apparatus **20** may include a scanner function besides a print function.

[0032] The print server **30** of the first exemplary embodiment has a function of receiving a print job from the client terminal **10** and outputting the print job to the image forming apparatus **20** and a function of simulating a texture of an object.

[0033] The texture refers to an impression that the hue and gloss of an object give to humans. The hue and gloss may be affected by an uneven structure of a surface of the object, a normal direction of the surface of the object, an incident direction of illumination, an intensity of the illumination, and a color of the illumination.

[0034] The print server **30** of the first exemplary embodiment receives from the client terminal **10** an image resulting from imaging an actual space (in other words, an ambient light image) and information on an object serving as a simulation target and reproduces using computer technology an appearance of the object at a posture specified by a user.

[0035] The client terminal **10** uploads the ambient light image used in simulation to the print server **30**. Also, the print server **30** may download or read from the Internet the ambient light image indicated by the client terminal **10**.

[0036] Referring to FIG. 1, the ambient light image imaged at a location A is referred to as an “ambient light image A,” and the ambient light image imaged at a location B is referred to as an “ambient light image B.”

[0037] The ambient light images include, for example, a spherical image, an upper-hemisphere image, and a plane image.

[0038] The upper-hemisphere image refers to an upper half of the spherical image above the equator. The upper-hemisphere image may not be strictly an image of a sphere from the equator to the apex but may be an image of the sphere from a given latitude to the apex.

[0039] The plane image refers to an image imaged by a camera, such as a smart phone, and having a specific angle of view.

[0040] A location where the ambient light image is imaged refers to a location where an object is observed. For example, the location may be a specific booth in an exhibition, an exhibition room, a conference room, or the like. The booth is a space delineated by partitions. The location where the ambient light image is imaged is not limited to an indoor environment and may be in an outdoor environment.

[0041] The observed textures of the same object may be different if the intensity and color of illumination light are different. With the intensity and color of the illumination light remaining unchanged, the observed texture of the object may be different if the incident direction of the illumination light and the normal direction of the surface of the object are different.

[0042] Referring to FIG. 1, a network N is a local-area network (LAN). The network N may be a wired network and/or wireless network. The wired network is, for example, Ethernet (registered trademark). The wireless network is, for example, Wi-Fi (registered trademark).

[0043] The network N in the print system **1** illustrated in FIG. 1 includes a single client terminal **10**, a single image forming apparatus **20**, and a single print server **30** but alternatively, a multiple number of each type of these apparatuses may be employed.

#### Configuration of Information Processing Apparatus

[0044] FIG. 2 illustrates a hardware configuration of an information processing apparatus. Referring to FIG. 2, the print server **30** is an example of the information processing apparatus. The client terminal **10** may also have the same hardware configuration as illustrated in FIG. 2.

[0045] The print server **30** illustrated in FIG. 2 includes a processor **31**, read-only memory (ROM) **32** storing basic input-output system (BIOS), random-access memory (RAM) **33** used as a working area of the processor **31**, auxiliary memory **34**, user interface **35**, and communication interface **36**.

[0046] These devices are interconnected to each other via a bus, such as a signal line **37**.

[0047] The processor **31** is a device that implements a variety of functions by executing a program.

[0048] The processor **31**, ROM **32**, and RAM **33** work as a computer.

[0049] The auxiliary memory **34** includes a hard disk device or a semiconductor storage. The auxiliary memory **34** stores a program and a variety of data. The program herein collectively refers to the operating system and application programs. One of the application programs is a program that simulates the texture of the object.

[0050] Referring to FIG. 2, the auxiliary memory **34** is built in the print server **30** but the auxiliary memory **34** may be external to the print server **30** or present over the network N (see FIG. 1).

[0051] The user interface **35** includes an output device and an input receiving device.

[0052] The output device may include, for example, a display and a loudspeaker. The display is a liquid-crystal display or an organic electroluminescent display.

[0053] The input receiving device may include, for example, a power button, keyboard, mouse, touch sensor, and the like. The touch sensor is, for example, an electrostatic capacitance sensor. A combination of the touch sensor and the display is referred to as a touch panel.

[0054] The communication interface **36** performs communication with the client terminal **10** and image forming apparatus **20** via the network N (as illustrated in FIG. 1). The communication interface **36** supports a variety of existing communication standards. The communication standards include Ethernet (registered trademark) and Wi-Fi (registered trademark).

### Simulation Process of Texture

**[0055]** A simulation process that the processor **31** (see FIG. 2) performs by executing the program is described below.

**[0056]** The simulation process of the texture according to the first exemplary embodiment starts when the client terminal **10** provides the print server **30** with an object serving as a simulation target and the ambient light image.

**[0057]** According to the first exemplary embodiment, the object is a white paper sheet. A color chart is printed on the paper sheet. The color chart is a collection of color samples.

**[0058]** The ambient light image is a spherical image imaged outdoors. The spherical image is a picture of the blue sky and the sun.

#### First Simulation Example

**[0059]** FIG. 3 illustrates a first simulation example performed by the processor **31**. The letter S in FIG. 3 is the abbreviation of the word “step.”

#### Step 1

**[0060]** The processor **31** retrieves the ambient light image from the client terminal **10**. The ambient light image gives information on the ambient light at an imaging point.

#### Step 2

**[0061]** The processor **31** generates a diffuse reflection illumination intensity map (hereinafter referred to as illumination intensity map E) from the acquired ambient light image. The illumination intensity map E represents an illumination intensity distribution or a luminance distribution of the ambient light image. Each of the illumination intensity distribution and luminance distribution is information representing a distribution of brightness per unit area. According to the first exemplary embodiment, the two distributions are collectively referred to as an “illumination intensity distribution.”

**[0062]** The illumination intensity map E may be produced using one of related-art techniques. For example, the processor **31** generates an environment map where the ambient light image is glued on the surface of a virtual cube and generates the illumination intensity map E from the produced environment map. The environment map and the illumination intensity map are cube maps.

#### Step 3

**[0063]** The processor **31** acquires information e on main illumination by analyzing the illumination intensity map E.

**[0064]** According to the first exemplary embodiment, the main illumination is defined as a position that provides a maximum mean illumination intensity value within a unit area. The main illumination may be identified using a maximum value, a percentile value, or a luminance variance of illumination intensities within the unit area. According to the first exemplary embodiment, the position where a mean illumination intensity value appears is set to be the location of the main illumination to remove the effect of noise.

**[0065]** The processor **31** estimates the color and intensity of the main illumination as the information e on the main illumination. Alternatively, the processor **31** may estimate only the color or only the intensity of the main illumination.

It is noted that the information e on the main illumination is not limited to the color and intensity of the illumination light.

#### Step 4

**[0066]** The processor **31** generates a corrected illumination intensity map E' by correcting the illumination intensity map E with the information e on the main illumination.

**[0067]** Referring to FIG. 3, the processor **31** calculates the corrected illumination intensity map E' in accordance with the following equation:

$$E'(i)=e+E(i).$$

**[0068]** It is noted that i represents each pixel on the illumination intensity map E and the corrected illumination intensity map E'.

**[0069]** The corrected illumination intensity map E' in step 4 is calculated by adding the information e on the main illumination to all pixels of the illumination intensity map E. The information e on the main illumination herein is a fixed value.

**[0070]** The illumination intensity map E is an example of a first function representing the illumination intensity distribution. The information e on the main illumination is an example of a second function. The corrected illumination intensity map E' is an example of a third function.

#### Step 5

**[0071]** The processor **31** retrieves a sample image from the client terminal **10**.

**[0072]** The sample image is a white paper sheet having a color chart printed thereon. The sample image is uploaded as an image file from the client terminal **10** to the print server **30**.

**[0073]** The sample image and ambient light image may be concurrently uploaded.

#### Step 6

**[0074]** The processor **31** receives from the client terminal **10** the mounting location and posture of the sample image within the ambient light image.

**[0075]** The posture is defined by the normal direction of the paper sheet. The posture of the sample image with respect to the main illumination plays a main role.

#### Step 7

**[0076]** Using the corrected illumination intensity map E', the processor **31** simulates the appearance of the sample image in response to the posture. The method of simulating the appearance of the sample image using an illumination intensity map is one of related-art techniques.

#### Step 8

**[0077]** The processor **31** displays simulation results on a display of the client terminal **10**. FIG. 4 illustrates an example of the simulation results displayed on the display.

**[0078]** A sample image **101** indicates how the simulation results look before being corrected with the information e on the main illumination and a sample image **102** indicates how the simulation results look after being corrected with the information e on the main illumination. Referring to FIG. 4, the state prior to correction is described as “not corrected

with information on main illumination” and the state subsequent to the correction is described as “corrected with information on main illumination.”

**[0079]** In each of the sample image **101** and sample image **102**, the normal direction of the paper sheet faces the sun serving as the main illumination in the ambient light image.

**[0080]** The color of the sky is used as the color of the illumination light in the simulation of the sample image **101**. As a result, the white paper sheet is reproduced in a blue-tinted color. The simulation results are an unnatural appearance different from the actual appearance.

**[0081]** On the other hand, the color of the sunlight (white-color lighting) of the main illumination of the illumination intensity map *E* serving as the color of the illumination light is dominant in the simulation of the sample image **102**. As a result, the white paper sheet is reproduced to be white.

**[0082]** The simulation using the corrected illumination intensity map *E'* may cause the appearance of the simulation results to look more like an actual object.

**[0083]** FIG. **5** illustrates another example of the simulation results displayed on the display.

**[0084]** The sample image **101** indicates how the simulation results look before being corrected with the information *e* on the main illumination and the sample image **102** indicates how the simulation results look after being corrected with the information *e* on the main illumination. Referring to FIG. **5**, the state prior to the correction is described as “not corrected with information on main illumination” and the state subsequent to the correction is described as “corrected with information on main illumination.”

**[0085]** Referring to FIG. **5**, in each of the sample image **101** and sample image **102**, the normal direction of the paper sheet is not in alignment with the direction of the sun serving as the main illumination in the ambient light image.

**[0086]** The paper sheet is reproduced to be darker in the sample image **101** in FIG. **5**. The simulation results look unnatural, and is thus different from the actual appearance.

**[0087]** The intensity of the corrected illumination intensity map *E'* used in the simulation of the sample image **102** in FIG. **5** is corrected to a value higher than the illumination intensity map *E*. Even when the normal direction of the paper sheet is not in alignment with the direction of the sun, the brightness of the sample image **102** is reproduced to be higher than the sample image **101**. The simulation using the corrected illumination intensity map *E'* may cause the simulation results to look closer to the actual appearance.

#### Second Simulation Example

**[0088]** FIG. **6** illustrates a second simulation example performed by the processor **31**. Referring to FIG. **6**, steps identical to the steps in FIG. **3** are designated with the same step numbers.

**[0089]** In the second simulation example, step 4A is performed in place of step 4. The operations in the remaining steps in the second simulation example are respectively identical to the operations in the first simulation example.

#### Step 4A

**[0090]** The processor **31** generates the corrected illumination intensity map *E'* by correcting the illumination intensity map *E* with a weighted mean of the illumination intensity map *E* and the information *e* on the main illumination.

**[0091]** Referring to FIG. **6**, the processor **31** corrects the illumination intensity map *E* in accordance with the following equation:

$$E'(i)=e*c+E(i)*(1-c).$$

**[0092]** It is noted that *i* represents each pixel on the illumination intensity map *E* and the corrected illumination intensity map *E'* and *c* represents a correction coefficient. The correction coefficient *c* satisfies the condition of  $0 < c < 1$ .

**[0093]** In the second simulation example, the color and intensity of the main illumination are added to all pixels of the illumination intensity map *E*.

**[0094]** However, because of the value of the correction coefficient *c*, the value of the correction coefficient *c* makes the effect of the color and intensity of the main illumination on each pixel on the corrected illumination intensity map *E'* in the second simulation example smaller than the effect of the color and intensity of the main illumination in the first simulation example.

**[0095]** In the second simulation example, the value of the correction coefficient *c* may be specified on the display of the client terminal **10**. Alternatively, the correction coefficient *c* may be set by vendor side.

**[0096]** In the second simulation example, the correction coefficient *c* may be modified in view of the environment of a location where the ambient light image is imaged or the time of the imaging. The simulation results may thus be set to be even closer to the actual appearance.

#### Third Simulation Example

**[0097]** FIG. **7** illustrates a third simulation example performed by the processor **31**. Referring to FIG. **7**, steps identical to the steps in FIG. **3** are designated with the same step numbers.

**[0098]** In the third simulation example, step 4B is performed in place of step 4. The operations in the remaining steps in the third simulation example are respectively identical to the operations in the first simulation example.

**[0099]** In the first and second simulation examples, the same value is added to all pixels in the illumination intensity map *E*. In other words, illumination intensities at all pixels are corrected to be higher than the illumination intensity map *E* but the illumination intensity after the correction is limited by an upper limit. As a result, the illumination intensity distribution becomes flatter than prior to the correction and the simulation results with the gloss reduced may be obtained.

#### Step 4B

**[0100]** The processor **31** corrects the information *e* on the main illumination with an index that represents gloss in response to a positional relationship between the location of the main illumination and each pixel in the illumination intensity map. The index may be a gloss coefficient *w*.

**[0101]** Referring to FIG. **7**, the processor **31** calculates the corrected illumination intensity map *E'* in accordance with the following equation:

$$E'(i)=e*w(i)+E(i).$$

**[0102]** It is noted that *i* represents each pixel on the illumination intensity map *E* and the corrected illumination intensity map *E'*.

[0103] FIGS. 8A and 8B illustrate the gloss coefficient  $w$  that is defined by a distance  $d$  between the main illumination and each pixel  $i$ .

[0104] Referring to FIGS. 8A and 8B, the gloss coefficient  $w$  is defined by a function  $f(d)$  having a distance  $d$  as a variable. The maximum value of the gloss coefficient  $w$  is higher than 1.

[0105] According to the first exemplary embodiment, the distance  $d$  is calculated as a distance between the location of the main illumination and each pixel  $i$  on the cube map.

[0106] In the function  $f(d)$  in FIG. 8A, the gloss coefficient  $w$  having a higher value is used for a pixel  $i$  having a shorter distance  $d$  and the gloss coefficient  $w$  having a lower value is used for a pixel  $i$  having a longer distance  $d$ . Specifically, the value of the gloss coefficient  $w$  is higher as the distance  $d$  is shorter.

[0107] Referring to FIGS. 8A and 8B, the function is non-linear and sharply reduced when the distance  $d$  to the main illumination exceeds a reference value. This does not necessarily exclude the possibility that the function is linearly reduced or stepwise reduced.

[0108] FIGS. 9A and 9B illustrate the gloss coefficient  $w$  that is defined by an angular difference  $\Delta\omega$  between the main illumination and each pixel  $i$ . The angular difference  $\Delta\omega$  is an angle made by a straight line connecting the center of a cube map to the location of the main illumination and a straight line connecting the center of the cube map to the position of each pixel  $i$ .

[0109] Referring to FIG. 9B, the straight line connecting the center of the cube map to the location of the main illumination represents the direction of the normal line passing through the location of the main illumination. The straight line connecting the center of the cube map to the position of each pixel  $i$  represents the normal direction of each pixel  $i$ .

[0110] The angular difference  $\Delta\omega$  of zero signifies that the main illumination is positioned in the normal direction of each pixel  $i$ . The angular difference  $\Delta\omega$  closer to  $90^\circ$  signifies that the normal direction of each pixel  $i$  is at about  $90^\circ$  from the direction of the main illumination.

[0111] The angular difference  $\Delta\omega$  of zero also signifies that the component of light reflected in the normal direction of the pixel  $i$  is maximized.

[0112] On the other hand, the angular difference  $\Delta\omega$  of  $90^\circ$  also signifies that the light reflected in the normal direction of the pixel  $i$  is minimized.

[0113] In the function ( $\Delta\omega$ ) in FIG. 9A, the gloss coefficient  $w$  having a larger value is used for the pixel  $i$  having a smaller angular difference  $\Delta\omega$  while the gloss coefficient  $w$  having a smaller value is used for the pixel  $i$  having a larger angular difference  $\Delta\omega$ . Specifically, the value of the gloss coefficient  $w$  is higher as the distance  $d$  is shorter.

[0114] Referring to FIG. 9A, the function is non-linear and sharply reduced when the angular difference  $\Delta\omega$  from the main illumination exceeds a reference value. This does not necessarily exclude the possibility that the function is linearly reduced or stepwise reduced.

[0115] FIG. 10 illustrates another example of the simulation results displayed on the display. Referring to FIG. 10, elements identical to the elements in FIG. 4 are designated with the same reference numerals.

[0116] The simulation results in FIG. 10 indicate that the normal direction of the paper sheet is substantially in

alignment with the direction of the main illumination, in other words, the angular difference  $\Delta\omega$  is approximately zero.

[0117] The simulation results in FIG. 10 indicating that the normal direction of the paper sheet is substantially in alignment with the direction of the main illumination signifies that the distance  $d$  between the location of the main illumination and each pixel  $i$  of the sample image is shorter.

[0118] Referring to FIG. 10, the sample image 102 corresponds to the sample image 102 in the first and second simulation examples.

[0119] The correction with the information  $e$  on the main illumination on the sample image 102 is uniform to the whole sample image. For this reason, the appearance of the color chart in the sample image 102 remains substantially unchanged from the appearance of the color chart even when the illumination intensity is lower.

[0120] A sample image 103 indicates simulation results corrected with the gloss coefficient  $w$ . Referring to FIG. 10, the state corrected with the gloss coefficient  $w(i)$  is described as "corrected with gloss."

[0121] In the sample image 103 in FIG. 10, a value obtained by amplifying the information  $e$  on the main illumination by the gloss coefficient  $w$  is added to each pixel  $i$  on the entire paper sheet on the original illumination intensity map  $E$ . As a result, the illumination intensity of the entire paper sheet in the sample image 103 becomes higher than the illumination intensity of the sample image 102, causing the color chart to be whitish.

[0122] The simulation performed using the corrected illumination intensity map  $E'$  may cause the simulation results to look closer to the actual appearance.

[0123] FIG. 11 illustrates another example of the simulation results displayed on the display.

[0124] Referring to FIG. 11, elements identical to the elements in FIG. 5 are designated with the same reference numerals.

[0125] The simulation results in FIG. 11 indicate that the normal direction of the paper sheet is tilted to be off alignment with the direction of the sun serving as the main illumination, namely, the angular difference  $\Delta\omega$  is larger. The normal direction of the paper sheet tilted to be off alignment with the direction of the sun serving as the main illumination signifies that the distance  $d$  between the location of the main illumination and the pixel  $i$  of the sample image is longer.

[0126] In the sample image 102 in FIG. 11, the correction with the information  $e$  on the main illumination is uniform on the entire sample image. The appearance of the color chart in the sample image 102 remains substantially unchanged from the appearance of the color chart even when the illumination intensity is lower.

[0127] A value obtained by amplifying the information  $e$  on the main illumination by the gloss coefficient  $w$  is added to all pixels of the entire paper sheet on the original illumination intensity map  $E$  in the sample image 103.

[0128] As a result, the illumination intensity of the entire paper sheet in the sample image 103 becomes higher than the illumination intensity of the sample image 102, causing the color chart to be whitish. Since the main illumination is present in FIG. 10 but not present in FIG. 11 in the normal direction of the paper sheet, the appearance of the color chart in the sample image 103 in FIG. 11 is slightly closer to the

appearance of the color chart in the sample image **102** than the appearance of the color chart in the sample image **103** in FIG. **10**.

[0129] The simulation performed using the corrected illumination intensity map  $E'$  may cause the simulation results to look closer to the actual appearance.

#### Fourth Simulation Example

[0130] FIG. **12** illustrates a fourth simulation example performed by the processor **31**. Referring to FIG. **12**, steps identical to the steps in FIG. **7** are designated with the same step numbers.

[0131] In the fourth simulation example, step **4C** is performed in place of step **4B**. The operations in the remaining steps in the fourth simulation is respectively identical to the operations in the third simulation example.

#### Step 4D

[0132] The processor **31** uses, as an index indicating of the degree of gloss, a value  $w*Tr$  resulting from multiplying the gloss coefficient  $w$  by a weighting coefficient  $Tr$ . The index is determined by a positional relationship between the location of the main illumination and each pixel  $i$  on the illumination intensity map.

[0133] Referring to FIG. **12**, the processor **31** calculates the corrected illumination intensity map  $E'$  in accordance with the following equation:

$$E'(i)=e*w(i)*Tr+E(i).$$

[0134] It is noted that  $i$  represents each pixel on the illumination intensity map  $E$  and the corrected illumination intensity map  $E'$ .

[0135] FIGS. **13A** and **13B** illustrate an example of a weighting gloss coefficient  $w*Tr$ . FIG. **13A** illustrates the weighting gloss coefficient  $w*Tr$  in which the gloss coefficient  $w$  is obtained as a function  $f(d)$ , and FIG. **13B** illustrates a weighting gloss coefficient  $w*Tr$  in which the gloss coefficient  $w$  is obtained as a function  $f(\Delta\omega)$  of the angular difference  $\Delta\omega$ .

[0136] The weighting coefficient  $Tr$  in FIGS. **13A** and **13B** is a fixed value that satisfies a condition of  $0<Tr<1$ . The value of the function  $f(d)$  responsive to the distance  $d$  in FIG. **13A** is smaller than the value of the function  $f(d)$  responsive to the distance  $d$  in FIG. **8A** and the value of the function  $(\Delta\omega)$  responsive to the angular difference  $\Delta\omega$  in FIG. **13B** is smaller than the value of the function  $(\Delta\omega)$  responsive to the angular difference  $\Delta\omega$  in FIG. **9A**. In the fourth simulation example, the effect of the gloss coefficient  $w$  may be adjusted by the value of the weighting coefficient  $Tr$ .

[0137] The value of the weighting coefficient  $Tr$  may be specified on the display of the client terminal **10**. Alternatively, the weighting coefficient  $Tr$  may be set by the vendor side.

[0138] In the fourth simulation example, the simulation results may be set to be even closer to the actual appearance by modifying the weighting coefficient  $Tr$  in response to the environment of the location where the ambient light image is imaged and the time of imaging.

#### Fifth Simulation Example

[0139] FIG. **14** illustrates a fifth simulation example performed by the processor **31**. Referring to FIG. **14**, steps identical to the steps in FIG. **12** are designated with the same step numbers.

[0140] In the fifth simulation example, step **4D** is performed in place of step **4C**. The operations in the remaining steps in fifth fourth simulation example is respectively identical to the operations in the fourth simulation example.

#### Step 4D

[0141] The processor **31** generates the corrected illumination intensity map  $E'$  by correcting the illumination intensity map  $E$  with the weighted mean of the information  $e$  on the main illumination corrected with the gloss coefficient  $w$ .

[0142] Referring to FIG. **14**, the processor **31** calculates the corrected illumination intensity map  $E'$  in accordance with the following equation:

$$E'(i)=e*w(i)*Tr+E(i)*(1.0-Tr).$$

[0143] It is noted that  $i$  represents each pixel on the illumination intensity map  $E$  and the corrected illumination intensity map  $E'$ ,  $w(i)$  represents a gloss coefficient, and  $Tr$  represents a weighting coefficient. The weighting coefficient  $Tr$  satisfies the condition of  $0<Tr<1$ .

[0144] In the fifth simulation example as well, a value resulting from correcting the color and intensity of the main illumination with the gloss coefficient  $w$  is added to each of the pixels on the illumination intensity map  $E$ .

[0145] It is noted however that the value of the weighting coefficient  $Tr$  makes the effect of correcting, with the gloss coefficient  $w$ , the color and intensity of the main illumination in each pixel on the corrected illumination intensity map  $E'$  in the second simulation example is smaller than the effect of the correction in the fourth simulation example.

[0146] In the fifth simulation example, the value of the weighting coefficient  $Tr$  may be specified on the display of the client terminal **10**. Alternatively, the weighting coefficient  $Tr$  may be set by the vendor side.

[0147] In the fifth simulation example, the simulation results may be set to be even closer to the actual appearance by modifying the weighting coefficient  $Tr$  in response to the environment of the location where the ambient light image is imaged and the time of imaging.

#### Second Exemplary Embodiment

[0148] FIG. **15** illustrates a configuration example of an information processing system **1A** used in a second exemplary embodiment. In FIG. **15**, elements identical to the elements in FIG. **1** are designated with the same reference numerals.

[0149] The information processing system **1A** in FIG. **15** includes a client terminal **10** and cloud server **40**. These apparatuses are communicably connected to each other via a cloud network **CN**.

[0150] The cloud server **40** is an example of an information processing apparatus. The hardware configuration of the cloud server **40** is identical to the hardware configuration in FIG. **2**.

[0151] The information processing system **1A** in FIG. **15** is different from the print system **1** in FIG. **1** in that the information processing system **1A** is not based on the

assumption that the image forming apparatus **20** (see FIG. 1) has an image forming function.

**[0152]** According to the second exemplary embodiment, the first through fifth simulation examples of texture are implemented by executing a program on the cloud server **40**.

**[0153]** Referring to FIG. 15, the cloud server **40** specialized in the texture simulation is available. Alternatively, the client terminal **10** alone may perform the first through fifth simulation examples of texture.

#### Other Exemplary Embodiments

**[0154]** (1) The exemplary embodiments of the disclosure have been described. The scope of the disclosure is not limited to the description of the exemplary embodiments. As defined by the claims, a variety of modifications and changes to the exemplary embodiments may fall within the scope of the disclosure.

**[0155]** (2) In the exemplary embodiments, the simulation target is a two-dimensional object, such as a paper sheet. Alternatively, the simulation target may be a three-dimensional object. If the simulation target is a three-dimensional object, the appearance of texture at an observation location is simulated using information defining the shape and surface of the three-dimensional object.

**[0156]** (3) In the second and fifth simulation examples in the exemplary embodiments, the sum of weights used in the weighted mean is 1. The sum of weights may not necessarily be 1.

**[0157]** (4) In the third simulation example of the exemplary embodiments, the gloss coefficient  $w$  is calculated using the distance  $d$  between the location of the main illumination and each pixel  $i$  on the cube map. Alternatively, the gloss coefficient  $w$  may be calculated using a distance on the spherical image. However, if the distance on the spherical image is calculated, the size of a sphere may be normalized to a unit sphere. Since a relative distance is acceptable as the distance  $d$  used to calculate the gloss coefficient  $w$ , normalization leads to no problem.

**[0158]** (5) In the third simulation example of the exemplary embodiments, the gloss coefficient  $w$  is calculated using the angular difference  $\Delta\omega$  made by a straight line connecting the center of the cube map to the location of the main illumination and a straight line connecting the center of the cube map to the position of each pixel  $i$ . Alternatively, an angular difference on the spherical image may be used. However, if the angular difference  $\Delta\omega$  is calculated on the spherical image, the size of a sphere may be normalized to a unit sphere. Since a relative distance is acceptable as the angular difference  $\Delta\omega$  used to calculate the gloss coefficient  $w$ , normalization leads to no problem.

**[0159]** (6) In the embodiments above, the term “processor” refers to hardware in a broad sense. Examples of the processor include general processors (e.g., CPU: Main Processing Unit) and dedicated processors (e.g., GPU: Graphics Processing Unit, ASIC: Application Specific Integrated Circuit, FPGA: Field Programmable Gate Array, and programmable logic device).

**[0160]** In the embodiments above, the term “processor” is broad enough to encompass one processor or plural processors in collaboration which are located physically apart from each other but may work cooperatively. The order of opera-

tions of the processor is not limited to one described in the embodiments above, and may be changed.

**[0161]** The foregoing description of the exemplary embodiments of the present disclosure has been provided for the purposes of illustration and description. It is not intended to be exhaustive or to limit the disclosure to the precise forms disclosed. Obviously, many modifications and variations will be apparent to practitioners skilled in the art. The embodiments were chosen and described in order to best explain the principles of the disclosure and its practical applications, thereby enabling others skilled in the art to understand the disclosure for various embodiments and with the various modifications as are suited to the particular use contemplated. It is intended that the scope of the disclosure be defined by the following claims and their equivalents.

#### APPENDIX

**[0162]** (((1))

**[0163]** An information processing apparatus including:

**[0164]** a processor configured to:

**[0165]** acquire information on main illumination from an illumination intensity distribution of an image that results from imaging an actual space; and

**[0166]** control an expression of a thing using an illumination intensity distribution that is corrected with the information on the main illumination.

((2))

**[0167]** In the information processing apparatus according to (((1))), the processor is configured to estimate a color of the main illumination from the illumination intensity distribution and use the color of the main illumination as the information on the main illumination.

((3))

**[0168]** In the information processing apparatus according to one of (((1))) and ((2)), the processor is configured to estimate an intensity of the main illumination from the illumination intensity distribution and use the intensity of the main illumination as the information on the main illumination.

((4))

**[0169]** In the information processing apparatus according to one of (((1))) through ((3))), the processor is configured to determine a third function that results from adding to a first function representing the illumination intensity distribution a second function representing the information on the main illumination, and treat the third function as the corrected illumination intensity distribution.

((5))

**[0170]** In the information processing apparatus according to (((4))), the processor is configured to add a fixed value as the second function to the first function.

((6))

**[0171]** In the information processing apparatus according to (((4))), the processor is configured to determine, as the third function, a weighted mean of the first function and the second function.

((7))

**[0172]** In the information processing apparatus according to (((4))), the processor is configured to:

**[0173]** calculate an index indicative of a degree of gloss in accordance with a positional relationship between a location of the main illumination and each pixel on the illumination intensity distribution; and

**[0174]** determine the third function by adding to the first function the second function that is corrected with the calculated index.

((8))

**[0175]** In the information processing apparatus according to ((7)), the processor is configured to set a value of the index of a pixel having a shorter distance to the location of the main illumination to be larger than a value of the index of a pixel having a longer distance to the location of the main illumination.

((9))

**[0176]** In the information processing apparatus according to ((7)), the processor is configured to set a value of the index to a pixel having a smaller angular difference from the location of the main illumination to be larger than a value of the index of a pixel having a larger angular difference from the location of the main illumination.

((10))

**[0177]** In the information processing apparatus according to ((7)), the processor is configured to determine the third function by adding to the first function the second function with the index corrected with an weighting coefficient.

((11))

**[0178]** In the information processing apparatus according to ((7)), the processor is configured to determine as the third function a weighted mean of the first function and the second function corrected with the index.

((12))

**[0179]** A program causing a computer to execute a process, the process including:

**[0180]** acquiring information on main illumination from an illumination intensity distribution of an image that results from imaging an actual space; and

**[0181]** controlling an expression of a thing using an illumination intensity distribution that is corrected with the information on the main illumination.

What is claimed is:

1. An information processing apparatus comprising:

a processor configured to:

acquire information on main illumination from an illumination intensity distribution of an image that results from imaging an actual space; and

control an expression of a thing using an illumination intensity distribution that is corrected with the information on the main illumination.

2. The information processing apparatus according to claim 1, wherein the processor is configured to estimate a color of the main illumination from the illumination intensity distribution and use the color of the main illumination as the information on the main illumination.

3. The information processing apparatus according to claim 1, wherein the processor is configured to estimate an intensity of the main illumination from the illumination intensity distribution and use the intensity of the main illumination as the information on the main illumination.

4. The information processing apparatus according to claim 2, wherein the processor is configured to estimate an intensity of the main illumination from the illumination intensity distribution and use the intensity of the main illumination as the information on the main illumination.

5. The information processing apparatus according to claim 1, wherein the processor is configured to determine a third function that results from adding to a first function representing the illumination intensity distribution a second function representing the information on the main illumination, and treat the third function as the corrected illumination intensity distribution.

6. The information processing apparatus according to claim 5, wherein the processor is configured to add a fixed value as the second function to the first function.

7. The information processing apparatus according to claim 5, wherein the processor is configured to determine, as the third function, a weighted mean of the first function and the second function.

8. The information processing apparatus according to claim 5, wherein the processor is configured to:

calculate an index indicative of a degree of gloss in accordance with a positional relationship between a location of the main illumination and each pixel on the illumination intensity distribution; and

determine the third function by adding to the first function the second function that is corrected with the calculated index.

9. The information processing apparatus according to claim 8, wherein the processor is configured to set a value of the index of a pixel having a shorter distance to the location of the main illumination to be larger than a value of the index of a pixel having a longer distance to the location of the main illumination.

10. The information processing apparatus according to claim 8, wherein the processor is configured to set a value of the index to a pixel having a smaller angular difference from the location of the main illumination to be larger than a value of the index of a pixel having a larger angular difference from the location of the main illumination.

11. The information processing apparatus according to claim 8, wherein the processor is configured to determine the third function by adding to the first function the second function with the index corrected with a weighting coefficient.

12. The information processing apparatus according to claim 8, wherein the processor is configured to determine as the third function a weighted mean of the first function and the second function corrected with the index.

13. A non-transitory computer readable medium storing a program causing a computer to execute a process, the process comprising:

acquiring information on main illumination from an illumination intensity distribution of an image that results from imaging an actual space; and

controlling an expression of a thing using an illumination intensity distribution that is corrected with the information on the main illumination.

14. An information processing method comprising: acquiring information on main illumination from an illumination intensity distribution of an image that results from imaging an actual space; and

controlling an expression of a thing using an illumination intensity distribution that is corrected with the information on the main illumination.

\* \* \* \* \*