DESCRIPTION

# IMAGE COLOR CORRECTION METHOD AND APPARATUS, COLOR CORRECTION ROBOT, AND STORAGE MEDIUM

The present disclosure claims the priority to Chinese Patent Application No. 202411902317.4, filed to the China National Intellectual Property Administration on December 23, 2024 and entitled "IMAGE COLOR CORRECTION METHOD AND APPARATUS, COLOR CORRECTION ROBOT, AND STORAGE MEDIUM", which is incorporated herein by reference in its entirety.

## TECHNICAL FIELD

The present disclosure relates to the technical field of image processing, and in particular to an image color correction method and apparatus, a color correction robot, and a storage medium.

## BACKGROUND ART

With the advancement of artificial intelligence technology, a role of a medical image in clinical diagnosis is increasingly prominent. However, quality of the medical image directly affects diagnostic accuracy of a doctor, particularly in a field where color information is critical to diagnosis, such as dermatology, stomatology, ophthalmology, and the like. For example, a high-quality tongue image serves as a data foundation for all subsequent intelligent analysis and assisted diagnosis of tongue diagnosis, and accuracy of a color of the tongue image directly relates to reliability of a diagnostic result.

When a tongue image is captured, during an imaging process of a camera, factors such as an illumination condition, a focal length change, and a shooting environment affect image quality. To compensate for the above unfavorable factors, the camera usually automatically adjusts the image quality through various built-in image processing algorithms. Existing image processing algorithms are mainly intended to make a captured image easier for a person to view and look more aesthetically pleasing, whereas in actual medical applications, the image processing algorithms may cause deviation and distortion of the color of the tongue image. Since the image processing algorithms are built into the camera and adopt an automatic adjustment mechanism, an imaging color is inaccurate, and especially under complex illumination and background conditions, this deviation may be manifested in color saturation, contrast, and even white balance shift of the tongue image.

The above color deviation not only affects the visual authenticity of the tongue image, but also seriously reduces a diagnostic value of the tongue image. Particularly in the field of intelligent analysis and assisted diagnosis of traditional Chinese medicine tongue diagnosis where accurate color information is required, the accuracy of the color of the tongue image is crucial, and a slight color difference may increase a difficulty in identifying a lesion site, or even cause a misdiagnosis or a missed diagnosis. It is urgent to overcome a challenge for performing accurate color correction on the tongue image.

## SUMMARY

Technical Problem to be Solved

To solve the above technical problem, the present disclosure provides an image color correction method and apparatus, a color correction robot, and a storage medium, which improve color accuracy of an image and ensure reliability and authenticity of image information, thereby providing reliable data support for subsequent intelligent analysis and assisted diagnosis.

Means for Solving the Problem

In a first aspect, the present disclosure provides an image color correction method, where the method includes acquiring an image to be processed, where the image to be processed includes a color checker region, and the color checker region includes a plurality of color blocks; extracting a color value of each pixel in the plurality of color blocks to obtain a color value list; setting a weight coefficient for each color value in the color value list; fitting a polynomial regression model by using the color value list with the weight coefficients to obtain a fitted polynomial regression model; generating a color conversion matrix by using the fitted polynomial regression model, where the color conversion matrix is used to represent a mapping relationship between a color value in the image to be processed and a standard color value in a color checker; and correcting the color value of each pixel in the image to be processed by using the color conversion matrix to obtain a corrected image.

In a second aspect, the present disclosure provides an image color correction apparatus, where the apparatus includes an image acquisition module configured to acquire an image to be processed, where the image to be processed includes a color checker region, and the color checker region includes a plurality of color blocks; a color value extraction module configured to extract a color value of each pixel in the plurality of color blocks to obtain a color value list; a weight setting module configured to set a weight coefficient for each color value in the color value list; a fitting module configured to fit a polynomial regression model by using the color value list with the weight coefficients to obtain a fitted polynomial regression model; a matrix generation module configured to generate a color conversion matrix by using the fitted polynomial regression model, where the color conversion matrix is used to represent a mapping relationship between a color value in the image to be processed and a standard color value in a color checker; and a color correction module configured to correct the color value of each pixel in the image to be processed by using the color conversion matrix to obtain a corrected image.

In a third aspect, the present disclosure provides a color correction robot, where the color correction robot includes one or more processors; a storage device configured to store one or more programs; and a camera configured to capture an image to be processed and transmit the image to the processor, where when the one or more programs are executed by the one or more processors, the image color correction method according to the above first aspect is achieved by the one or more processors.

In a fourth aspect, the present disclosure provides a storage medium, which may be a computer-readable storage medium, where a computer program is stored on the storage medium, and when the program is executed by a processor, the image color correction method according to the above first aspect is achieved.

In a fifth aspect, an embodiment of the present disclosure provides a computer program product, including a computer program or instructions, where the image color correction method according to any one of the above first aspect is implemented when the computer program or the instructions are executed by a processor.

Beneficial Effects

Compared with the prior art, technical solutions provided by the embodiment of the present disclosure have the following advantages:

The embodiment of the present disclosure provides an image color correction method and apparatus, a color correction robot, and a storage medium, where the method includes acquiring an image to be processed, where the image to be processed includes a color checker region, and the color checker region includes a plurality of color blocks; extracting a color value of each pixel in the

plurality of color blocks to obtain a color value list; setting a weight coefficient for each color value in the color value list; fitting a polynomial regression model by using the color value list with the weight coefficients to obtain a fitted polynomial regression model; generating a color conversion matrix by using the fitted polynomial regression model, where the color conversion matrix is used to represent a mapping relationship between a color value in the image to be processed and a standard color value in a color checker; and correcting the color value of each pixel in the image to be processed by using the color conversion matrix to obtain a corrected image. This embodiment improves the color accuracy of an image, and ensures the reliability and authenticity of image information, thereby providing reliable data support for subsequent intelligent analysis and assisted diagnosis.

## BRIEF DESCRIPTION OF THE DRAWINGS

The drawings herein are incorporated into the description and constitute a part of the description, illustrate embodiments consistent with the present disclosure, and together with the description serve to explain a principle of the present disclosure.

FIG. 1 is a flowchart of an image color correction method provided by an embodiment of the present disclosure.

FIG. 2 is a construction flowchart of a color correction robot provided by an embodiment of the present disclosure.

FIG. 3 is a schematic diagram of an example of an original image provided by an embodiment of the present disclosure.

FIG. 4 is a schematic diagram of a comparison before and after image preprocessing provided by an embodiment of the present disclosure.

FIG. 5 is a schematic diagram of an annotated color checker region in an original image provided by an embodiment of the present disclosure.

FIG. 6 is a schematic diagram of annotating color blocks in a color checker region image provided by an embodiment of the present disclosure.

FIG. 7 is a flowchart of embedding a color correction robot program into a standard robot provided by an embodiment of the present disclosure.

FIG. 8 is a schematic structural diagram of a color checker detection model provided by an embodiment of the present disclosure.

FIG. 9 is a schematic structural diagram of a color block segmentation model provided by an embodiment of the present disclosure.

FIG. 10 is a complete flowchart from color checker detection to color block segmentation provided by an embodiment of the present disclosure.

FIG. 11 is a flowchart of generating a color value list provided by an embodiment of the present disclosure.

FIG. 12 is a flowchart of adjusting a weight coefficient provided by an embodiment of the present disclosure.

FIG. 13 is a flowchart of fitting a polynomial regression model provided by an embodiment of the present disclosure.

FIG. 14 is a flowchart of generating a color conversion matrix provided by an embodiment of the present disclosure.

FIG. 15 is a flowchart of color value conversion provided by an embodiment of the present disclosure.

FIG. 16 is a schematic structural diagram of an image color correction apparatus provided by an embodiment of the present disclosure.

FIG. 17 is a schematic structural diagram of an electronic device provided by an embodiment of the present disclosure.

**DETAILED DESCRIPTION OF THE EMBODIMENTS**

To provide better understanding of the above objectives, features, and advantages of the present disclosure, a solution of the present disclosure is further described below. It should be noted that, if there is no conflict, embodiments of the present disclosure and features in the embodiments may be combined with each other.

With the advancement of artificial intelligence technology, a role of a medical image in clinical diagnosis is increasingly prominent. However, quality of the medical image directly affects diagnostic accuracy of a doctor, particularly in a field where color information is critical to diagnosis, such as dermatology, stomatology, ophthalmology, and the like. For example: a tongue image, as an important basis for traditional Chinese medicine tongue diagnosis, has color accuracy that directly relates to reliability of a diagnostic result.

In an actual process of collecting tongue image data, factors such as an illumination condition, an imaging device setting, and a shooting environment cause a color deviation in the tongue image. This color deviation seriously reduces a diagnostic value of the tongue image. Particularly in the field of intelligent analysis and assisted diagnosis of traditional Chinese medicine tongue diagnosis where accurate color information is required, it is urgent to overcome a challenge for performing accurate color correction on the tongue image. To address these problems, in a related technology, methods for tongue image color correction mainly include the following categories: a color correction method based on polynomial regression and a color checker, a color correction method based on machine learning and a color checker, and a color correction method based on deep learning and a color checker.

In the above three color-correction methods, a step of extracting a color value mostly relies on an image grayscale conversion and an edge detection algorithm (such as Canny edge detection) to find a boundary of a color block and determine a contour position of each color block of a color checker. By calculating an average color value of a central area of each color block, the influence of an edge effect in an imaging process on a correction result is effectively reduced.

Although color correction methods based on polynomial regression, machine learning, and deep learning may improve the color accuracy of an image to a certain extent, in an actual application of traditional Chinese medicine tongue diagnosis, which highly relies on a true color restoration degree of a tongue image, the above color correction methods still have many deficiencies. Traditional Chinese medicine tongue diagnosis is extremely sensitive to an accurate presentation of color features such as a tongue body color and a coating color, and any color deviation may affect a diagnosis by a doctor. Therefore, the above color correction methods still fail to meet requirements of intelligent analysis and assisted diagnosis of traditional Chinese medicine tongue diagnosis in practical applications, and the above color correction methods mainly have the following deficiencies:

(1) Deficiencies of the color correction method based on polynomial regression and a color checker

A polynomial regression model corrects an image color by fitting a relationship between a standard color value and a color value in a captured image. However, this method has deficiencies in a selection of a polynomial order. When an order is high, the model may overfit, that is, be too sensitive to noise in training data, leading to poor performance on a new image; and while when an order is too low, complex color changes may not be captured, resulting in an unsatisfactory correction effect. Furthermore, the polynomial regression model usually models each color channel independently and

ignores a correlation between color channels, which may cause a corrected image to appear unnatural.

(2) Deficiencies of the color correction method based on machine learning and a color checker

A machine learning method such as a support vector machine (SVM) is capable of handling complex nonlinear problems, but may face challenges when dealing with high-dimensional data and complex color mapping. In particular, the performance of a model is highly dependent on quality and diversity of training data, which means that when there is a lack of sufficient annotated data or the diversity of data is insufficient, a correction effect of the model is affected. In addition, a training and tuning process of an SVM model is complex and usually requires a large amount of computing resources and time.

(3) Deficiencies of the color correction method based on deep learning and a color checker

A deep learning model is capable of learning a complex mapping relationship between a color value of a captured image and a standard color value, and has certain advantages in color correction. However, the training of the deep learning model usually requires a large amount of high-quality annotated data, a training process is time-consuming, and a demand for computing resources is high. Furthermore, the deep learning model faces an overfitting problem and may lack a good generalization ability when processing tongue images with diverse backgrounds and illuminations.

The above three color-correction methods all face two common significant problems: (1) a limited amount of training data; and (2) an assumption that a color checker and a subject are in the same plane.

(1) Data amount limitation

The above three color-correction methods all use a color value of a color checker for correction, and usually only obtain an average color value of each color block. Taking a commonly used 24-color standard color checker as an example, data ultimately used for correction is only 24 color values. This limitation of a data amount causes a model to face an insufficient data problem during training, and cannot fully learn complex color changes in an image. Moreover, a color change in an actual image is usually gradual and multi-dimensional, and it is difficult to capture these subtle changes with data of only a few color blocks, thereby affecting a detail expression and an overall effect of the correction.

(2) Assumption that the color checker and the subject are in the same plane

Existing methods generally assume that the color checker and the subject are in the same plane, and that an illumination intensity and an angle are consistent. However, in an actual shooting process, illumination and viewing angle conditions usually vary, which causes a deviation in a color value of a color block. Since the above three color-correction methods usually use a mean value of a color checker region as a representative color of a color block, and fail to consider the influence caused by illumination changes and viewing angle differences, accuracy and applicability of color correction are limited.

To solve the above technical problems, an embodiment of the present disclosure provides an image color correction method. The image color correction method provided by the embodiment of the present disclosure is described in detail below in conjunction with the drawings and embodiments.

FIG. 1 is a flowchart of an image color correction method in an embodiment of the present disclosure. This embodiment is applicable to a situation where a color in a captured image is corrected. The method may be executed by an image color correction apparatus, which may be implemented in a form of software and/or hardware, and the image color correction apparatus may be arranged in a color correction robot. The color correction robot may include a standard robot equipped with a medical health monitoring or medical auxiliary treatment capability.

The image color correction method provided by the embodiment of the present disclosure is mainly implemented by a color correction robot program built in the color correction robot. A process of constructing the color correction robot is first introduced.

The color correction robot in this embodiment is mainly used to overcome deficiencies of a conventional color correction method, such as an insufficient amount of training data and an assumption that a color checker and a subject are in the same plane. By introducing a detection and segmentation model, an intelligent, accurate, and integrated image color correction method is designed, which is capable of maintaining high-precision color restoration in complex imaging environments. Main components of the color correction robot include the following modules: an image acquisition module, a standard color checker, a detection and segmentation module, and a color correction module.

The color correction robot is equipped with a high-resolution camera and a camera control unit, configured to capture a high-precision image. The color correction robot is capable of adjusting a shooting angle and an illumination condition in different environments, thereby ensuring accurate capture of color information in a scene, and storing the captured image in an internal storage unit for subsequent processing.

A standard color checker is used in the color correction robot as a reference for color correction. The color checker includes a plurality of color blocks with known standard color values, and these color blocks provide reliable reference points for image color correction, thereby ensuring the accuracy of color adjustment.

The detection and segmentation module mainly includes a color checker detection model and a color block segmentation model. The color checker detection model is based on a deep learning algorithm, and is capable of automatically recognizing and locating a position of a color checker in an image. The model ensures that the position of the color checker in the image is accurately detected, laying a foundation for subsequent color block segmentation and color value data extraction. The color block segmentation model is also based on a deep learning algorithm, and is responsible for performing pixel-level accurate segmentation on color blocks in the color checker. The model analyzes color information in the color blocks pixel by pixel, extracts all pixel data of each color block, and significantly improves an amount and accuracy of data used for color correction.

The color correction module calculates and generates a color conversion matrix based on color block pixel data extracted by the color checker detection model and the color block segmentation model. The color conversion matrix is applied to each pixel of an original image to correct the color value thereof, ultimately achieving high-precision image color correction. In this way, the color correction robot is capable of effectively coping with complex illumination and environmental changes, thereby ensuring the accuracy of image color restoration.

A construction process of the color correction robot provided by this embodiment mainly includes five steps: data preprocessing, model training, constructing a detection and segmentation module, constructing a color correction module, and module embedding. A specific flow of constructing the color correction robot is shown in FIG. 2 below, and the specific content is as follows:

a. Data preprocessing

In a data preprocessing stage, three major steps of data acquisition, data processing, and data annotation are performed to provide data support for subsequent model training and module construction. The specific steps are as follows:

Step (1): Data acquisition. A large number of images containing a color checker are captured as original images through a high-definition camera built in a standard robot, ensuring that the original

images cover various illumination conditions, shooting angles, and different scenes. To ensure data quality, the captured original images are screened, blurred or unevenly illuminated images are removed, and original images with clearly visible color checker regions are retained. Through this step, high-quality original images are obtained.

Accurate and comprehensive original images lay a solid foundation for subsequent model training and color correction. The capture of original images mainly revolves around capturing images containing a color checker, aiming to ensure that the color correction robot is capable of working stably under various illumination conditions, angles, and scenes. Therefore, a large number of original images containing a standard color checker are captured by a built-in high-resolution camera. Furthermore, it is necessary to ensure that the color checker is photographed under different environmental conditions, including various illumination conditions and different shooting angles, to ensure a breadth and representativeness of the captured data. A specific original image capture strategy table is shown in Table 1 below.

Table 1 Original image capture strategy

| Item | Content | Details | Description |
|---|---|---|---|
| Capture device | High-definition camera | Built-in high-definition camera | --- |
| Environment | Illumination condition | Natural light (low light) 100~500 lux, 2,000~3,000 K | Early morning (dusk) |
| | | Natural light (strong light) 50,000~100,000 lux, 3,000~5,500 K | Noon |
| | | Incandescent lamp 300~800 lux, 2,700 K | Indoor (night) |
| | | Fluorescent lamp 500~2,000 lux, 4,000 K | Indoor (office) |
| | | LED lamp 300~3,000 lux, 3,000~6,500 K | Indoor (various) |
| | | Mixed light source 2,000~5,000 lux | Indoor (window side, daytime) |
| | | Low light 10~300 lux | Indoor (dusk) |
| Angle | Shooting angle | Front view | --- |
| | | Left view at a 15° tilt angle | |
| | | Right view at a 15° tilt angle | |
| | | Top view at a 10° tilt angle | |
| | | Bottom view at a 10° tilt angle | |
| Distance | Shooting distance | 0.5 m | --- |
| | | 1 m | |
| | | 1.5 m | |

Using the above original image capture strategy, a total of 12,000 original images with a resolution of 1,080×1,000 pixels are captured. To ensure image quality, during an image screening process, a total of 492 images that are blurred, unevenly illuminated, or otherwise likely to affect color checker recognition are removed, and finally 11,508 original images with clearly visible color checker regions are retained. An example of a captured original image is shown in FIG. 3 below. As shown in FIG. 3, taking an application of the image color correction method to a field of tongue diagnosis as an example, an original image 30 includes a tongue region 31 and a color checker region 32.

Step (2): Data preprocessing. The original images captured in step (1) are processed. A main operation is to crop a color checker region in the original image to generate a color checker region

image for use in training a color block segmentation model. During a cropping process, it is necessary to ensure the integrity of color blocks in the color checker region image, and avoid an outer frame of the color checker or other objects from affecting an image quality. Through this step, a color checker region image suitable for training the color block segmentation model is obtained.

The data preprocessing stage is an important step to ensure data quality and applicability, providing basic support for subsequent model training and color correction. Data preprocessing mainly involves appropriately cropping the original images captured in step (1), and saving the images as color checker region images required for training the color block segmentation model, serving as a data annotation source for the color block segmentation model in subsequent step (3). During a preprocessing process, it should be noted that while maintaining the integrity of the color blocks in the color checker region image, some outer frames of the color checker may be appropriately removed to prevent objects other than a standard color checker from being included in a cropped image. An example diagram of data preprocessing is shown in FIG. 4. Before data preprocessing, as shown in a left figure of FIG. 4, the original image 30 includes the tongue region 31 and the color checker region 32. After data preprocessing, as shown in a right figure of FIG. 4, a color checker region image 40 includes only the color checker region, and does not include the tongue region.

Step (3): Data annotation. This step includes two parts: color checker detection data annotation and color block segmentation data annotation. The color checker detection data annotation uses the original images including a tongue region and a color checker region from the data acquisition in step (1), and the color block segmentation data annotation uses the color checker region images cropped in step (2). An open-source annotation tool, Labelme, is used as an annotation tool for color checker detection and color block segmentation. During an annotation process, it is necessary to specify a boundary of a color checker and a specific position of each color block, providing an accurate reference for subsequent color value extraction and model training. Through this step, a color checker detection dataset and a color block segmentation dataset are obtained.

In step (3), the color checker detection data annotation needs to use the original images captured in step (1) for annotation to specify a boundary and a position of a color checker. The annotated dataset is used to train a color checker detection model, ensuring that the model is capable of accurately recognizing a position of a color checker in an image. The color block segmentation data annotation needs to use the color checker region images preprocessed in step (2) to annotate color block segmentation data. The Labelme annotation tool is also used to accurately annotate each color block in the color checker for recording a specific position and boundary of each color block. The annotated dataset is used to train a color block segmentation model to ensure that the model may accurately segment color block regions in the color checker. An annotation example of the color checker detection data is shown in FIG. 5, where a color checker region in an original image is annotated, and an annotation example of the color block segmentation data is shown in FIG. 6, where a specific position and boundary of each color block are annotated.

It should be noted that FIGS. 3-6 are grayscale images, and are only used to illustrate key steps of an image processing process during image color correction. In an actual use process, images used for model training and image color correction are all color images containing a color checker, such as images in a Red, Green and Blue (RGB) format.

After completing the data annotation for color checker detection and color block segmentation, the annotated datasets are reasonably divided to ensure the scientific nature and validity of model training, validation, and testing. Specifically, the original images after the color checker detection data

annotation are randomly divided into a training set, a validation set, and a test set in a ratio of 8:1:1 to obtain a color checker detection dataset; and the color checker region images after the color block segmentation data annotation are randomly divided into a training set, a validation set, and a test set in a ratio of 70:15:15 to obtain a color block segmentation dataset. Detailed content of the color checker detection dataset and the color block segmentation dataset is shown in Table 2 below.

Table 2 Contents of color checker detection dataset and color block segmentation dataset

| Dataset name | Total data amount [images; GB] | Type | Data amount (images) | Categories | Description |
|---|---|---|---|---|---|
| Color checker detection | 11,508; 4.54 | Training set | 9,206 | 1 | Color checker detection annotation for model training |
| | | Validation set | 1,151 | | Color checker detection annotation for model validation |
| | | Test set | 1,151 | | Color checker detection annotation for model testing |
| Color block segmentation | 11,508; 2.37 | Training set | 8,056 | 24 | Color block segmentation annotation for model training |
| | | Validation set | 1,726 | | Color block segmentation annotation for model validation |
| | | Test set | 1,726 | | Color block segmentation annotation for model testing |

b. Model training

In the model training stage, a main objective is to build an automated detection and segmentation system, such that image color correction is more accurate and efficient in various complex scenarios, reducing manual intervention. The specific steps are as follows:

Step (4): Color checker detection model training. A pre-trained detection model is trained using the color checker detection dataset obtained in step (3) to build a model capable of automatically recognizing a position of a color checker under different illumination conditions, angles, and scenes. A function of the color checker detection model is to automatically locate a color checker region, providing a basis for subsequent color block segmentation and color correction. During a training process, information such as a boundary and a position of the color checker needs to be trained and learned, ensuring that the color checker detection model has high accuracy and robustness in practical applications. A process of training the color checker detection model mainly involves establishing a mapping relationship between an input image and an output result through a large number of annotated original images. Through this step, a color checker detection model capable of automatically detecting a position of a color checker is obtained.

Step (5): In this step, the color block segmentation dataset obtained in step (3) is used to train a pre-trained segmentation model, thereby constructing a model capable of accurately segmenting color block regions in a color checker region image. A main task of the color block segmentation model is to segment each color block in the color checker region image individually, ensuring that a pixel value of each color block is accurately extracted. A key point of this step is to obtain fine color data in the color checker region image through the color block segmentation model, far exceeding the 24 color values used in a conventional method. Compared with using a regional mean value, color value data may achieve ten thousand or even a hundred thousand times the original amount, greatly enriching data resources required for color correction. Through this step, a color block segmentation model capable of accurately segmenting color blocks is obtained. An accurate and effective color block segmentation model may achieve accurate segmentation of a region of each color block in a color checker, ensure accurate extraction of all pixel values within each color block, and provide a large amount of diverse color value data for subsequent color correction.

c. Constructing a detection and segmentation module

To achieve an interactive processing of the color checker detection model and the color block segmentation model, and effectively extract pixel values within color blocks of the color checker, a detection and segmentation module is constructed, integrating the color checker detection model, the color block segmentation model, and a color value extraction algorithm, so as to subsequently realize an automated image color correction flow. By interactively integrating the color checker detection model, the color block segmentation model, and the color value extraction algorithm, a complete automated flow from color checker detection and color block segmentation to color value extraction is achieved.

d. Constructing a color correction module

A color correction module is a core component of a system, and a purpose thereof is to apply the rich color data obtained in the preceding steps to actual image correction, so as to improve color accuracy of a tongue image. The color correction module is mainly used to perform a weight adjustment on an extracted color value, and fit a polynomial regression model by using the adjusted weight and color value as input data, and finally apply a color conversion matrix based on the fitted polynomial regression model to a tongue image to be corrected, so as to achieve high-quality tongue image color correction.

e. Module embedding

In this stage, the detection and segmentation module and the color correction module are integrated and embedded into a standard robot to obtain a color correction robot, such that the color correction robot may realize a fully automated image color correction flow. This stage ensures that various parts of the system work in coordination, allowing the color correction robot to perform color correction processing while capturing an image.

The detection and segmentation module and the color correction module are embedded into the standard robot to endow the standard robot with an integrated image color correction capability, that is, the standard robot is enabled to have a color correction capability. In other words, the detection and segmentation module and the color correction module are embedded into the standard robot to obtain a color correction robot. The standard robot is equipped with a high-resolution camera and a camera control unit, used for capturing a high-precision tongue image. The standard robot is capable of adjusting a shooting angle and an illumination condition in different environments, thereby ensuring accurate capture of color information in a scene, and storing the captured image in an internal storage unit for subsequent processing.

Optionally, a main structure and functions of the standard robot are shown in Table 3, and a main structure and functions of the color correction robot are shown in Table 4. It can be seen from Table 3 and Table 4 that hardware structures and accessories of the standard robot are the same as those of the color correction robot, and software configurations both include a camera control module; and compared with the standard robot, a software configuration of the color correction robot additionally includes the detection and segmentation module and the color correction module.

Table 3 Main structure and functions of standard robot

| Category | Name | Function description | Remarks |
|---|---|---|---|
| Hardware | High-definition camera | Capture a high-resolution image | Standard equipped |
| | Fill light | Ensure the subject is clearly visible | Standard equipped |
| | Touch screen display | Information display and human-machine | Standard equipped |

| | | | |
|---|---|---|---|
| | | interaction | |
| | Processor | Core computing unit | Standard equipped |
| | Memory | Store data and programs | Standard equipped |
| | Battery | Power the robot during a power outage | Standard equipped |
| Software | Camera control module | Control a camera to shoot | Standard equipped |
| Accessories | Power cord | Power the robot and recharge the battery | Standard equipped |
| | Standard color checker | Color correction reference object | Standard equipped |

Table 4 Main structure and functions of color correction robot

| Category | Name | Function description | Remarks |
|---|---|---|---|
| Hardware | High-definition camera | Capture a high-resolution image | Standard equipped |
| | Fill light | Ensure the subject is clearly visible | Standard equipped |
| | Touch screen display | Information display and human-machine interaction | Standard equipped |
| | Processor | Core computing unit | Standard equipped |
| | Memory | Store data and programs | Standard equipped |
| | Battery | Power the robot during a power outage | Standard equipped |
| Software | Camera control module | Control a camera to shoot | Standard equipped |
| | Detection and segmentation module | Perform detection and segmentation on a color checker | Color correction robot configuration |
| | Color correction module | Perform color correction on an image | Color correction robot configuration |
| Accessories | Power cord | Power the robot and recharge the battery | Standard equipped |
| | Standard color checker | Color correction reference object | Standard equipped |

A specific flow of embedding the detection and segmentation module and the color correction module into the standard robot is shown in FIG. 7: first, a standard robot program within the standard robot is obtained; and then, the detection and segmentation module and the color correction module are embedded into the standard robot program in series to form a color correction robot program; and finally, the color correction robot program is overwritten into the standard robot to form a color correction robot. The standard robot program includes the following steps: a camera completes shooting based on a shooting signal, and then an imaging module outputs a captured image, and an output module stores the output captured image. The color correction robot program includes the following steps: a camera completes shooting based on a shooting signal, an imaging module outputs a captured image, a detection and segmentation module processes the captured image and outputs color block coordinates and color value data, a color correction module performs color correction on the captured image according to the color block coordinates and the color value data, and an output module outputs and stores the color-corrected image.

The image color correction method using the color correction robot is introduced as follows. As shown in FIG. 1, the image color correction method provided by the embodiment of the present disclosure mainly includes steps S101 to S106.

S101. An image to be processed is acquired, where the image to be processed includes a color checker region, and the color checker region includes a plurality of color blocks.

The image to be processed may be understood as an image with a color deviation captured by an electronic device. The electronic device refers to an electronic device deploying a color correction robot program. For example: a color correction robot. A color checker includes a standard color checker, usually composed of a series of predefined standard color blocks. These color blocks are printed or displayed in a certain arrangement, and each color has a unique number or name, facilitating a user to search and reference. The standard color checker is used as a reference for color correction, and the color checker includes a plurality of color blocks with known standard color values. The color blocks serve as reliable reference points for image color correction, thereby ensuring the accuracy of color adjustment.

Further, the image to be processed includes a target object region, and the target object region is

used to display a target object. The target object is a target whose color needs to be corrected, and a color correction is performed on the target object region to improve color correctness of the target object. The target object is specifically determined according to a use of the color correction robot. For example: when the color correction robot is an auxiliary device for tongue diagnosis, the target object is a tongue; and when the color correction robot is an auxiliary device for eye diagnosis, the target object is an eye. A type of the target object is not specifically limited in the embodiment of the present disclosure, and the embodiment of the present disclosure takes the target object which is a tongue as an example for illustration.

In an actual application scenario, the target object and the color checker are placed in the same scene, then a scene is photographed by using a camera, and an image captured by the camera is obtained as the image to be processed. In a tongue diagnosis application scenario, a patient's tongue and the color checker are placed in the same scene, for example, the color checker is placed below the tongue, and then the scene is photographed by using a camera, and an image captured by the camera is obtained as the image to be processed. As shown in FIG. 3, the image to be processed includes a color checker region and a tongue region. The color checker region includes a plurality of color blocks with known standard color values. The color blocks serve as reliable reference points for color correction of the image to be processed, thereby ensuring the accuracy of color adjustment.

Further, the color correction robot is configured with a high-resolution camera and a camera control unit, and the camera is used to capture a high-precision image as the image to be processed. The color correction robot is capable of adjusting a shooting angle and an illumination condition in different environments, thereby ensuring accurate capture of color information in a scene, and storing the captured image in an internal storage unit for subsequent processing.

S102. A color value of each pixel in the plurality of color blocks is extracted to obtain a color value list.

The color checker region includes a plurality of color blocks, and each color block is composed of a plurality of pixels. Each color block in the color checker region has a corresponding standard color value, that is, each color block has a one-to-one correspondence with a standard color value. For each color block, pixels within the color block are traversed, a color value of each pixel is extracted, and a color block code and the color value corresponding to each pixel are stored in a color value list.

In a possible embodiment, extracting a color value of each pixel in the plurality of color blocks to obtain a color value list includes detecting the image to be processed by using a color checker detection model to obtain position information of the color checker region; cropping the image to be processed based on the position information of the color checker region to obtain a color checker region image; performing recognition and segmentation on the color checker region image by using a color block segmentation model to obtain coordinates of each pixel in each color block; and extracting a color value of each pixel in each color block based on the coordinates of each pixel of each color block to obtain the color value list.

First, a trained color checker detection model is used to automatically detect the image to be processed, recognizing a position of the color checker region in the image to be processed. After the detection is completed, the color checker region in the image to be processed is cropped based on the position information of the color checker region, and a cropped color checker region image is passed to a trained color block segmentation model. The color block segmentation model performs fine segmentation on the cropped color checker region image to accurately recognize each color block region. After the color block segmentation is completed, position information of each color block is

output, where the position information of the color block includes a code of the color block and specific region position thereof in the image. This step ensures that all pixel information of each color block in the color checker region is accurately obtained.

The color checker detection model is obtained by training based on a deep learning algorithm, and is capable of automatically recognizing and locating the color checker region in the image to be processed. The color checker detection model is used to ensure that a position of the color checker in the image to be processed is accurately detected, laying a foundation for subsequent color block segmentation and color value extraction. Specifically, the color checker detection model is a detection model capable of automatically recognizing and locating a color checker region in an image to be processed, thereby providing a basis for subsequent color block segmentation and color correction.

A structure of the color checker detection model is shown in FIG. 8. An input of the color checker detection model is the image to be processed, and an output of the color checker detection model is position information (x, y, w, h), and an image type is a color checker, that is, position information of the color checker region is output, where the position information includes an abscissa, an ordinate, a width, and a height (x, y, w, h) of the color checker region. The color checker detection model uses a convolutional neural network (CNN) as a feature extraction network, a fully connected layer further processes and combines these features, and an output layer generates a final detection result. As shown in FIG. 8, the color checker detection model performs feature extraction on the input image to be processed to obtain a first feature map, performs feature extraction on the first feature map to obtain a second feature map, performs feature extraction on the second feature map to obtain a third feature map, performs feature extraction on the third feature map to obtain a fourth feature map, and inputs the fourth feature map to a first fully connected layer; at the same time, performs an upsampling process on the fourth feature map to obtain a fifth feature map, fuses the fifth feature map with the third feature map to obtain a sixth feature map, and inputs the sixth feature map to a second fully connected layer; performs an upsampling process on the fifth feature map to obtain a seventh feature map, fuses the second feature map with the seventh feature map to obtain an eighth feature map, and inputs the eighth feature map to a third fully connected layer; and inputs output data of the three fully connected layers to a detection head for processing to obtain position information and a classification result, where the position information includes an abscissa, an ordinate, a width, and a height (x, y, w, h); and the classification result is a color checker.

The above network structure enables the model to accurately detect a color checker region and features thereof, thereby improving the detection capability of the color correction robot.

The color block segmentation model is obtained by training based on a deep learning algorithm, and is mainly used to perform pixel-level accurate segmentation on color blocks in a color checker region image. The color block segmentation model analyzes color information within the color blocks pixel by pixel, extracts position information of all pixels of each color block, and significantly improves an amount and accuracy of data used for color correction.

An accurate and effective color block segmentation model is capable of achieving accurate segmentation of a region of each color block in a color checker region image, ensuring accurate extraction of all pixel values within each color block, and laying a foundation for providing a large amount of diverse color values for subsequent color correction.

As shown in FIG. 9, an input of the color block segmentation model is a color checker region image, and an output of the color block segmentation model is a code of each color block and coordinates of each pixel in each color block. The code of the color block is used to indicate a standard

color value corresponding to the color block. Further, the color block segmentation model adopts a CNN as a main feature extraction network, and combines a feature pyramid network (FPN) structure. The color block segmentation model first extracts features through a plurality of layers of CNN to extract different levels of information of the image, including an edge, a shape, and internal details of the color blocks, and then, an upsampling technique is used to restore a scale of a feature map, and with the help of the feature pyramid network, a multi-scale feature representation is constructed.

Specifically, as shown in FIG. 9, an input of the color block segmentation model is the color checker region image. The color block segmentation model performs a convolution process on the color checker region image to obtain a ninth feature map, performs a convolution process on the ninth feature map again to obtain a tenth feature map, performs a convolution process on the tenth feature map again to obtain an eleventh feature map, performs a convolution process on the eleventh feature map again to obtain a twelfth feature map, performs an upsampling process on the twelfth feature map to obtain a thirteenth feature map, fuses the eleventh feature map and the thirteenth feature map to obtain a fourteenth feature map, and performs an upsampling process on the fourteenth feature map to obtain a fifteenth feature map; and fuses the tenth feature map and the fifteenth feature map to obtain a sixteenth feature map, performs a convolution process on the sixteenth feature map to obtain a seventeenth feature map, fuses the fourteenth feature map and the seventeenth feature map to obtain an eighteenth feature map, performs a convolution process on the eighteenth feature map to obtain a nineteenth feature map, fuses the nineteenth feature map and the twelfth feature map to obtain a twentieth feature map, and inputs the twentieth feature map, the eighteenth feature map, and the sixteenth feature map to a segmentation head, where the segmentation head outputs a classification result and pixel coordinates corresponding to each classification result. The classification result includes a label of each color block, and the pixel coordinates corresponding to each classification result include coordinates of each pixel within the labeled color block.

This feature pyramid structure is capable of better capturing multi-level information of the image, allowing the model to accurately understand and segment color block regions at different scales.

Through multi-level feature extraction and multi-scale feature fusion, the color block segmentation model is capable of accurately recognizing and segmenting the 24 color blocks in the color checker under complex illumination and angle conditions, including Dark skin, Skin, Blue sky, Foliage, Blue flower, Bluish green, Orange, Purplish blue, Moderate red, Purple, Yellow, Green, Orange yellow, Blue, Red, Magenta, Cyan, White, Neutral 8, Neutral 6.5, Neutral 5, Neutral 3.5, and Black. In the color checker, the above color blocks are sequentially coded from 1 to 24 from left to right and top to bottom. The color block segmentation model ensures that all pixel values within each color block region is accurately extracted, thereby providing a solid and reliable data foundation for subsequent color correction.

In the embodiment of the present disclosure, a color checker detection model and a color block segmentation model obtained by model training are interactively integrated, such that a complete automated flow from color checker detection to color block segmentation is achieved. An integration workflow of the color checker detection model and the color block segmentation model is shown in FIG. 10 below: first, the image to be processed is input into the trained color checker detection model, and the color checker detection model performs inference on the image to be processed to obtain a color checker detection result to output a position and a boundary (x, y, w, h) of the color checker region. Based on the position and boundary of the color checker region, the color checker region in the image to be processed is automatically cropped to obtain a color checker region image, and the

color checker region image is passed to the color block segmentation model. In this way, a detection box generated by the color checker detection model serves as an input of the color block segmentation model, thereby providing accurate region information for subsequent accurate segmentation. The cropped color checker region image is input into the color block segmentation model. The color block segmentation model uses an FPN structure to segment the color blocks at different scales, ensuring that a boundary and an internal region of each color block is accurately recognized to obtain a color block segmentation result, and output coordinates of each color block. Through this manner, the color correction robot may obtain an accurate position of each color block.

In a possible embodiment, extracting a color value of each pixel in each color block based on the coordinates of each pixel of each color block to obtain the color value list includes extracting a color value of each pixel in the image to be processed based on the coordinates of each pixel; and establishing an association relationship between a number of the color block and the color value of each pixel, and storing the association relationship in the color value list.

In the embodiment of the present disclosure, based on the coordinates of each pixel in each color block, combined with a color value extraction algorithm, a color value of a corresponding coordinate position is extracted from the color checker region image. The extracted color values are summarized into a color value list, providing data support for subsequent color correction. The color value list contains a large number of color values of each color block in the color checker, far exceeding a limitation of using only a single regional average color value in a conventional method, usually reaching ten thousand to a hundred thousand times the number of regional average color values. Through this manner, more color details are captured to provide richer and more accurate data support for subsequent color correction. Finally, the color value list of all color blocks is output as basic data input for a subsequent color correction step. This ensures an automated and high-precision execution of a color correction flow.

Further, after the integration of the color checker detection model and the color block segmentation model, a next step is to combine the color value extraction algorithm with output results of the preceding models to achieve high-precision color data extraction. A main task of the color value extraction algorithm is to extract an accurate color value (RGB value) of each pixel within each color block from the segmented color blocks, and these color values are used for a subsequent color correction process. A specific flow is shown in FIG. 11 below. After completion of the segmentation of the color blocks, region information of each color block has been obtained, including a boundary and an internal region of each color block. The color value extraction algorithm first reads the region information, and recognizes coordinates of all pixels within each color block. Next, the pixel coordinates within each color block are traversed, a color value (RGB value) of each pixel is extracted, and a color block code and the color value are stored in the color value list. Finally, the color value list is output to a color correction module. A schematic diagram of a structure of the color value list is as shown in a right figure of FIG. 11. The color value list structure includes a plurality of color value information, and the color value information includes a color block label and a color value of each pixel within the color block corresponding to the label. For example: 01, 06, 24 in FIG. 11 identify an identifier of a color block, and (R, G, B) after each label identifies a color value of one pixel of the color block corresponding to the label.

S103. A weight coefficient is set for each color value in the color value list to obtain a color value list with the weight coefficients.

To adapt to different shooting conditions (such as an illumination intensity and an angle change),

a weight adjustment is performed on the color values according to a distribution condition of different color blocks. A purpose of the weight adjustment is to assign a weight coefficient to a color value within the color block according to actual illumination and shooting angle information in a scene, so as to reduce or increase the weight influence when a polynomial regression model is fitted. Specifically, weight coefficients of different color values are adjusted according to a color value distribution in the color value list.

Specifically, according to the color value list, a weight adjustment is performed by analyzing a distribution condition of the color values. The performance of different color blocks in an image is affected by an illumination intensity and an angle, so it is necessary to adjust the weight coefficients, such that a fitting of the polynomial regression model better reflects illumination conditions in an actual scene. After a weight coefficient is added to each color value, a color value list with the weight coefficients is formed. Through the weight adjustment, the model is prevented from being overly sensitive to some abnormal or extreme color values, such that the fitting is smoother and conforms to actual illumination conditions during shooting.

In a possible embodiment, setting a weight coefficient for each color value in the color value list includes performing statistics on the color value of each pixel in the color value list to obtain a color distribution of each channel; performing analysis based on the color distribution of each channel to obtain a first parameter and a second parameter respectively corresponding to each channel, where the first parameter is equal to one half of a channel width, and the second parameter is a channel value with a highest proportion in the channel; and calculating a weight coefficient of each channel based on the first parameter and the second parameter respectively corresponding to each channel and a predefined weight calculation formula.

In the embodiment of the present disclosure, color distribution statistics are respectively performed on 24 color blocks in an image to be processed captured by an ultra-high pixel camera and in an actually captured image. It can be known that, whether it is the image to be processed captured by the ultra-high pixel camera or the actually captured image, a pixel distribution of three channels of R, G, and B in the color blocks of the color checker basically conforms to a normal distribution.

As shown in FIG. 12, a specific flow of a weight adjustment strategy is as follows: first, statistics are performed on pixel color values contained in all color blocks to respectively obtain a pixel value distribution condition of an R channel, a pixel value distribution condition of a G channel, and a pixel value distribution condition of a B channel in the color blocks, and singular values in each channel are deleted; and next, according to the channel color value distribution, a weight coefficient of a pixel is adjusted, and an adjustment formula of a weight coefficient k is as follows:

$$k = F(v) = \begin{cases} e^{-\left(0.632 + \frac{3(|v - v_m| - 0.632\sigma)}{0.736\sigma}\right)} & v \in [v_m - 0.865\sigma, v_m - 0.632\sigma) \cup (v_m + 0.632\sigma, v_m + 0.865\sigma] \\ e^{-\frac{|v - v_m|}{\sigma}} & v \in [v_m - 0.632\sigma, v_m + 0.632\sigma] \\ e^{-\left(0.581728 + e^{\frac{(|v - v_m| - 0.865\sigma)}{0.135\sigma}}\right)} & v \in [0, v_m - 0.865\sigma) \cup (v_m + 0.865\sigma, 255] \end{cases},$$

where:

$e$ represents a natural logarithm;

$v$ represents a channel value of a current channel of a pixel, i.e., an abscissa value at this moment;

$v_m$ represents a channel value with a highest proportion in a single channel, i.e., a corresponding abscissa value of a maximum ordinate value; and

$\sigma$ is equal to one half of a channel width of a single channel, i.e., one half of a maximum abscissa value minus a minimum abscissa value.

After statistics are performed on the color value distribution, $\sigma$, $v_m$, and a weight conversion function $F(v)$ are obtained. After a weight adjustment is performed through $F(v)$, the color value list is converted into a color value list with the weight coefficients, and the color value list with the weight coefficients is passed as an input to a polynomial regression model fitting process to fit a polynomial regression model.

S104. A polynomial regression model is fitted by using the color value list with the weight coefficients to obtain a fitted polynomial regression model.

A purpose of fitting the polynomial regression model is to construct a color correction model suitable for different shooting scenes according to the color value list after the weight adjustment, so as to adjust a color of the image to be processed to a standard state.

The polynomial regression model is fitted by using the color value list with the weight coefficients. According to a difference between a standard color value of the color checker and a color value in the captured image, a polynomial regression model is established, and the weight coefficients are considered in a loss function calculation to reduce a fitting error. A polynomial coefficient of the model is iteratively optimized to ensure that the model accurately reflects a mathematical relationship between a color deviation of each pixel in the image to be processed and a standard color. Finally, an optimized polynomial regression model is capable of better reflecting an overall color shift condition of a tongue image.

In a possible embodiment, fitting a polynomial regression model by using a target color value list to obtain a fitted polynomial regression model includes performing fitting by using the color values in the color value list and the numbers of the color blocks to obtain an initial polynomial regression model; and iteratively adjusting the initial polynomial regression model by using a weight coefficient of each color value in the color value list to obtain the fitted polynomial regression model, where the fitted polynomial regression model includes a polynomial regression model that minimizes a loss function.

A specific flow of fitting the polynomial regression model is shown in FIG. 13 below. First, a weight value, a color value, and a color block label in the color value list with the weight coefficients are extracted, and a polynomial regression model is fitted by using the color value and the color block label; a Loss function output when the polynomial regression model is being fitted is corrected by using the weight value in the color value list with the weight coefficients; third, model parameters are iteratively adjusted such that a fitted polynomial curve reflects a color change law between the color blocks as accurately as possible; and finally, a fitted polynomial regression model is output.

Specifically, in FIG. 13, the Loss function represents a loss function of the polynomial regression model, where $R'$, $G'$, and $B'$ respectively represent actual color values of red, green, and blue channel values of a target; x, y, z represent initialization coefficients of a polynomial regression model f; $k_R$, $k_G$, and $k_B$ represent weighting coefficients of the red, green, and blue channels respectively; $f = x'R + y'G + z'B$ represents a polynomial regression model after minimizing the loss function,

and this model mainly adjusts coefficients in the polynomial regression model by minimizing the loss function to achieve a best fit for color data; $x'$, $y'$, and $z'$ represent coefficients of the fitted polynomial regression model; $f = (a+b+c)R + (e+f+g)G + (i+j+k)B$ represents a fitting function after splitting the coefficients of the polynomial regression model; and a, b, and c represent a result after splitting a coefficient of the red channel, e, f, and g represent a result after splitting a coefficient of the green channel, and i, j, and k represent a result after splitting a coefficient of the blue channel.

S105. A color conversion matrix is generated by using the fitted polynomial regression model, where the color conversion matrix is used to represent a mapping relationship between a color value in the image to be processed and a standard color value in a color checker.

A purpose of generating the color conversion matrix is to convert the fitted polynomial regression model into a conversion matrix suitable for tongue image color correction, so as to adjust a color value in the image to be processed to a color state of a standard color checker. The color conversion matrix is generated by using the fitted polynomial regression model. The fitted polynomial regression model generates a color conversion matrix for actual color correction. The color conversion matrix contains coefficients in the polynomial regression model, and is passed as a whole to a subsequent tongue image color conversion step. A function of the color conversion matrix is to perform a correction process on each pixel color value of the tongue image in an RGB space.

In a possible embodiment, generating a color conversion matrix by using the fitted polynomial regression model includes splitting a coefficient in the fitted polynomial regression model to obtain a polynomial regression model after coefficient splitting; and combining the coefficients of the polynomial regression model after coefficient splitting into the color conversion matrix.

A specific flow of generating the color conversion matrix is shown in FIG. 14 below. First, coefficients in the fitted polynomial regression model are extracted. These coefficients are key parameters describing a color change law, and determine an adjustment manner of color values under different illumination conditions and shooting angles. Next, the coefficients in the polynomial regression model are combined into a standardized color conversion matrix. The matrix represents a mapping relationship from a color value of the image to be processed to a standard color value of the color checker. Usually, a dimension of the color conversion matrix depends on a dimension of a color space (a 3x3 matrix for an RGB space). Finally, a final color conversion matrix (M) is output for use in a subsequent tongue image color conversion calculation.

Specifically, in FIG. 14, $f = (a+b+c)R + (e+f+g)G + (i+j+k)B$ represents a fitting function after splitting the coefficients of the polynomial regression model, where R, G, and B respectively represent input red, green, and blue components, and a, b, c, e, f, g, i, j, and k represent model coefficients. Through a matrix conversion, a formula f is expressed in a form of a matrix multiplication to output Matrix, and the Matrix is converted into a color conversion matrix M, where $a = M_{11}$,b $= M_{21}$,c $= M_{31}$,e $= M_{12}, f = M_{22}, g = M_{32}, i = M_{13}, j = M_{23}, k = M_{33}$.

S106. The color value of each pixel in the image to be processed is corrected by using the color conversion matrix to obtain a corrected image.

Color correction is performed on all pixels in the image to be processed using the color conversion matrix. The color conversion matrix is applied to an RGB value of the image to be processed, and a color-corrected image is generated. Through this manner, each pixel in the image to be processed undergoes a color value adjustment according to a polynomial fitting result, ensuring that the corrected image matches a standard color value of the color checker, thereby generating a final corrected image.

By using the generated color conversion matrix, a color correction conversion is performed on the RGB value in the image to be processed, and color values of all pixels in the image to be processed are adjusted to corrected color values, thereby generating a final corrected image. As shown in FIG. 15, a specific operation flow is as follows: the image to be processed is read, and an RGB value of each pixel in the image to be processed is extracted. These original color values in the image to be processed are adjusted to a standard state in subsequent steps; using the color conversion matrix, a color conversion is performed on the RGB value of each pixel; corrected color values of all pixels in the image to be processed are reassembled into a complete image. At this moment, all pixel colors in the corrected image have been mapped and adjusted with colors in a standard color checker; and finally, a corrected image after color conversion is output. A color distribution of the corrected image is more in line with an actual standard, and may be used for subsequent intelligent analysis and assisted diagnosis of traditional Chinese medicine tongue diagnosis. Specifically, when the color conversion matrix is used for color conversion, for each pixel, the following matrix operation is applied:

$$\begin{bmatrix} R' \\ G' \\ B' \end{bmatrix} = \begin{bmatrix} M_{11} & M_{12} & M_{13} \\ M_{21} & M_{22} & M_{23} \\ M_{31} & M_{32} & M_{33} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix},$$

where:

$[R, G, B]$ represents an RGB value of an original pixel in the image to be processed, and $[R', G', B']$ represents a corrected pixel value in the corrected image; and $M_{ij}$ represents a corresponding element in the color conversion matrix M.

Further, after the color correction is completed, the corrected image is saved to a built-in storage space of the color correction robot. The stored corrected image data is properly preserved by a system for later use or further analysis. Security and traceability of the corrected image data are ensured, including version information, a generation date, and a timestamp of the corrected image. In addition, a hash value (such as MD5) of a file is generated for integrity checking, and a regular backup is performed on a secure storage medium or a cloud to prevent data loss or damage.

To facilitate later use or further analysis, the corrected image after color correction is output to the built-in storage space of the color correction robot, thereby ensuring the security and traceability of the corrected tongue image data. To ensure that the corrected image achieves a balance between quality and storage efficiency, the image is stored in a losslessly compressed PNG format, and a traceable file naming format is adopted, including version information, a date, a timestamp, and an image number. For example: Corrected_ver001_20240101_001.png. To ensure the security of the image, after saving, a hash value (MD5) of the file is generated for integrity checking, and a regular backup is performed on a secure storage medium or the cloud to prevent data loss.

To allow a user to intuitively view and evaluate an effect of color correction, a visualization function of the corrected image is designed. This function helps the user quickly understand a result of the color correction and determine whether the color correction meets an expected standard.

The saved corrected image is read from a storage space, and output to a display screen of the robot. Through the display screen, the user may intuitively view and evaluate the effect of the color correction, and determine whether the corrected image meets the expected standard. This function provides a direct interaction manner, making a color correction process more transparent and easier to understand, and ensuring that a final tongue image meets quality requirements of traditional Chinese medicine tongue diagnosis.

To intuitively display the effect of color correction, a convenient evaluation and analysis interface is provided for the user. The saved corrected image is read from the built-in storage space of the color correction robot, output to the display screen of the robot, and visually displayed. Through the display screen, the user may clearly see a tongue image after color correction, and quickly evaluate the correction effect in combination with a comparison with an original image.

The image color correction method provided by the embodiment of the present disclosure mainly includes the following advantages:

First, through a weight adjustment of color values, accuracy and adaptability of a color correction model are improved.

A polynomial regression model is fitted with color values, and a weight adjustment algorithm is combined to optimize a fitting process for color correction. Aiming at a color deviation problem of an image to be processed under different illumination conditions and shooting angles, a correction mechanism capable of adaptively adjusting is provided. The weight adjustment algorithm optimizes and adjusts color values of different color blocks, such that the model reflects a color change law more accurately between the color blocks during fitting, thereby achieving higher precision color correction. A polynomial regression model fitting method based on a weight adjustment has strong adaptability, is capable of coping with complex illumination and angle changes, and has very high practical value and innovativeness.

Second, through a large amount of raw color value data extracted by a detection and segmentation module, stability and reliability of a system are enhanced.

A polynomial regression model fitting based on a large amount of raw color value data uses a large amount of raw color value data to fit a polynomial regression model to construct a high-precision color correction model. Through rich raw color value data, the model is capable of more comprehensively capturing a color change law in an actual shooting scene, such that the polynomial regression model exhibits better stability and reliability under different shooting conditions and environments. A large amount of raw color value data covers more illumination condition and shooting angle changes, making the model perform more accurately when dealing with complex illumination conditions and different angles. This accurate fitting capability significantly improves the accuracy of color correction, making a final color correction result closer to an actual color value.

Third, color checker detection and color block segmentation are automated, thereby improving efficiency and accuracy.

In a flow of image color correction, by combining a color checker detection model with a color block segmentation model, a modular and automated data processing solution for a color checker and color blocks in an image is proposed to provide a large amount of raw color value data for a subsequent color correction module. The color checker detection model is used to automatically recognize a position and boundary of a color checker in an image to be processed, while the color block segmentation model further accurately segments each color block in a color checker region image. Through this organic combination, a system may efficiently and accurately extract color information of the color checker, greatly reducing a workload of manual annotation and intervention. This automated detection and segmentation flow has high flexibility and scalability, may be applied to various different image processing scenarios, not only improves processing efficiency, but also ensures the accuracy of results, and is suitable for an image color correction task.

Fourth, full-flow automation and integration are achieved through a robot system to reduce a labor cost and improve overall processing efficiency.

A color checker detection and segmentation module and a color correction module are embedded into a robot system, forming a full-stage integrated robot image color correction system solution. A robot automatically captures an image to be processed through a camera, and sequentially executes flows such as color checker detection, color block segmentation, and color correction, ensuring a seamless connection of each step. The system design covers a whole flow from image acquisition to processing, correction, storage, and finally visualization, and a medical user only needs to complete an entire process of data acquisition and color correction of an image through the robot system. This highly automated design not only reduces manual intervention and lowers an operation cost, but also improves processing speed and accuracy, thereby greatly enhancing the stability and reliability of the system, and is suitable for various medical and scientific research application scenarios. A storage and visualization function embedded in the system also allows the user to conveniently perform data management and real-time evaluation of a correction effect, further enhancing practicality and convenience of the system.

FIG. 16 is a schematic structural diagram of an image color correction apparatus in an embodiment of the present disclosure. As shown in FIG. 16, an image color correction apparatus 40 provided by the embodiment of the present disclosure mainly includes: an image acquisition module 41, a color value extraction module 42, a weight setting module 43, a fitting module 44, a matrix generation module 45, and a color correction module 46.

Specifically, the image acquisition module 41 is configured to acquire an image to be processed, where the image to be processed includes a color checker region, and the color checker region includes a plurality of color blocks; the color value extraction module 42 is configured to extract a color value of each pixel in the plurality of color blocks to obtain a color value list; the weight setting module 43 is configured to set a weight coefficient for each color value in the color value list; the fitting module 44 is configured to fit a polynomial regression model by using the color value list with the weight coefficients to obtain a fitted polynomial regression model; the matrix generation module 45 is configured to generate a color conversion matrix by using the fitted polynomial regression model, where the color conversion matrix is used to represent a mapping relationship between a color value in the image to be processed and a standard color value in a color checker; and the color correction module 46 is configured to correct the color value of each pixel in the image to be processed by using the color conversion matrix to obtain a corrected image.

The embodiment of the present disclosure provides an image color correction apparatus, where the apparatus is configured to execute the following flow: acquiring an image to be processed, where the image to be processed includes a color checker region, and the color checker region includes a plurality of color blocks; extracting a color value of each pixel in the plurality of color blocks to obtain a color value list; setting a weight coefficient for each color value in the color value list; fitting a polynomial regression model by using the color value list with the weight coefficients to obtain a fitted polynomial regression model; generating a color conversion matrix by using the fitted polynomial regression model, where the color conversion matrix is used to represent a mapping relationship between a color value in the image to be processed and a standard color value in a color checker; and correcting the color value of each pixel in the image to be processed by using the color conversion matrix to obtain a corrected image. This embodiment improves the color accuracy of an image, and ensures the reliability and authenticity of image information, thereby providing reliable data support for subsequent intelligent analysis and assisted diagnosis.

In a possible embodiment, the color value extraction module 42 is specifically configured to

detect the image to be processed by using a color checker detection model to obtain position information of the color checker region; crop the image to be processed based on the position information of the color checker region to obtain a color checker region image; perform recognition and segmentation on the color checker region image by using a color block segmentation model to obtain coordinates of each pixel in each color block; and extract a color value of each pixel in each color block based on the coordinates of each pixel of each color block to obtain the color value list.

In a possible embodiment, the color value extraction module 42 is specifically configured to extract a color value of each pixel in the image to be processed based on the coordinates of each pixel; and establish an association relationship between a number of the color block and the color value of each pixel, and store in the color value list.

In a possible embodiment, the weight setting module 43 is specifically configured to set a weight coefficient for each color value in the color value list, including performing statistics on the color value of each pixel in the color value list to obtain a color distribution of each channel; performing analysis based on the color distribution of each channel to obtain a first parameter and a second parameter respectively corresponding to each channel, where the first parameter is equal to one half of a channel width, and the second parameter is a channel value with a highest proportion in the channel; and calculating a weight coefficient of each channel based on the first parameter and the second parameter respectively corresponding to each channel and a predefined weight calculation formula.

In a possible embodiment, the weight calculation formula is as follows:

$$k = F(v) = \begin{cases} e^{-\left(0.632 + \frac{3(|v - v_m| - 0.632\sigma)}{0.736\sigma}\right)} & v \in [v_m - 0.865\sigma, v_m - 0.632\sigma) \cup (v_m + 0.632\sigma, v_m + 0.865\sigma] \\ e^{-\frac{|v - v_m|}{\sigma}} & v \in [v_m - 0.632\sigma, v_m + 0.632\sigma] \\ e^{-\left(0.581728 + e^{\frac{(|v - v_m| - 0.865\sigma)}{0.135\sigma}}\right)} & v \in [0, v_m - 0.865\sigma) \cup (v_m + 0.865\sigma, 255] \end{cases},$$

where k represents a weight coefficient, $e$ represents a natural logarithm, $\sigma$ represents a first parameter, and $v_m$ represents a second parameter.

In a possible embodiment, the fitting module 44 is specifically configured to perform fitting by using a color value and a number of a color block in the color value list to obtain an initial polynomial regression model; and iteratively adjust the initial polynomial regression model by using a weight coefficient of each color value in the color value list to obtain the fitted polynomial regression model, where the fitted polynomial regression model includes a polynomial regression model that minimizes a loss function.

In a possible embodiment, the matrix generation module 45 is specifically configured to split a coefficient in the fitted polynomial regression model to obtain a polynomial regression model after coefficient splitting; and combine the coefficients of the polynomial regression model after coefficient splitting into the color conversion matrix.

The image color correction apparatus provided by the embodiment of the present disclosure is capable of executing the image color correction method provided by any embodiment of the present

disclosure, and has corresponding functional modules and beneficial effects for executing the method.

FIG. 17 is a schematic structural diagram of an electronic device provided by this embodiment. The electronic device may include an image color correction device. As shown in FIG. 17, the electronic device 500 includes a processor 510, a memory 520, an input device 530, and an output device 540. The electronic device may include one or more processors 510, and one processor 510 is taken as an example in FIG. 17. The processor 510, the memory 520, the input device 530, and the output device 540 in the electronic device may be connected through a bus or in other ways, and FIG. 17 takes the connection through the bus as an example.

As a computer-readable storage medium, the memory 520 may be used to store a software program, a computer-executable program, and a module, such as a program instruction/module corresponding to the image color correction method in the embodiment of the present disclosure. The processor 510 runs the software program, instructions, and modules stored in the memory 520 to execute various functional applications and data processing of the electronic device, that is, to achieve the image color correction method provided by the embodiment of the present disclosure.

The memory 520 may mainly include a program storage area and a data storage area, where the program storage area may store an operating system, an application program required for at least one function; and the data storage area may store data created according to use of a terminal. In addition, the memory 520 may include a high-speed random access memory, and may also include a non-volatile memory, such as at least one disk storage device, a flash memory device, or other non-volatile solid-state storage devices. In some examples, the memory 520 may further include memories remotely arranged relative to the processor 510, and these remote memories may be connected to the electronic device via a network. Examples of the network include, but are not limited to, the Internet, an intranet, a local area network, a mobile communication network, and combinations thereof.

The input device 530 may be used to receive input numeric or character information, and generate a signal input related to a user setting and a function control of the electronic device, and may include a keyboard, a mouse, and the like. The output device 540 may include a display device such as a display screen.

This embodiment further provides a storage medium containing computer-executable instructions, where the computer-executable instructions, when executed by a computer processor, are used to achieve the image color correction method provided by the embodiment of the present disclosure.

Of course, for a storage medium containing computer-executable instructions provided by an embodiment of the present disclosure, computer-executable instructions thereof are not limited to the method operations described above, and may also execute related operations in the image color correction method provided by any embodiment of the present disclosure.

Through the above description of embodiments, those skilled in the art may clearly understand that the present disclosure may be implemented by means of software and necessary general-purpose hardware, and of course may also be implemented by hardware, but in many cases the former is a better choice. Based on such an understanding, contributions made by the technical solution of the present disclosure to the prior art may be embodied essentially or partially in a form of a software product. The computer software product may be stored in a computer-readable storage medium, such as a floppy disk of a computer, a read-only memory (ROM), a random access memory (RAM), a flash memory (FLASH), a hard disk, or an optical disk, and includes a number of instructions to enable a computer device (which may be a personal computer, a server, or a network device) to execute the methods described in various embodiments of the present disclosure.

It is worth noting that, in the above embodiment of the image color correction apparatus, the units and modules are only divided according to functional logic, but are not limited to the above division, as long as corresponding functions are achieved; and in addition, specific names of various functional units are only for convenience of distinguishing each other, and are not used to limit a protection scope of the present disclosure.

It should be noted that relational terms herein such as first and second are only used for distinguishing one entity or operation from another entity or operation without necessarily requiring or implying any actual such relationship or order between such entities or operations. The terms "comprising", "including" or any other variants thereof are intended to cover non-exclusive inclusion, such that a process, a method, an article or an apparatus including a series of elements not only includes those elements, but also includes other elements not listed clearly or further includes elements inherent to such process, method, article or apparatus. Without more restrictions, the elements defined by the sentence “including a ...” do not exclude the existence of other identical elements in the process, method, article, or apparatus including the elements.

What are described above are embodiments of the present disclosure such that those skilled in the art can understand or implement the present disclosure. Various modifications to these embodiments are apparent to those skilled in the art, and general principles defined herein may be implemented in other embodiments without departing from a spirit or scope of the present disclosure. Therefore, the present disclosure is not limited to the embodiments shown herein but should fall within the widest scope consistent with the principles and novel features disclosed herein.

**Industrial Applicability**

The present disclosure provides an image color correction method, which improves color accuracy of an image, and ensures reliability and authenticity of image information, thereby providing reliable data support for subsequent intelligent analysis and assisted diagnosis, and has a wide range of industrial applicability.

WHAT IS CLAIMED IS:

1. An image color correction method, wherein the method comprises:

acquiring an image to be processed, wherein the image to be processed comprises a color checker region, and the color checker region comprises a plurality of color blocks;

extracting a color value of each pixel in the plurality of color blocks to obtain a color value list;

setting a weight coefficient for each color value in the color value list, comprising performing statistics on the color value of each pixel in the color value list to obtain a color distribution of each channel; performing analysis based on the color distribution of each channel to obtain a first parameter and a second parameter respectively corresponding to each channel, wherein the first parameter is equal to one half of a channel width, and the second parameter is a channel value with a highest proportion in the channel; and calculating a weight coefficient of each channel based on the first parameter and the second parameter respectively corresponding to each channel and a predefined weight calculation formula;

fitting a polynomial regression model by using the color value list with the weight coefficients to obtain a fitted polynomial regression model;

generating a color conversion matrix by using the fitted polynomial regression model, wherein the color conversion matrix is used to represent a mapping relationship between a color value in the image to be processed and a standard color value in a color checker; and

correcting the color value of each pixel in the image to be processed by using the color conversion matrix to obtain a corrected image.

2. The method according to claim 1, wherein extracting the color value of each pixel in the plurality of color blocks to obtain the color value list comprises:

detecting the image to be processed by using a color checker detection model to obtain position information of the color checker region;

cropping the image to be processed based on the position information of the color checker region to obtain a color checker region image;

performing recognition and segmentation on the color checker region image by using a color block segmentation model to obtain coordinates of each pixel in each color block; and

extracting a color value of each pixel in each color block based on the coordinates of each pixel of each color block to obtain the color value list.

3. The method according to claim 2, wherein extracting the color value of each pixel in each color block based on the coordinates of each pixel of each color block to obtain the color value list comprises:

extracting a color value of each pixel in the image to be processed based on the coordinates of each pixel; and

establishing an association relationship between a number of the color block and the color value of each pixel, and storing the association relationship into the color value list.

4. The method according to claim 1, wherein the predefined weight calculation formula is as follows:

$$k = F(v) = \begin{cases} e^{-\left(0.632 + \frac{3(|v - v_m| - 0.632\sigma)}{0.736\sigma}\right)} & v \in [v_m - 0.865\sigma, v_m - 0.632\sigma) \cup (v_m + 0.632\sigma, v_m + 0.865\sigma] \\ e^{-\frac{|v - v_m|}{\sigma}} & v \in [v_m - 0.632\sigma, v_m + 0.632\sigma] \\ e^{-\left(0.581728 + e^{\frac{(|v - v_m| - 0.865\sigma)}{0.135\sigma}}\right)} & v \in [0, v_m - 0.865\sigma) \cup (v_m + 0.865\sigma, 255] \end{cases},$$

wherein k represents a weight coefficient, e represents a natural logarithm, σ represents the first parameter, $V_m$ represents the second parameter, and v represents a channel value of a current channel of a pixel.

5. The method according to claim 4, wherein fitting the polynomial regression model by using the color value list with the weight coefficients to obtain the fitted polynomial regression model comprises:

performing fitting by using the color values in the color value list and the numbers of the color blocks to obtain an initial polynomial regression model; and

iteratively adjusting the initial polynomial regression model by using a weight coefficient of each color value in the color value list to obtain a fitted polynomial regression model, wherein the fitted polynomial regression model comprises a polynomial regression model determined based on minimizing a loss function.

6. The method according to claim 5, wherein generating the color conversion matrix by using the fitted polynomial regression model comprises:

splitting a coefficient in the fitted polynomial regression model to obtain a polynomial regression model after coefficient splitting; and

combining the coefficients of the polynomial regression model after coefficient splitting into a color conversion matrix.

7. An image color correction apparatus, wherein the apparatus comprises:

an image acquisition module configured to acquire an image to be processed, wherein the image to be processed comprises a color checker region, and the color checker region comprises a plurality of color blocks;

a color value extraction module configured to extract a color value of each pixel in the plurality of color blocks to obtain a color value list;

a weight setting module configured to set a weight coefficient for each color value in the color value list, wherein the setting a weight coefficient for each color value in the color value list comprises performing statistics on the color value of each pixel in the color value list to obtain a color distribution of each channel; performing analysis based on the color distribution of each channel to obtain a first parameter and a second parameter respectively corresponding to each channel, wherein the first parameter is equal to one half of a channel width, and the second parameter is a channel value with a highest proportion in the channel; and calculating a weight coefficient of each channel based on the first parameter and the second parameter respectively corresponding to each channel and a predefined weight calculation formula;

a fitting module configured to fit a polynomial regression model by using the color value list with the weight coefficients to obtain a fitted polynomial regression model;

a matrix generation module configured to generate a color conversion matrix by using the fitted polynomial regression model, wherein the color conversion matrix is used to represent a mapping relationship between a color value in the image to be processed and a standard color value in a color checker; and

a color correction module configured to correct the color value of each pixel in the image to be processed by using the color conversion matrix to obtain a corrected image.

8. A color correction robot, wherein the color correction robot comprises:

one or more processors;

a storage device configured to store one or more programs; and

a camera configured to capture an image to be processed and transmit the image to the processor, wherein

when the one or more programs are executed by the one or more processors, the image color correction method according to any of claims 1 to 6 is implemented by the one or more processors.

9. A storage medium, wherein a computer program is stored on the storage medium, and when the program is executed by a processor, the image color correction method according to any of claims 1 to 6 is implemented.