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Display control apparatus used for color matching between reference image pickup apparatus and adjustment image pickup apparatus, control method therefor, and storage medium storing control program therefor

Abstract

A display control apparatus that easily discriminates residual color difference between a plurality of image pickup apparatuses at a site where the image pickup apparatuses are used. The display control apparatus including a memory device that stores a set of instructions, and at least one processor that executes the set of instructions to obtain an adjustment image from an adjustment image pickup apparatus that performs predetermined color matching with a reference image pickup apparatus, generate residual color difference information showing color difference from a reference image picked up by the reference image pickup apparatus that remains in the adjustment image, and generate display information from the residual color difference information.

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Background/Summary

BACKGROUND OF THE INVENTION
Field of the Invention
(1) The present invention relates to a display control apparatus used for color matching between a reference image pickup apparatus and an adjustment image pickup apparatus, a control method therefor, and a storage medium storing a control program therefor.
Description of the Related Art
(2) Japanese Laid-Open Patent Publication (Kokai) No. 2018-088618 (JP 2018-088618A) discloses an image pickup apparatus. This image pickup apparatus allocates a pixel value of a saturation-

pixel warning color to a saturation pixel in an image picked up by an image pickup system. Moreover, the image pickup apparatus allocates a pixel value, which is obtained by converting an imaging color gamut into a display color gamut, to a pixel within the display color gamut in the image picked up by the image pickup system. Furthermore, the image pickup apparatus allocates a pixel value of an out-of-display-color-gamut warning color to a pixel without the display color gamut in the image picked up by the image pickup system.

(3) Japanese Laid-Open Patent Publication (Kokai) No. 2003-224775 (JP 2003-224775A) discloses a technique that enables a user to easily visually recognize a part changed in time series of an object by adding a difference image between a plurality of images picked up in time series to an image that is obtained by lowering contrast of the difference image.

(4) Incidentally, such an image pickup apparatus picks up a static image or a video image by receiving light entering through an optical system using an image sensor like a CCD sensor or a CMOS sensor, for example. Then, an image pickup apparatus may be used with another image pickup apparatus. In this case, even if a plurality of image pickup apparatuses pick up the same object, colors of the object in images may be different because of difference in light receiving characteristic between the image sensors of the image pickup apparatuses. Hereinafter, difference between colors in images picked up by image pickup apparatuses is called color difference.

(5) In order to correct the color difference, it is considerable to use one image pickup apparatus as a reference image pickup apparatus, to use another image pickup apparatus as an adjustment image pickup apparatus, and to generate a correction lookup table used by the adjustment image pickup apparatus so as to match colors. This should be able to match the colors of the image of the adjustment image pickup apparatus with that of the reference image pickup apparatus.

(6) However, even if the adjustment image pickup apparatus uses such a correction lookup table, not all the colors of the pickup image of the adjustment image pickup apparatus match the colors of the pickup image of the reference image pickup apparatus. On a site where a plurality of image pickup apparatuses are used actually, the color difference may remain in some objects even if the correction lookup table is used. Hereinafter, the color difference that remains after correction using the correction lookup table is called residual color difference. When there is such residual color difference, a user needs much effort to find the residual color difference by visually comparing the pickup image of the reference image pickup apparatus and the pickup image of adjustment image pickup apparatus.

SUMMARY OF THE INVENTION

(7) The present invention provides a technique that easily discriminates the residual color difference between a plurality of image pickup apparatuses at a site where the image pickup apparatuses are used.

(8) Accordingly, an aspect of the present invention provides a display control apparatus including a memory device that stores a set of instructions, and at least one processor that executes the set of instructions to obtain an adjustment image from an adjustment image pickup apparatus that performs predetermined color matching with a reference image pickup apparatus, generate residual color difference information showing color difference from a reference image picked up by the reference image pickup apparatus that remains in the adjustment image, and generate display information from the residual color difference information.

(9) The present invention enables easy discrimination of the residual color difference between the reference image pickup apparatus and the adjustment image pickup apparatus at the site where these image pickup apparatuses are used.

(10) Further features of the present invention will become apparent from the following description of exemplary embodiments with reference to the attached drawings.

Description

BRIEF DESCRIPTION OF THE DRAWINGS

(1) FIG. **1** is a configuration diagram showing a color difference correction system that corrects color difference between a plurality of image pickup apparatuses and includes a display control apparatus according to a first embodiment of the present invention.

(2) FIG. **2** is a block diagram showing a main configuration of the display control apparatus in FIG. **1**.

(3) FIG. **3** is a flowchart showing a process for generating a correction LUT (lookup table) by the display control apparatus in FIG. **1**.

(4) FIG. **4** is a view showing an example of a combination of a pickup image of a reference camera and a pickup image of a target camera that are currently displayed on a display unit of the display control apparatus.

(5) FIG. **5** is a view showing an example of a combination of RGB values of color patches in the pickup images in FIG. **4**.

(6) FIG. **6** is a view showing an example of a combination of XYZ values of the color patches obtained on the basis of the RGB values of the color patches in FIG. **5**.

(7) FIG. **7** is an explanatory view of an example of the correction LUT generated by the display control apparatus in FIG. **1**.

(8) FIG. **8** is a flowchart showing a process for generating residual color difference information about the target camera that uses the correction LUT.

(9) FIG. **9** is a view showing an example of a combination of RGB values of color patches in an image from the target camera to which color matching has been applied.

(10) FIG. **10** is a view showing an example of a combination of XYZ values after the color matching that are obtained on the basis of the RGB values of the color patches in FIG. **9**.

(11) FIG. **11** is a flowchart showing a process for generating a display image for displaying the residual color difference information.

(12) FIG. **12** is a table showing correspondence relations between ranges of a residual color difference value defined by the residual color difference information and conversion colors used as colors of pixels included in the respective ranges.

(13) FIG. **13** is an explanatory view showing an example of the display image that displays the residual color difference information on the basis of the pickup image of the target camera that uses the correction LUT.

(14) FIG. **14** is a flowchart showing a process for generating residual color difference information by a display control apparatus according to a second embodiment of the present invention.

(15) FIG. **15** is a view showing an example of a combination of a pickup image of the target camera that uses the correction LUT and a color distribution image that is generated independently therefrom to show distribution of residual color difference values.

(16) FIG. **16** is a view showing an example of the color distribution image that shows the distribution of the residual color difference values of a case of applying this embodiment.

(17) FIG. **17** is a view showing an example of a vector scope image that shows the residual color difference information.

(18) FIG. **18** is a flowchart showing a process for outputting a message when a value of the residual color difference information is not less than a threshold.

DESCRIPTION OF THE EMBODIMENTS

(19) Hereafter, embodiments according to the present invention will be described in detail by referring to the drawings. However, configurations described in the following embodiments are just examples, and the scope of the present invention is not limited to the configurations described in the embodiments.

(20) FIG. **1** is a configuration diagram showing a color difference correction system that corrects color difference between a plurality of image pickup apparatuses. The color difference correction

system **1** in FIG. **1** has a display control apparatus **200** according to a first embodiment of the present invention. A reference camera **100** that is an example of a reference image pickup apparatus and a target camera **101** that is an example of an adjustment image pickup apparatus are connected to the display control apparatus **200** via image lines. The reference camera **100** and target camera **101** pick up a same type object like a color chart.

(21) The reference camera **100** outputs a pickup image to the display control apparatus **200** through the image line. The target camera **101** outputs a pickup image to the display control apparatus **200** through the image line. The reference camera **100** and target camera **101** may pick up static images or may pick up video images.

(22) The display control apparatus **200** compares input pickup images and generates a correction lookup table (LUT) for color matching that can be used by the target camera **101**. When using the correction LUT generated in this way, the target camera **101** can pick up an image of which color difference from an image of the reference camera **100** is reduced. The process that reduces the color difference between the images of the apparatuses using the correction LUT etc. is called color matching. When the target camera **101** that is color-matched with the reference camera **100** is used in the same image pickup environment with the reference camera **100**, a pickup image (an adjustment image) of which colors are close to that of a pickup image (a reference image) of the reference camera **100** can be obtained.

(23) FIG. **2** is a block diagram showing a main configuration of the display control apparatus **200** in FIG. **1**. The reference camera **100** is connectable with a first input terminal **221** through the image line. The reference camera **101** is connectable with a second input terminal **222** through the image line. A memory **223** stores programs that are executed by a controller **203** and various kinds of data. The memory **223** is constituted by a nonvolatile semiconductor memory, an SSD, an HDD, a RAM, or the like. A work area that is used when running a program is allocated to the RAM. The nonvolatile semiconductor memory, SSD, HDD, etc. can record a program and data in a nonvolatile manner.

(24) The controller **203** controls the entire display control apparatus **200**, reads a program from the memory **223**, and controls respective sections of the apparatus. The controller **203** is a CPU, for example.

(25) The image reception unit **201**b receives an image from the target camera **101** connected to the second input terminal **222** through the image line and outputs it to an image capture unit **202**b. The image capture unit **202**b captures the image received from the target camera **101**. Then, the image capture unit **202**b outputs the image captured to the controller **203**. The image capture unit **202**b can obtain an image before performing the color matching and the image after performing the color matching from the target camera **101** as an obtaining unit. The image capture unit **202**b captures an image of one frame of a video image by recording it to a frame memory. Although an image of one frame may be an interlace image, a progressive image is preferable.

(26) The image reception unit **201**a receives an image from the reference camera **100** connected to the first input terminal **221** through the image line and outputs it to an image capture unit **202**a. The image capture unit **202**a captures the image received from the reference camera **100**. Then, the image capture unit **202**a outputs the image captured to the controller **203**.

(27) A UI operation unit **204** receives an operation from a user and outputs a corresponding instruction to the controller **203**. For example, a pointing device, a pen tablet, etc. that are operated by a user are connected to the UI operation unit **204**. The UI operation unit **204** receives operations to instruct the color matching, switching of a display content, etc. Moreover, the UI operation unit **204** receives an operation to select each of rectangle color patches in an image. In this case, the UI operation unit **204** outputs a rectangle area from a start point to an end point of a color patch selected by the user to the controller **203** as area information about the color patch.

(28) The controller **203** achieves various control processes, such as a record control process, a display control process, and an image process, by controlling the respective sections of the display

control apparatus **200**. For example, the controller **203** displays the image from the reference camera **100** and the image from the target camera **101** on the display unit **211** side by side, as shown in FIG. **1**. The user can compare the image from the reference camera **100** and the image from the target camera **101** by viewing the display unit **211**.

(29) When the area information about the color patch is input through the UI operation unit **204**, the controller **203** superimposes a rectangle frame on the image currently displayed on the display unit **211**. The controller **203** may generate a warning screen and a message screen and may display them on the display unit **211**. When generating the correction LUT, the controller **203** outputs the image from the reference camera **100**, the image from the target camera **101**, and the area information about the color patches in the images to a correction LUT generation unit **205**.

(30) Moreover, when generating residual color difference information, the controller **203** outputs the image from the target camera **101** to a color coincidence determination unit **209**. Moreover, the controller **203** may generate a display image for showing the residual color difference information and may display it on the display unit **211**. This display image corresponds to display information generated on the basis of the residual color difference information. Moreover, the controller **203** switches a display content on the display unit **211** in accordance with a user operation through the UI operation unit **204**. Thereby, the controller **203** can switch generation of the correction LUT and display of the residual color difference information on the basis of the user operation.

(31) The correction LUT generation unit **205** obtains the information for generating the correction LUT from the controller **203** and generates the correction LUT for matching the colors of the image picked up by the target camera **101** with the colors of the image picked up by the reference camera **100**. The information obtained from the controller **203** includes the image from the reference camera **100**, the image from the target camera **101**, and the area information about the color patches corresponding to these images. Then, the correction LUT generation unit **205** outputs the correction LUT generated to a correction LUT output unit **206**. Moreover, the correction LUT generation unit **205** outputs the RGB values of the color patches in the images from the cameras and the image from the target camera **101**, which are used to generate the correction LUT, to a camera-characteristic-information storage unit **207**.

(32) The correction LUT output unit **206** converts the correction LUT input from the correction LUT generation unit **205** into a file of a format that the target camera **101** can import. For example, the file of the correction LUT generated by the correction LUT output unit **206** may be recorded in a portable medium (not shown) and may be imported to the target camera **101** by copying. Thereby, the target camera **101** can pick up a color-matched image to which the color matching is applied using the correction LUT. It should be noted that the correction LUT output unit **206** may transmit the file of the correction LUT to the target camera **101** by wireless communication etc. Moreover, when the target camera **101** and the display control apparatus **200** are connected via a LAN cable, the correction LUT output unit **206** may transmit the file of the correction LUT to the target camera **101** via the LAN cable.

(33) The camera-characteristic-information storage unit **207** records and holds camera characteristic information. The unit **207** may be constituted by a storage medium like an independent RAM or may function by using a part of the memory **223**. The camera characteristic information includes various kinds of information about the color matching of the target camera **101**. The camera characteristic information may include the information about the reference camera **100** and the information about the target camera **101** that are related to the color matching, for example. Moreover, the camera characteristic information may include the RGB values of the color patches obtained in performing the color matching of the reference camera **100** and the target camera **101**, for example. Moreover, the camera characteristic information may include the image from the reference camera **100** used for the color matching with the target camera **101**.

(34) A residual-color-difference-information generation unit **208** generates residual color difference information on the basis of the camera characteristic information held by the camera-characteristic-

information storage unit **207** by calculating color difference between the image from the target camera **101** and the image from the reference camera **100** on a pixel basis. Then, the residual-color-difference-information generation unit **208** may generate the residual color difference information about the color difference that remains in the image from the target camera **101** after the color matching using the camera characteristic information held by the camera-characteristic-information storage unit **207**. The residual-color-difference-information generation unit **208** may calculate the color difference between each pixel of the image from the target camera **101** and each pixel of the held image from the reference camera **100**. Thereby, the residual-color-difference-information generation unit **208**, as a residual color difference generation means, generates the residual color difference information showing the residual color difference that remains in the image from the target camera **101** that performs the color matching as the difference from the image from the reference camera **100**. The residual color difference information shows the residual color difference that remains between each pixel value of the image from the target camera **101** after performing the color matching and each pixel value of the image from the reference camera **100**.

(35) A color coincidence determination unit **209** determines a color coincidence degree between each pixel value of the image from the target camera **101** and each pixel value of the image from the reference camera **100**. The color coincidence determination unit **209** outputs each pixel value of the image from the target camera **101** to the residual-color-difference-information generation unit **208** and determines the color coincidence degree on the basis of the residual color difference information generated by the residual-color-difference-information generation unit **208**. A color-coincidence-information generation unit **210** generates a display image for showing the residual color difference information about the image from the target camera **101** that performs the color matching.

(36) For example, the color-coincidence-information generation unit **210** may generate the display image for showing the residual color difference information by converting each pixel value of the image from the corresponding target camera **101** in accordance with the color coincidence degree determined by the color coincidence determination unit **209**. In this case, when the color coincidence degree of the pixel is lower than a threshold, the color-coincidence-information generation unit **210** may convert the pixel value of the pixel into a pixel value that shows the residual color difference. Thereby, the color-coincidence-information generation unit **210**, as a display information generation means, generates display information based on the residual color difference information. The display unit **211** has a monitor, for example, and displays an image on the monitor. For example, the display unit **211** may display the warning screen received from the controller **203**, a residual-color-difference value Display image received from the color-coincidence-information generation unit **210**, etc.

(37) It should be noted that the configuration of the image processing apparatus is not limited to the configuration shown in FIG. **2**. For example, each control process can be executed by a single hardware unit or a plurality of hardware units may function as a single means as a whole by sharing a process. Moreover, a single hardware unit may function as a plurality of means depending on programs to run. This is the same about a storage process. Various kinds of data may be stored to a single hardware unit like the memory **223**. Or a plurality of recording media may be prepared depending on various kinds of storage processes. Moreover, the display unit **211** is not necessarily mounted in the display control apparatus **200**. The display control apparatus **200** should have at least an interface with the display unit **211**.

(38) Hereinafter, a process that generates the correction LUT used by the target camera **101** for the color matching is described first. FIG. **3** is a flowchart showing the process that the display control apparatus **200** generates the correction LUT for matching a color characteristic of the target camera **101** to a color characteristic of the reference camera **100** by comparing the image from the reference camera **100** and the image from the target camera **101**. A user operates the UI operation unit **204** to generate the correction LUT. For example, the user selects an item of "Generate color

matching LUT" in a menu screen. The controller **203** starts the process to generate the correction LUT by the display control apparatus **200** in response to the input operation through the UI operation unit **204**.

(39) FIG. **4** is a view showing an example of a combination of a pickup image **400***a* of the reference camera **100** and a pickup image **400***b* of the target camera **101** that are currently displayed on the display unit **211**. Each of the images **400***a* and **400***b* in FIG. **4** has predetermined color patches **401**, **402**, and **403**. The color patch **401** is red. The color patch **402** is green. The color patch **403** is blue. The user operates the UI operation unit **204** to generate the correction LUT.

(40) The controller **203** selects areas of the color patches **401**, **402**, and **403** in the images **400***a* and **400***b* on the basis of the user operations input through the UI operation unit **204**. After that, the controller **203** controls the respective sections of the display control apparatus **200** to execute the process in FIG. **3**. The controller **203** outputs the area information about the selected color patches and the images **400***a* and **400***b* to the correction LUT generation unit **205**. Thereby, this control is started. Although it is preferable to include the predetermined color patches **401**, **402**, and **403** in the images **400***a* and **400***b* that are compared to generate the correction LUT, images that do not include such color patches can be also used to generate the correction LUT.

(41) In a step S**301** in FIG. **3**, the correction LUT generation unit **205** extracts the RGB values showing colors of the color patches in the images **400***a* and **400***b*. The correction LUT generation unit **205** may extract the RGB values using the image **400***a* from the reference camera **100**, the image **400***b* form the target camera **101**, and the area information about the color patches **401**, **402**, and **403** that are received from the controller **203**. Then, the correction LUT generation unit **205** stores the extracted RGB values of the color patches of the images **400***a* and **400***b* to the camera-characteristic-information storage unit **207** as camera characteristic information. The correction LUT generation unit **205** may extract averages of pixel values in the areas of the designated color patches **401**, **402**, and **403** as the RGB values or may extract the pixel values of the centers of the areas as the RGB values.

(42) In a step S**302**, the correction LUT generation unit **205** converts the RGB values of the color patches **401**, **402**, and **403** into XYZ values. The correction LUT generation unit **205** may convert the RGB values into the XYZ values using the following formula 1, for example. The following formula 1 is a determinant that converts the RGB values into the XYZ values using a conversion matrix (an RGB-to-XYZ conversion matrix). For example, the RGB-to-XYZ conversion matrix can be generated by calculation using an xy coordinate of a display color gamut of the display control apparatus **200** and an xy coordinate of a white point. Moreover, it is preferable to substitute values that are obtained by normalizing the RGB values of the color patches **401**, **402**, and **403** into values r, g, and b of the following formula 1. Thereby, the RGB values of the color patches **401**, **402**, and **403** of the images in FIG. **5** are converted into the XYZ values of the color patches **401**, **402**, and **403** shown in FIG. **6**, for example.

(43) $\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} = \begin{bmatrix} RGB\text{-}to\text{-}XYZ \\ ConversionMatrix \end{bmatrix} \begin{bmatrix} r \\ g \\ b \end{bmatrix}$ Formula1

(44) FIG. **5** is a view showing an example of a combination of the RGB values of the color patches **401** in the pickup images **400***a* and **400***b* in FIG. **4**. FIG. **6** is a view showing an example of a combination of the XYZ values of the color patches obtained on the basis of the RGB values of the color patches **401**, **402**, and **403** in FIG. **4**. The XYZ values converted from the RGB values of the color patches **401**, **402**, and **403** in the image from the reference camera **100** shall be an arithmetic matrix R. The XYZ values converted from the RGB values of the color patches **401**, **402**, and **403** in the image from the target camera **101** shall be an arithmetic matrix T.

(45) In a step S**303** in FIG. **3**, the correction LUT generation unit **205** calculates a correction matrix M for matching the color characteristic of the target camera **101** with the color characteristic of the

reference camera **100**. The correction matrix M is a matrix for correcting the XYZ values of the color patches in the image from the target camera **101** to the XYZ values of the color patches in the image from the reference camera **100**. The correction matrix M can be calculated by the following formula 2, for example.

[Correction Matrix M]=[Arithmetic Matrix R][Arithmetic Matrix T].sup.−1   Formula 2

(46) In a step S**304**, the correction LUT generation unit **205** generates the correction LUT using the correction matrix M calculated in the step S**303**. The correction LUT generation unit **205** outputs the correction LUT generated to the correction LUT output unit **206**. Thereby finishes the process of FIG. **3**.

(47) FIG. **7** is an explanatory view of an example of the correction LUT generated by the display control apparatus **200** in FIG. **1**. The correction LUT is used to convert the RGB values (In) at the left side in FIG. **7** into the XYZ values (Out) at the right side in FIG. **7**. The correction LUT may consist of lattice points of 17*17*17. The RGB values (In) of each lattice point of the correction LUT can be converted into the XYZ values using the RGB-to-XYZ conversion matrix mentioned above. Then, corrected XYZ values X.sub.C, Y.sub.C, and Z.sub.C of such a lattice point are calculable by the following formula 3 using the XYZ values X, Y, Z of the lattice point and the correction matrix M mentioned above. Moreover, the corrected RGB values (Out) corresponding to the RGB values (In) of each lattice point of the correction LUT are calculated using the corrected XYZ values X.sub.C, Y.sub.C, and Z.sub.C of the lattice point and an inverse matrix of the RGB-to-XYZ conversion matrix. In the correction LUT in FIG. **7**, the RGB values (In) and RGB values (Out) are associated by such a process.

$$(48) \quad \begin{bmatrix} X_C \\ Y_C \\ Z_C \end{bmatrix} = [\text{CorrectionMatrix}M]\begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \quad \text{Formula3}$$

(49) Moreover, the correction LUT generation unit **205** calculates an arithmetic matrix S used in a flow of a residual color difference calculation process mentioned later by the following formula 4 using the above-mentioned arithmetic matrix T and the correction matrix M. The correction LUT generation unit **205** stores the calculated arithmetic matrix S in the camera-characteristic-information storage unit **207**.

[Arithmetic Matrix S]=[Correction Matrix M][Arithmetic Matrix T]   Formula 4

(50) The above process enables the display control apparatus **200** to generate the correction LUT that reduces the color difference of the target camera **101** and improves the coincidence degree with the color characteristic of the reference camera **100**. The target camera **101** to which such color matching is applied and the reference camera **100** can be used to pick up the same object as shown in FIG. **1** by reducing the color difference therebetween. Each of the target camera **101** and reference camera **100** picks up a static image or a video image by receiving light entering through an optical system using an image sensor like a CCD sensor or a CMOS sensor, for example. There is a difference of a light receiving characteristic etc. in image sensors. In such a case, it is expectable that the colors of the pickup image of the target camera **101** and the colors of the pickup image of the reference camera **100** coincide satisfactorily by using the above-mentioned correction LUT to the image generation by the target camera **101**.

(51) However, even if the target camera **101** uses such a correction LUT, not all the colors of the pickup image of the target camera **101** match the colors of the pickup image of the reference camera **100**. On a site where a plurality of image pickup apparatuses are used actually, color difference may remain in some objects even if the above-mentioned correction LUT is used. Generally, although large color difference value Does not remain in the entire color space, color difference that is relatively easy to confirm visually may remain in some colors.

(52) In this way, the color difference that remains also after the predetermined color matching, such as an application of the correction LUT, is called residual color difference. When there is such

residual color difference, it is difficult for a user to find the residual color difference by comparing the pickup image of the reference camera **100** with the pickup image of the target camera **101** to which the color matching has been applied by visual observation.

(53) On a site where a plurality of image pickup apparatuses are used, it is required to easily discriminate the residual color difference that may remain between the plurality of image pickup apparatuses. Accordingly, the display control apparatus **200** of this embodiment generates the above-mentioned correction LUT and further generates residual color difference information corresponding to the coincidence degree of the color characteristic of the target camera **101** after the color matching using the correction LUT. Then, the display control apparatus **200** supplies the residual color difference information to a user by displaying it so as to be easily discriminated.

(54) FIG. **8** is a flowchart showing a process for generating the residual color difference information about the target camera **101** that reads the correction LUT generated by the process of FIG. **3**. The target camera **101** outputs the image to which the color matching is applied by using the read correction LUT to the display control apparatus **200**. The user operates the UI operation unit **204** after generating the correction LUT. For example, the user selects an item of "Show color difference" from the menu screen. The controller **203** starts the residual color difference information generation process in FIG. **8** on the basis of an input operation through the UI operation unit **204**. The controller **203** outputs the color-matched image that is picked up by the target camera **101** using the correction LUT to the color coincidence determination unit **209**.

(55) In a step S**801**, the color coincidence determination unit **209** extracts the RGB values of the color patches from the image on the basis of a color-matched image of the target camera **101** received from the controller **203** and the area information about the color patches. It should be noted that examples of the RGB values of the color patches obtained here are shown in FIG. **9** FIG. **9** is a view showing an example of a combination of RGB values of the color patches in the image from the target camera **101** after the color matching. Since the color matching is performed, the RGB values of the color patches in FIG. **9** are different from the RGB values of the color patches from the target camera **101** in FIG. **5**.

(56) In a step S**802**, the color coincidence determination unit **209** converts the RGB values of the color patches into XYZ values. The color coincidence determination unit **209** outputs the generated XYZ values of the color patches to the residual-color-difference-information generation unit **208**. The conversion process by the color coincidence determination unit **209** may be the same as the conversion process by the correction LUT generation unit **205** in the step S**302** mentioned above. FIG. **10** is a view showing an example of a combination of XYZ values after the color matching that are obtained on the basis of the RGB values of the color patches in FIG. **9**. The XYZ values of the color patches obtained here are different from the XYZ values from the target camera **101** before the color matching shown in FIG. **6**. Then, the XYZ values of the color patches obtained here are used as a 3-row and 3-column arithmetic matrix H.

(57) In a step S**803**, the residual-color-difference-information generation unit **208** calculates an error correction matrix GM and stores it to the camera-characteristic-information storage unit **207**. The residual-color-difference-information generation unit **208** may calculate the error correction matrix GM on the basis of the XYZ values of the color patches received from the color coincidence determination unit **209** and the arithmetic matrix S held in the camera-characteristic-information storage unit **207**. It should be noted that the error correction matrix GM shows the residual color difference that remains after the color matching. Thereby finishes the process of FIG. **8**.

(58) The error correction matrix GM is a correction matrix for correcting the residual color difference. The error correction matrix GM can be calculated by the following formula 5 from the arithmetic matrix H, which shows the XYZ values of the color patches actually picked up by the target camera **101** after the color matching, and the arithmetic matrix S that is found by the above-mentioned formula 4.

[Error Correction Matrix *GM*]=[Arithmetic Matrix *S*][Arithmetic Matrix *H*].sup.−1   Formula 5

(59) The display control apparatus **200** can generate the residual color difference information showing the color difference that remains in the image from the target camera **101** after the color matching by the above process. The residual color difference information corresponds to the error correction matrix GM. The residual color difference information is information about the value corresponding to the color coincidence degree in the image. The residual color difference information shows the color difference that remains in the adjustment image from the target camera **101** that performs the color matching as the difference from the reference image from the reference camera **100**. Then, the residual color difference information may be recorded in the memory **223** that functions as the camera-characteristic-information storage unit **207**, for example.

(60) Next, the color-coincidence-information generation unit **210** generates the display image for displaying the residual color difference information about the image from the target camera **101** that performs the color matching on the display unit **211** on the basis of the residual color difference information generated. A part or the whole of the process by the color-coincidence-information generation unit **210** for generating the display image may be executed by the color coincidence determination unit **209**. For example, the color coincidence determination unit **209** may determine the color coincidence degree between the pixel value of the image from the reference camera **100** and the pixel value of the image from the target camera **101**.

(61) FIG. **11** is a flowchart showing a process for generating the display image for displaying the residual color difference information. The camera-characteristic-information storage unit **207** holds the residual color difference information that shows the residual color difference that remains in the adjustment image from the target camera **101** that performs the color matching as the difference from the reference image from the reference camera **100**. When the UI operation unit **204** receives an instruction based on a predetermined user operation, the controller **203** instructs generation of the display image to the color-coincidence-information generation unit **210** through the color coincidence determination unit **209** in order to display the residual color difference information on the display unit **211**. Thereby, the color-coincidence-information generation unit **210** starts the process of FIG. **11**.

(62) In a step S**1101**, the color-coincidence-information generation unit **210** obtains a vertical pixel count (the number of pixels in a vertical direction) of the image that is picked up by the target camera **101** and is processed by the color coincidence determination unit **209**, and starts a first loop process. In the first loop process, a loop variable "i" is incremented by one for every loop and the loop process is finished when the loop variable "i" reaches the vertical pixel count. In a step S**1102**, the color-coincidence-information generation unit **210** obtains a horizontal pixel count (the number of pixels in a horizontal direction) of the image that is picked up by the target camera **101** and is processed by the color coincidence determination unit **209**, and starts a second loop process. In the second loop process, a loop variable "j" is incremented for every loop by one and the loop process is finished when the loop variable "j" reaches the horizontal pixel count.

(63) In a step S**1103**, the color-coincidence-information generation unit **210** obtains the RGB values of a pixel at a position (i, j) in the image from the target camera **101** that performs the color matching. In a step S**1104**, the color-coincidence-information generation unit **210** outputs the obtained RGB values of the pixel to the residual-color-difference-information generation unit **208** through the color coincidence determination unit **209**. The residual-color-difference-information generation unit **208** compares the color of the obtained RGB values of the pixel concerned with the color of the pixel at the corresponding position in the image from the reference camera **100**, and calculates the residual color difference value of the pixel concerned in the image from the target camera **101** that performs the color matching.

(64) The color-coincidence-information generation unit **210** obtains the residual color difference information from the residual-color-difference-information generation unit **208** through the color coincidence determination unit **209**. The residual-color-difference-information generation unit **208** converts the RGB values obtained through the color coincidence determination unit **209** into the

XYZ values using an RGB-to-XYZ conversion matrix similar to that used in the step S**302**. After that, the residual-color-difference-information generation unit **208** calculates inherent corrected XYZ values X.sub.TC, Y.sub.TC, and Z.sub.TC, which are obtained when the correction LUT is correctly applied, by using the converted XYZ values and the error correction matrix GM that is calculated in the step S**803** by the following formula 6. Then, the residual-color-difference-information generation unit **208** calculates the residual color difference value D by the following formula 7 by using the inherent corrected XYZ values X.sub.TC, Y.sub.TC, and Z.sub.TC, and the values X, Y, and Z that are obtained by XYZ-converting the RGB values obtained from the target camera **101**. It should be noted that the arithmetic method of the residual color difference value D shown here is an example. The residual-color-difference-information generation unit **208** may calculate the residual color difference value D by using the RGB values obtained, for example.

$$(65) \quad \begin{bmatrix} X_{TC} \\ Y_{TC} \\ Z_{TC} \end{bmatrix} = \begin{bmatrix} \text{ErrorCorrection} \\ \text{MatrixGM} \end{bmatrix} \begin{bmatrix} X \\ Y \\ Z \end{bmatrix} \quad \text{Formula6}$$

$$D = \sqrt{(X_{TC} - X)^2 + (Y_{TC} - Y)^2 + (Z_{TC} - Z)^2} \quad \text{Formula7}$$

(66) In a step S**1105**, the color-coincidence-information generation unit **210** determines whether the residual color difference value D received from the residual-color-difference-information generation unit **208** is less than a threshold. The threshold of the residual color difference value is determined on the basis of the range of value that is allowable as the residual color difference. At this time point, the color-coincidence-information generation unit **210** grasps the position and the residual color difference value D of the pixel that is a target of the determination process. When the residual color difference value D is less than the threshold, the color-coincidence-information generation unit **210** proceeds with the process to a step S**1106**. When the residual color difference value D is not less than the threshold, the color-coincidence-information generation unit **210** proceeds with the process to a step S**1107**.

(67) In the step S**1106**, the color-coincidence-information generation unit **210** executes the process that maintains the pixel value at the position of the pixel that is a target of the determination process in the image from the target camera **101** after the color matching. That is, the color-coincidence-information generation unit **210** does not convert the pixel value at the position of the pixel that is a target of the determination process. After that, the color-coincidence-information generation unit **210** proceeds with the process to a step S**1108**.

(68) In the step S**1107**, the color-coincidence-information generation unit **210** converts the pixel value at the position of the pixel that is a target of the determination process in the image from the target camera **101** after the color matching into a pixel value for displaying the residual color difference information. The pixel value for displaying the residual color difference information represents a predetermined color that is easily distinguished from other pixels in the image from the target camera **101** after the color matching. After that, the color-coincidence-information generation unit **210** proceeds with the process to a step S**1108**.

(69) In the step S**1108**, the color-coincidence-information generation unit **210** determines finishing about the second loop process started in the step S**1102**. When the loop variable "j" does not reach the horizontal pixel count, the color-coincidence-information generation unit **210** returns the process to the step S**1102** and increments the variable "j" by one. The color-coincidence-information generation unit **210** repeats the process from the step S**1102** to the step S**1108** until the loop variable "j" reaches the horizontal pixel count of the image. The color-coincidence-information generation unit **210** repeats the second loop process from the step S**1102** to the step S**1108** by the horizontal pixel count of the image from the target camera **101** after the color matching. Thereby, the color-coincidence-information generation unit **210** executes the conversion process based on the residual color difference information about the pixels on one line aligned in

the horizontal direction in the image from the target camera **101** after the color matching. The color-coincidence-information generation unit **210** proceeds with the process to a step S**1109**, when the loop variable "j" reaches the horizontal pixel count.

(70) In the step S**1109**, the color-coincidence-information generation unit **210** determines finishing about the first loop process started in the step S**1101**. When the loop variable "i" does not reach the vertical pixel count, the color-coincidence-information generation unit **210** returns the process to the step S**1101** and increments the variable "i" by one. The color-coincidence-information generation unit **210** repeats the process from the step S**1101** to the step S**1109** until the loop variable "i" reaches the vertical pixel count of the image. The color-coincidence-information generation unit **210** repeats the first loop process from the step S**1101** to the step S**1109** by the vertical pixel count of the image from the target camera **101** after the color matching. Thereby, the color-coincidence-information generation unit **210** executes the conversion process based on the residual color difference information about the pixels on lines aligned in the vertical direction in the image from the target camera **101** after the color matching. When the loop variable "i" reaches the vertical pixel count, the color-coincidence-information generation unit **210** finishes this process.

(71) Thereby, the color-coincidence-information generation unit **210** generates the image in which pixel values of a part of pixels of the image from the target camera **101** after the color matching are converted into the pixel value that displays the residual color difference information as the display image that displays the residual color difference information. In this display image, a part where the residual color difference more than the threshold occurs in the image from the target camera **101** after the color matching is displayed by the pixel value that displays the residual color difference information. The color-coincidence-information generation unit **210** outputs the generated display image to the display unit **211**. The display unit **211** displays the display image generated by the color-coincidence-information generation unit **210**. The user can easily visually confirm the part where the residual color difference occurs in the image that is picked up by the target camera **101** after the color matching and is displayed on the display unit **211** because the part is displayed by the pixel value that displays the residual color difference information.

(72) FIG. **12** is a table showing correspondence relations between ranges of the residual color difference value defined by the residual color difference information and conversion colors used as colors of pixels included in the respective ranges. In FIG. **12**, the residual color difference value D is classified to three steps. Then, when the residual color difference value D is more than 0 and less than 1, the color-coincidence-information generation unit **210** determines that the difference value D is less than the threshold and does not convert the pixel value of the target position. When the residual color difference value D is more than 1 and less than 2, the color-coincidence-information generation unit **210** determines that the difference value D is not less than the threshold and converts the pixel value of the target position into the pixel value (R, G, B=128, 0, 0) that displays the residual color difference information. Moreover, when the residual color difference value D is two or more, the color-coincidence-information generation unit **210** determines that the difference value D is not less than the threshold and converts the pixel value of the target position into the pixel value (R, G, B=255, 0, 0) that displays the residual color difference information. A red tone of the pixel value (R, G, B=255, 0, 0) is stronger than the pixel value (R, G, B=128, 0, 0). In the display image, the color of the part where the residual color difference information showing that the residual color difference value is more than the threshold in the image from the target camera **101** that performs the color matching is converted into the different color depending on the value of the residual color difference information. The table of the correspondence relations in FIG. **12** is recorded in the memory **223**. In this case, the color-coincidence-information generation unit **210** obtains the residual color difference and the threshold compared from the memory **223** and executes the determination in the step S**1105** in accordance with the table of the correspondence relations in FIG. **12**.

(73) FIG. **13** is an explanatory view showing an example of the display image that displays the residual color difference information on the basis of the pickup image of the target camera **101** that uses the correction LUT. The display image in FIG. **13** is displayed on the display unit **211**. In the display image in FIG. **13**, its partial areas are displayed by the pixel value that displays the residual color difference information. When such a display image is displayed on the display unit **211**, the user can determine the presence and degree of occurrence of the residual color difference intuitively only by glancing at the display unit **211**. The user can immediately execute a necessary process that regenerates or adjusts the correction LUT, for example, on the basis of the determination. The user is not required to compare the pickup image from the target camera **101** that uses the correction LUT with the pickup image from the reference camera **100** that are displayed on the display unit **211** so as to discriminate the minute residual color difference that remains between them by visual observation.

(74) As mentioned above, in this embodiment, the color coincidence degree between the pickup image of the reference camera **100** and the pickup image of the target camera **101** can be determined based on the information about the residual color difference between the cameras, and the residual color difference information that is the determination result can be explicitly displayed in the image from the target camera **101**. The color difference correction system **1** of this embodiment can be used in order to discriminate easily the residual color difference between the image pickup apparatuses at the site where the reference camera **100** and the target camera **101** are used.

(75) It should be noted that the threshold of the residual color difference value and the converted pixel value may be designated by the user through the UI operation unit **204**. The user can designate so that a pixel of which the residual color difference value is less than the threshold will be displayed in monochrome. In this case, the display image of which a part where the residual color difference value is more than the threshold is colored will be displayed, which enables the user to intuitively discriminate the color coincidence degree.

(76) Moreover, in the above-mentioned embodiment, the color-coincidence-information generation unit **210** generates the display image by converting the pixel value of the color-matched image from the target camera **101** into the pixel value that displays the residual color difference. In addition, for example, the color-coincidence-information generation unit **210** may generate the image for displaying the residual color difference as the display image. The color-coincidence-information generation unit **210** may display the display image for displaying the residual color difference on the display unit **211** by superimposing on the color-matched image from the target camera **101**.

(77) Moreover, the above-mentioned embodiment describes the method for calculating the residual color difference by calculating the error correction matrix using the red, green, and blue color patches **401**, **402**, and **403**. In addition, for example, the color-coincidence-information generation unit **210** may calculate the residual color difference on the basis of the colors at the vertex of the lattice points of the correction LUT measured by the reference camera **100** and the target camera **101**. Furthermore, the color-coincidence-information generation unit **210** may calculate the residual color difference using a table that stores the residual color difference values of all the colors. The table is generated by picking up all the colors by the reference camera **100** and the target camera **101** beforehand and is held in the camera-characteristic-information storage unit **207**.

(78) Next, the color difference correction system **1** including the display control apparatus **200** according to a second embodiment of the present invention will be described. Hereinafter, differences from the first embodiment are mainly described. The display control apparatus **200** of this embodiment differs from the first embodiment in the process of the color-coincidence-information generation unit **210**. Moreover, it is different from the first embodiment in that a display image that is generated by the color-coincidence-information generation unit **210** on the basis of the color-matched image from the target camera **101** is a color distribution image that

shows distribution of the residual color difference values.

(79) FIG. **14** is a flowchart showing a process for generating residual color difference information by the display control apparatus **200** according to the second embodiment of the present invention. In the process in FIG. **14**, the color-coincidence-information generation unit **210** generates distribution information about the residual color difference values by calculating a color coincidence degree (a residual color difference value) of each pixel of a color-matched image (an image to which a correction LUT is applied) from the target camera **101** with respect to a corresponding pixel of an image from the reference camera **100**. When the UI operation unit **204** receives an instruction based on a predetermined user operation, the controller **203** instructs generation of the display image to the color-coincidence-information generation unit **210** through the color coincidence determination unit **209** in order to display the residual color difference information on the display unit **211**. Thereby, the color-coincidence-information generation unit **210** executes the process of FIG. **14**.

(80) In a step S**1501**, the color-coincidence-information generation unit **210** obtains the vertical pixel count of the image that is picked up by the target camera **101** and is processed by the color coincidence determination unit **209**, and starts a first loop process. In the first loop process, a loop variable "i" is incremented by one for every loop and the loop process is finished when the loop variable "i" reaches the vertical pixel count. In a step S**1502**, the color-coincidence-information generation unit **210** obtains a horizontal pixel count of the image that is picked up by the target camera **101** and is processed by the color coincidence determination unit **209**, and starts a second loop process. In the second loop process, a loop variable "j" is incremented for every loop by one and the loop process is finished when the loop variable "j" reaches the horizontal pixel count.

(81) In a step S**1503**, the color-coincidence-information generation unit **210** obtains the RGB values of a pixel at a position (i, j) in the image from the target camera **101** that performs the color matching. In a step S**1504**, the color-coincidence-information generation unit **210** outputs the obtained RGB values of the pixel to the residual-color-difference-information generation unit **208** through the color coincidence determination unit **209**. The residual-color-difference-information generation unit **208** compares the color of the obtained RGB values of the pixel concerned with the color of the pixel at the corresponding position in the image from the reference camera **100**, and calculates the residual color difference value of the pixel concerned in the image from the target camera **101** that performs the color matching. The color-coincidence-information generation unit **210** obtains the residual color difference information from the residual-color-difference-information generation unit **208** through the color coincidence determination unit **209**.

(82) In a step S**1505**, the color-coincidence-information generation unit **210** receives the residual color difference and the pixel position in the image at which the residual color difference is calculated from the color coincidence determination unit **209**, and generates the display image displaying the residual color difference. In a step S**1506**, the color-coincidence-information generation unit **210** determines finishing about the second loop process started in the step S**1502**. When the loop variable "j" does not reach the horizontal pixel count, the color-coincidence-information generation unit **210** returns the process to the step S**1502** and increments the variable "j" by one. The color-coincidence-information generation unit **210** repeats the process from the step S**1502** to the step S**1506** until the loop variable "j" reaches the horizontal pixel count of the image. The color-coincidence-information generation unit **210** repeats the second loop process from the step S**1502** to the step S**1506** by the horizontal pixel count of the image from the target camera **101** after the color matching. Thereby, the color-coincidence-information generation unit **210** plots the residual color difference values on the color distribution image showing distribution of the residual color difference values about the pixels on one line aligned in the horizontal direction in the image from the target camera **101** after the color matching. The color-coincidence-information generation unit **210** proceeds with the process to a step S**1507**, when the loop variable "j" reaches the horizontal pixel count.

(83) In the step S**1507**, the color-coincidence-information generation unit **210** determines finishing about the first loop process started in the step S**1501**. When the loop variable "i" does not reach the vertical pixel count, the color-coincidence-information generation unit **210** returns the process to the step S**1501** and increments the variable "i" by one. The color-coincidence-information generation unit **210** repeats the process from the step S**1501** to the step S**1507** until the loop variable "i" reaches the vertical pixel count of the image. The color-coincidence-information generation unit **210** repeats the first loop process from the step S**1501** to the step S**1507** by the vertical pixel count of the image from the target camera **101** after the color matching. Thereby, the color-coincidence-information generation unit **210** executes the conversion process based on the residual color difference information about the pixels on lines aligned in the vertical direction in the image from the target camera **101** after the color matching. When the loop variable "i" reaches the vertical pixel count, the color-coincidence-information generation unit **210** finishes this process.

(84) Thereby, the color-coincidence-information generation unit **210** can generate the color distribution image showing distribution of the residual color difference values as the display image that displays the residual color difference information. The color-coincidence-information generation unit **210** outputs the generated color distribution image showing the distribution of the residual color difference values to the display unit **211**. The display unit **211** displays the color distribution image showing the distribution of the residual color difference values.

(85) FIG. **15** is a view showing an example of a combination of a pickup image of the target camera **101** that uses the correction LUT and a color distribution image that is generated independently therefrom to show the distribution of the residual color difference values. The color-coincidence-information generation unit **210** sequentially obtains the residual color difference information about each pixel of the pickup image, which is shown in an upper part in FIG. **15**, of the target camera **101** that uses the correction LUT. Then, the color-coincidence-information generation unit **210** plots the residual color difference value of the pixel at the obtained position on the color distribution image showing the distribution of the residual color difference values shown in a lower part in FIG. **15**. A background image of the color distribution image showing the distribution of the residual color difference values may be stored in the memory **223** beforehand. Then, the horizontal axis of the color distribution image showing the distribution of the residual color difference values shows a horizontal position in the image. A vertical axis shows the residual color difference value. In this case, the color-coincidence-information generation unit **210** plots a point showing the residual color difference value at the position on the vertical axis corresponding to the residual color difference value of the pixel at the obtained position. The color-coincidence-information generation unit **210** may repeat plotting of points at positions corresponding to the residual color difference values about the pixels on one line in the horizontal direction in the pickup image of the target camera **101** that uses the correction LUT.

(86) FIG. **16** is a view showing an example of the color distribution image showing the distribution of the residual color difference values of a case of applying this embodiment. In the color distribution image showing the distribution of the residual color difference values in FIG. **16**, the large residual color difference occurs in the left part in the image mainly. Moreover, the maximum residual color difference value reaches 2.0. The user can intuitively grasp a position and a degree of the residual color difference in the pickup image of the target camera **101** that uses the correction LUT by only visually confirming the color distribution image in FIG. **16** showing the distribution of the residual color difference values. Moreover, the color distribution image showing the distribution of the residual color difference values shown in FIG. **16** displays a color phase designated by the user. In addition, for example, the color distribution image showing the distribution of the residual color difference values may be displayed by superimposing a plurality of color phases by using different colors.

(87) As mentioned above, in this embodiment, the color coincidence degree between the image

from the reference camera **100** and the image from the target camera **101** is determined, and the color distribution image showing the distribution of the residual color difference values between these images is generated and displayed. The user can intuitively discriminate presence of the residual color difference and its position in the image by visually confirming the color distribution image showing the distribution of the residual color difference values.

(88) The color-coincidence-information generation unit **210** may generate a display image other than the color distribution image showing the distribution of the residual color difference values mentioned above as a display image that displays the residual color difference. For example, the color-coincidence-information generation unit **210** may generate the display image that totals up a ratio of pixels of which the residual color difference values are more than a certain value for each line in the horizontal direction of the image as a display image for displaying residual color difference. Moreover, the color-coincidence-information generation unit **210** may display the distribution information of the residual color difference values of positions of pixels for each line in the vertical direction rather than in the horizontal direction. Moreover, the color-coincidence-information generation unit **210** may not necessarily generate the color distribution image showing the distribution of the residual color difference values about all the pixels of the color-matched image of the target camera **101**. The color-coincidence-information generation unit **210** may generate the color distribution image showing the distribution of the residual color difference values about the specific color that is designated by the user, for example. In this case, the user can check the distribution of the residual color difference values for each color designated while switching the color to designate. Moreover, the color-coincidence-information generation unit **210** may display the residual color difference values in a vector scope image as a display image that displays the residual color difference values.

(89) FIG. **17** is a view showing an example of the vector scope image that displays the residual color difference information about the image from the target camera **101** that performs the color matching. The vector scope image shows a color phase and saturation of each pixel in an image basically. The color-coincidence-information generation unit **210** changes at least one of a color, a shape, and a size of a point plotted on such a vector scope image according to the color coincidence degree that can be determined on the basis of the residual color difference information. As a result, the center area in the vector scope image is colored in a color corresponding to the residual color difference as shown in FIG. **17**.

(90) Moreover, the color-coincidence-information generation unit **210** may generate a screen or a message to prompt a user to perform the color matching again in addition to or in place of the generation of the above-mentioned various display images that display the residual color difference. FIG. **18** is a flowchart showing a process for outputting a message when the residual color difference value is not less than a threshold. The color-coincidence-information generation unit **210** may execute the process of FIG. **18** together with the process of FIG. **14** or after the process of FIG. **14**.

(91) In a step S**1901**, the color-coincidence-information generation unit **210** obtains the maximum residual color difference value from all the pixels in the color-matched image of the target camera **101**. In a step S**1902**, the color-coincidence-information generation unit **210** determines whether the obtained maximum residual color difference value is equal to or more than its threshold. The threshold may be a residual color difference value that is expected to be reduced by regenerating the correction LUT, for example. In the example in FIG. **16**, the threshold of the residual color difference value may be 2.0 or more.

(92) When the obtained maximum residual color difference value is not less than the threshold, the color-coincidence-information generation unit **210** proceeds with the process to a step S**1903**. When the obtained maximum residual color difference value is less than the threshold, the color-coincidence-information generation unit **210** finishes this process. In the step S**1903**, the color-coincidence-information generation unit **210** generates the screen or message to prompt the user to

perform the color matching again. The color-coincidence-information generation unit **210** outputs the generated screen or message to the display unit **211**. The display unit **211** displays the screen or message. After that, the color-coincidence-information generation unit **210** finishes this process. Thereby, the color-coincidence-information generation unit **210** can generate the screen or message to prompt the user to perform the color matching again when the maximum residual color difference value that can be determined on the basis of the residual color difference information is not less than the threshold.

(93) Although the present invention has been described in detail on the basis of the suitable embodiments, the present invention is not limited to these specific embodiments, and various configurations that do not deviate from the scope of the present invention are also included in the present invention.

(94) For example, when generating the vector scope image shown in FIG. **17**, the color-coincidence-information generation unit **210** may change the point plotted on the vector scope image in accordance with the RGB values of the image from the target camera **101** or the arithmetic value based on the RGB values. In addition, for example, when generating the vector scope image, the color-coincidence-information generation unit **210** may calculate the residual color difference from the image from the reference camera **100** simultaneously and may plot a different point in accordance with the residual color difference from the image from the reference camera **100**. When such a point is plotted, the user can easily intuitively discriminate an area where the colors are matched in the vector scope image.

Other Embodiments

(95) Embodiment(s) of the present invention can also be realized by a computer of a system or apparatus that reads out and executes computer executable instructions (e.g., one or more programs) recorded on a storage medium (which may also be referred to more fully as a 'non-transitory computer-readable storage medium') to perform the functions of one or more of the above-described embodiment(s) and/or that includes one or more circuits (e.g., application specific integrated circuit (ASIC)) for performing the functions of one or more of the above-described embodiment(s), and by a method performed by the computer of the system or apparatus by, for example, reading out and executing the computer executable instructions from the storage medium to perform the functions of one or more of the above-described embodiment(s) and/or controlling the one or more circuits to perform the functions of one or more of the above-described embodiment(s). The computer may comprise one or more processors (e.g., central processing unit (CPU), micro processing unit (MPU)) and may include a network of separate computers or separate processors to read out and execute the computer executable instructions. The computer executable instructions may be provided to the computer, for example, from a network or the storage medium. The storage medium may include, for example, one or more of a hard disk, a random-access memory (RAM), a read only memory (ROM), a storage of distributed computing systems, an optical disk (such as a compact disc (CD), digital versatile disc (DVD), or Blu-ray Disc (BD)™), a flash memory device, a memory card, and the like.

(96) While the present invention has been described with reference to exemplary embodiments, it is to be understood that the invention is not limited to the disclosed exemplary embodiments. The scope of the following claims is to be accorded the broadest interpretation so as to encompass all such modifications and equivalent structures and functions.

(97) This application claims the benefit of Japanese Patent Application No. 2022-053840, filed Mar. 29, 2022, which is hereby incorporated by reference herein in its entirety.

Claims

1. A display control apparatus comprising: a memory device that stores a set of instructions; and at least one processor that executes the set of instructions to: perform a predetermined color matching

between a reference image picked up by a reference image pickup apparatus and a first adjustment image picked up by an adjustment target image pickup apparatus; obtain a second adjustment image from the adjustment target image pickup apparatus; generate residual color difference information showing color difference from the reference image picked up by the reference image pickup apparatus that remains in the second adjustment image; and generate display information from the generated residual color difference information, wherein the second adjustment image is an image picked up by the adjustment target image pickup apparatus and corrected using a correction information based on said predetermined color matching in the adjustment target image pickup apparatus after importing the correction information to the adjustment target image pickup apparatus.

2. The display control apparatus according to claim 1, wherein the predetermined color matching is performed by comparing images obtained by picking up a predetermined object by the adjustment target image pickup apparatus and the reference image pickup apparatus.

3. The display control apparatus according to claim 2, wherein the predetermined object comprises a color chart.

4. The display control apparatus according to claim 1, further comprising a holding unit configured to hold the reference image used for the predetermined color matching with the adjustment target image pickup apparatus, wherein the at least one processor executes instructions in the memory device to generate the residual color difference information corresponding to a color coincidence degree between the images by comparing the second adjustment image with the reference image held in the holding unit.

5. The display control apparatus according to claim 1, wherein the at least one processor executes instructions in the memory device to generate an image in which a color of an area where the residual color difference information is generated in the second adjustment image is converted into a color corresponding to a value of the residual color difference information as the display information.

6. The display control apparatus according to claim 1, wherein the at least one processor executes instructions in the memory device to generate a color distribution image corresponding to the second adjustment image as the display information; and display color distribution corresponding to a color coincidence degree that can be determined based on the residual color difference information on the color distribution image.

7. The display control apparatus according to claim 6, wherein the at least one processor executes instructions in the memory device to generate an image that displays at least one color phase among a plurality of color phases included in the second adjustment image as the color distribution image.

8. The display control apparatus according to claim 1, wherein the at least one processor executes instructions in the memory device to: generate a vector scope image about the second adjustment image as the display information; and plot a point of which at least one of a color, a shape, and a size corresponds to a color coincidence degree that can be determined based on the residual color difference information on the vector scope image.

9. The display control apparatus according to claim 1, wherein the at least one processor executes instructions in the memory device to generate and display at least one of a screen and a message that prompt a user to perform the predetermined color matching again in place of a display image that displays the residual color difference information in a case where a maximum residual color difference value that can be determined based on the residual color difference information is not less than a threshold.

10. The display control apparatus according to claim 1, wherein the at least one processor executes instructions in the memory device to generate and display at least one of a screen and a message that prompt a user to perform the predetermined color matching in addition to a display image that displays the residual color difference information in a case where a maximum residual color

difference value that can be determined based on the residual color difference information is not less than a threshold.

11. A control method for a display control apparatus, the control method comprising: performing a predetermined color matching between a reference image picked up by a reference image pickup apparatus and a first adjustment image picked up by an adjustment target image pickup apparatus; obtaining a second adjustment image from the adjustment target image pickup apparatus; generating residual color difference information showing color difference from the reference image picked up by the reference image pickup apparatus that remains in the second adjustment image; and generating display information from the generated residual color difference information, wherein the second adjustment image is an image picked up by the adjustment target image pickup apparatus and corrected using a correction information based on said predetermined color matching in the adjustment target image pickup apparatus after importing the correction information to the adjustment target image pickup apparatus.

12. A non-transitory computer-readable storage medium storing a control program causing a computer to execute a control method for a display control apparatus, the control method comprising: performing a predetermined color matching between a reference image picked up by a reference image pickup apparatus and a first adjustment image picked up by an adjustment target image pickup apparatus; obtaining a second adjustment image from the adjustment target image pickup apparatus; generating residual color difference information showing color difference from the reference image picked up by the reference image pickup apparatus that remains in the second adjustment image; and generating display information from the generated residual color difference information, wherein the second adjustment image is an image picked up by the adjustment target image pickup apparatus and corrected using a correction information based on said predetermined color matching in the adjustment target image pickup apparatus after importing the correction information to the adjustment target image pickup apparatus.