

Description

Colored Contact Lens Detection Method and Apparatus, Iris Recognition Method and Apparatus, and Readable Storage Medium and Device

Cross-Reference to Related Application

The disclosure claims the priority to Chinese Patent Application No. 202111372916.6, filed with the Chinese Patent Office on November 19, 2021 and entitled “Colored Contact Lens Detection Method and Apparatus, Iris Recognition Method and Apparatus, and Readable Storage Medium and Device”, which is incorporated in its entirety herein by reference.

Technical Field

The disclosure relates to the field of iris recognition, and in particular to colored contact lens detection method and apparatus, iris recognition method and apparatus, and readable storage medium and device.

Background

As shown in Fig. 1, a portion between an outer iris circle and an inner iris circle is the iris, which is a ring-like structure positioned between a pupil and a sclera. Owing to the blockage by eyelids and eyelashes, part of iris information is lost. The iris has a diameter of 12 mm or so and a thickness of 0.5 mm or so. Interlaced fine features in a filament or streak shape indicate the uniqueness of the iris. These textured features are typically used for iris recognition.

The iris recognition primarily includes iris image acquisition, iris image quality evaluation, iris image preprocessing, iris image normalization, iris image feature extraction, iris feature comparison, etc.

The iris recognition is actually to recognize an iris region from an eye. However, in practical application, users (especially female users) often wear colored contact lenses, which brings some problems to iris recognition and affects the accuracy of iris recognition accordingly. The colored contact lenses can generally include transparent colored contact lenses (similar to contact lenses, having basically no impact on iris recognition), light colored contact lenses, and dark colored contact lenses. Specifically, the dark colored contact lens and the light colored contact lens are shown in Figs. 2 and 3 below.

Two methods for detecting colored contact lenses are primarily available in the prior art:

1) One method is to determine a grayscale on the basis of a feature that a colored contact lens region is darker, which primarily includes: a grayscale value of pixels is determined directly, and then, the colored contact lens region is determined according to a set threshold.

The method can recognize some dark colored contact lenses, but can hardly recognize the light colored contact lenses.

2) The other method is based on deep learning, which primarily includes: training sample data that are divided into colored contact lens samples and non-colored contact lens samples are collected; and then, deep training is performed according to a deep network model constructed, so as to recognize whether colored contact lenses are worn.

Deep learning is highly dependent on training samples, especially types of colored contact lenses. But it is actually impossible to collect all types of colored contact lenses. In consequence, the deep network model trained cannot classify the colored contact lenses accurately.

Summary

In order to solve the technical problems that the above methods for detecting colored contact lenses cannot recognize the colored contact lenses and are dependent on training samples, the disclosure provides colored contact lens detection method and apparatus, iris recognition method and apparatus, and readable storage medium and device. Accordingly, a dark colored contact lens and a light colored contact lens may be accurately recognized without depending on image samples and with robustness.

The disclosure provides the technical solutions as follows:

In a first aspect, the disclosure provides a colored contact lens detection method. The method includes:

an eye image is acquired;

an average pixel value of the eye image is calculated, grayscale values of pixels having grayscale values smaller than the average pixel value in the eye image are stretched to a range [0,1], and grayscale values of pixels having grayscale values greater than the average pixel value are set to 0, so as to obtain a first image matrix;

a gradient transformation is performed on the eye image, and a grayscale value of each pixel in an image obtained through the gradient transformation is normalized to a range [0,1], so as to obtain

a second image matrix;

a matrix addition operation is performed on the first image matrix and the second image matrix, and each pixel in an image obtained through the matrix addition operation is binarized according to a set binarization threshold, so as to obtain a binarized image; and

a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region, of the binarized image is counted, a binarized image having a proportion greater than a set colored contact lens threshold is determined as indicating that no colored contact lens is worn, and a binarized image having a proportion smaller than or equal to the set colored contact lens threshold is determined as indicating that the colored contact lens is worn.

In an example, the step that an eye image is acquired includes:

a pupil is preliminarily located from an initial eye image, so as to obtain a pupil position, a pupil radius, an upper eyelid boundary, and a low eyelid boundary;

the initial eye image is intercepted by selecting a vertex of the upper eyelid boundary, a bottom point of the lower eyelid boundary, and two intersections between the upper eyelid boundary and the lower eyelid boundary as interception boundaries individually, so as to obtain an eye region image; and

a spot is detected from the eye region image, and for the eye region image from which the spot is detected, the spot detected from the eye region image is filled through biquadratic interpolation.

In an example, the step that a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region, of the binarized image is counted includes:

a middle region is selected from the binarized image, and a total number N_T of pixels in the middle region is counted;

a number N_1 of pixels having grayscale values of 1 in a portion, outside the pupil region, of the middle region is counted; and

the proportion is calculated according to a formula N_1/N_T .

In an example, the binarization threshold is 0.6.

In an example, the colored contact lens threshold is 0.8.

In an example, the step that a pupil is preliminarily located from an initial eye image, so as to obtain a pupil position, a pupil radius, an upper eyelid boundary, and a low eyelid boundary includes:

the pupil is preliminarily located from the initial eye image through an edge detection operator and edge gradient binarization detection, so as to preliminarily determine the pupil position, the pupil radius, the upper eyelid boundary, and the lower eyelid boundary.

In an example, the middle region is an image obtained by cutting off 1/3 of the binarized image in a vertical direction downwards from an upper edge, cutting off 1/3 of the binarized image in the vertical direction upwards from a lower edge, cutting off 1/3 of the binarized image in a horizontal direction rightwards from a left boundary, and cutting off 1/3 of the binarized image in the horizontal direction leftwards from a right boundary.

In a second aspect, the disclosure provides a colored contact lens detection apparatus. The apparatus includes: an image acquisition module, a first image matrix calculation module, a second image matrix calculation module, a binarized image calculation module, and a colored contact lens determination module.

The image acquisition module is configured to acquire an eye image.

The first image matrix calculation module is configured to calculate an average pixel value of the eye image, stretch grayscale values of pixels having grayscale values smaller than the average pixel value in the eye image to a range [0,1], and set grayscale values of pixels having grayscale values greater than the average pixel value to 0, so as to obtain a first image matrix.

The second image matrix calculation module is configured to perform a gradient transformation on the eye image, and normalize a grayscale value of each pixel in an image obtained through the gradient transformation to a range [0,1], so as to obtain a second image matrix.

The binarized image calculation module is configured to perform a matrix addition operation on the first image matrix and the second image matrix, and binarize each pixel in an image obtained through the matrix addition operation according to a set binarization threshold, so as to obtain a binarized image.

The colored contact lens determination module is configured to count a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region, of the binarized image, determine a binarized image having a proportion greater than a set colored contact lens threshold as indicating that no colored contact lens is worn, and determine a binarized image having a proportion smaller than or equal to the set colored contact lens threshold as indicating that the colored contact lens is worn.

In an example, the image acquisition module includes:

a preliminary pupil location unit configured to preliminarily locate a pupil from an initial eye image, so as to obtain a pupil position, a pupil radius, an upper eyelid boundary, and a low eyelid boundary;

an image interception unit configured to intercept the initial eye image by selecting a vertex of the upper eyelid boundary, a bottom point of the lower eyelid boundary, and two intersections between the upper eyelid boundary and the lower eyelid boundary as interception boundaries individually, so as to obtain an eye region image; and

a spot filling unit configured to detect a spot from the eye region image, and fill, for the eye region image from which the spot is detected, the spot detected from the eye region image through biquadratic interpolation.

In an example, the colored contact lens determination module includes:

a middle region selection unit configured to select a middle region from the binarized image, and count a total number N_T of pixels in the middle region;

a pixel counting unit configured to count a number N_1 of pixels having grayscale values of 1 in a portion, outside the pupil region, of the middle region; and

a proportion calculation unit configured to calculate the proportion according to a formula N_1/N_T .

In a third aspect, the disclosure provides a computer-readable storage medium for detecting a colored contact lens. The computer-readable storage medium stores a computer program executable by a processor, where the computer program implements steps of the colored contact lens detection method in the first aspect when executed by the processor.

In a fourth aspect, the disclosure provides a colored contact lens detection device. The device includes at least one processor and a memory storing a computer program, where the processor implements steps of the colored contact lens detection method in the first aspect when executing the computer program.

In a fifth aspect, the disclosure provides an iris recognition method. The method includes:

a colored contact lens is detected through the colored contact lens detection method in the first aspect;

the iris is detected from an eye image, so as to obtain an iris region; and

a proportion of pixels having a grayscale value of 1 in the iris region of a binarized image is counted, and for a binarized image having a proportion smaller than a set recognition threshold, the iris is recognized from the eye image.

In an example, the step that the iris is detected from an eye image includes: a region of the pixels having grayscale values of 1 in the binarized image is processed as a noise region.

In a sixth aspect, the disclosure provides an iris recognition apparatus. The apparatus includes:

the colored contact lens detection apparatus in the second aspect;

an iris detection module configured to detect the iris from an eye image, so as to obtain an iris region; and

a recognition and determination module configured to count a proportion of pixels having grayscale values of 1 in the iris region of a binarized image, and recognize the iris from the eye image, for a binarized image having a proportion smaller than a set recognition threshold.

In a seventh aspect, the disclosure provides a computer-readable storage medium for recognizing an iris. The computer-readable storage medium stores a computer program executable by a processor, where the computer program implements steps of the iris recognition method in the fifth aspect when executed by the processor.

In an eighth aspect, the disclosure provides an iris recognition device. The device includes at least one processor and a memory storing a computer program, where the processor implements steps of the iris recognition method in the fifth aspect when executing the computer program.

The disclosure has the beneficial effects as follows:

According to the disclosure, the colored contact lens is detected according to features that a colored contact lens region has complex textures and a large relative gradient, while the iris normally has a smooth outer circle, and that the colored contact lens region has a smaller pixel value compared to an entire iris region. Firstly, the eye image is acquired. Then, grayscale stretching and the gradient transformation are performed on the eye image individually, and the matrix addition operation and binarization are performed. Finally, whether the colored contact lens is worn is determined according to the proportion of the pixels having grayscale values of 1 in the portion, outside the pupil region, of the binarized image obtained.

According to the disclosure, a dark colored contact lens and a light colored contact lens may be accurately recognized without depending on image samples, the robustness is realized, and various types of colored contact lenses can be recognized.

Brief Description of the Drawings

Fig. 1 is a schematic diagram of all parts (including an iris) of an eye in an example of the

disclosure;

Fig. 2 is a schematic diagram of an eye image with a dark colored contact lens in an example of the disclosure;

Fig. 3 is a schematic diagram of an eye image with a light colored contact lens in an example of the disclosure;

Fig. 4 is a flowchart of a colored contact lens detection method in an example of the disclosure;

Fig. 5 is a schematic diagram of a preliminary pupil location result in an example of the disclosure;

Fig. 6 is a schematic diagram of an eye region image intercepted in an example of the disclosure;

Fig. 7 is a schematic diagram of an eye image with a spot filled in an example of the disclosure;

Fig. 8 is a schematic diagram of a binarized image in an example of the disclosure;

Fig. 9 is a schematic diagram of selecting a middle region from a binarized image in an example of the disclosure;

Fig. 10 is a schematic diagram of a colored contact lens detection apparatus in an example of the disclosure;

Fig. 11 is a flowchart of an iris recognition method in an example of the disclosure;

Fig. 12 is a schematic diagram of an inner iris boundary location result and an outer iris boundary location result on an iris image in an example of the disclosure;

Fig. 13 is a schematic diagram of a noise template in an example of the disclosure; and

Fig. 14 is a schematic diagram of an iris recognition apparatus in an example of the disclosure.

Detailed Description of the Embodiments

In order to make the technical problem to be solved, technical solutions, and advantages of the disclosure clearer, the technical solutions of the disclosure will be clearly and completely described below in conjunction with the accompanying drawings and specific examples. Apparently, the examples described are merely some examples rather than all examples of the disclosure. Components in the examples of the disclosure generally described and shown in the accompanying drawings herein may be arranged and designed in a variety of different configurations. Therefore, the following detailed description of the examples of the disclosure provided in the accompanying

drawings is not intended to limit the scope of the disclosure claimed, and is merely indicates the examples selected of the disclosure. Based on the examples the disclosure, all other examples derived by those skilled in the art without creative efforts fall within the scope of protection of the disclosure.

A colored contact lens detection method is provided in an example of the disclosure. As shown in Fig. 4, the method includes S100-S500.

S100: an eye image is acquired.

The eye image may be an initial eye image or an image obtained by preprocessing the initial eye image as required. In an instance, preprocessing includes S101-S103.

S101: a pupil is preliminarily located from the initial eye image, so as to obtain a pupil position, a pupil radius, an upper eyelid boundary, and a low eyelid boundary.

In the step, firstly, the pupil is preliminarily located from the initial eye image through an edge detection operator and edge gradient binarization detection, so as to preliminarily determine the pupil position, the pupil radius, the upper eyelid boundary, and the lower eyelid boundary. The upper eyelid boundary and the lower eyelid boundary are parabolic, as shown in Fig. 5.

S102: the initial eye image is intercepted by selecting a vertex of the upper eyelid boundary, a bottom point of the lower eyelid boundary, and two intersections between the upper eyelid boundary and the lower eyelid boundary as interception boundaries individually, so as to obtain an eye region image.

The step is configured to intercept the initial eye image according to a preliminary pupil location result in S101, so that a size of the initial eye image and noise are reduced.

A specific process may be as follows: the initial eye image is intercepted by selecting a vertex of a parabola of the upper eyelid boundary, a bottom point of a parabola of the lower eyelid boundary, a left intersection between the parabola of the upper eyelid boundary and the parabola of the lower eyelid boundary, and a right intersection between the parabola of the upper eyelid boundary and the parabola of the lower eyelid boundary, as an upper boundary, a lower boundary, a left boundary, and a right boundary for intercepting the image respectively, and the eye region image obtain after interception is shown in Fig. 6.

S103: a spot is detected from the eye region image, and for the eye region image from which the spot is detected, the spot detected from the eye region image is filled through biquadratic interpolation.

When the eye image is collected, under the impact of light supplement, etc., the spot is likely to be generated in the pupil. In the disclosure, the spot is filled through spot detection and the biquadratic interpolation. An effect image after the spot is filled is shown in Fig. 7.

S200: an average pixel value of the eye image is calculated, grayscale values of pixels having grayscale values smaller than the average pixel value in the eye image are stretched to a range [0,1], and grayscale values of pixels having grayscale values greater than the average pixel value are set to 0, so as to obtain a first image matrix.

A specific embodiment of the step is as follows: grayscale values of all pixels in the eye image are summed and averaged, so as to calculate the average pixel value. Grayscale values of pixels having grayscale values smaller than the average pixel value in the eye image are stretched to a range [0,1], and grayscale values of pixels having grayscale values greater than the average pixel value are set to 0, so as to obtain a first image matrix *Img1*. In the disclosure, the grayscale value means the pixel value.

S300: a gradient transformation is performed on the eye image, and a grayscale value of each pixel in an image obtained through the gradient transformation is normalized to a range [0,1], so as to obtain a second image matrix.

In the step, the gradient transformation is performed on the eye image through an edge detection Canny operator. Then, the grayscale value of each pixel in the image obtained through the gradient transformation is normalized to the range [0,1], so as to obtain a second image matrix *Img2*.

S400: a matrix addition operation is performed on the first image matrix and the second image matrix, and each pixel in an image obtained through the matrix addition operation is binarized according to a set binarization threshold, so as to obtain a binarized image.

In the step, the first image matrix *Img1* and the second image matrix *Img2* are added, so as to obtain a result matrix *Image*= *Img1*+*Img2*. Then, the result matrix is compared with the binarization threshold. For example, the binarization threshold is set to 0.6. Then, the pixel is binarized. The binarization threshold value of 0.6 is merely illustrative and is not intended to limit the disclosure. A specific binarization method is as follows:

$$\text{Image}(x, y) = \begin{cases} 0 & \text{Image}(x, y) < 0.6 \\ 1 & \text{Image}(x, y) \geq 0.6 \end{cases}$$

The binarized image is illustratively shown in Fig. 8.

S500: a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region,

of the binarized image is counted, a binarized image having a proportion greater than a set colored contact lens threshold is determined as indicating that no colored contact lens is worn, and a binarized image having a proportion smaller than or equal to the set colored contact lens threshold is determined as indicating that the colored contact lens is worn.

Normally, in a non-colored contact lens image, except for those in the pupil region, most pixels have grayscale values of 1. While in a colored contact lens image, except for those in the pupil region, a large proportion of pixels have grayscale values of 0. Therefore, whether the colored contact lens is worn may be determined according to the proportion of the pixels having grayscale values of 1 in the portion, outside the pupil region, of the binarized image.

The pupil position and the pupil radius have been obtained in S101. In other words, a size and coordinates of the pupil region are obtained. Then, distribution of the pixels having grayscale values of 1 outside the pupil region in Fig. 8 may be counted. A region composed of the pixels having grayscale values of 1 outside the pupil region may be deemed as a colored contact lens region. Then, a proportion of the colored contact lens region to the binarized image is calculated. The proportion denotes a proportion of the colored contact lens outside the pupil region. Whether the colored contact lens is worn may be determined by comparing the proportion with the set colored contact lens threshold.

In consideration of the impact of some edge noise, in some examples, the colored contact lens threshold is 0.8. Moreover, 0.8 is merely illustrative and is not intended to limit the disclosure. The proportion of the pixels having grayscale values of 1 outside the pupil region of the binarized image is counted. If the proportion is greater than 0.8, it is deemed that no colored contact lens is worn. If the proportion is smaller than or equal to 0.8, it is deemed that the colored contact lens is worn.

According to the disclosure, the colored contact lens is detected according to features that the colored contact lens region has complex textures and a large relative gradient, while an iris normally has a smooth outer circle, and that the colored contact lens region has a smaller pixel value compared to an entire iris region. Firstly, the eye image is acquired. Then, grayscale stretching and the gradient transformation are performed on the eye image individually, and the matrix addition operation and binarization are performed. Finally, whether the colored contact lens is worn is determined according to the proportion of the pixels having grayscale values of 1 in the portion, outside the pupil region, of the binarized image obtained.

According to the disclosure, a dark colored contact lens and a light colored contact lens may be accurately recognized without depending on image samples, the robustness is realized, and various types of colored contact lenses can be recognized.

In some examples of the disclosure, in order to eliminate the impact of an upper eyelid, a lower eyelid, and eyelash noise, the step that a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region, of the binarized image is counted specifically includes S051-S053.

S501: a middle region is selected from the binarized image, and a total number N_T of pixels in the middle region is counted.

Illustratively, the middle region is an image obtained by cutting off 1/3 of the binarized image in a vertical direction downwards from an upper edge, cutting off 1/3 of the binarized image in the vertical direction upwards from a lower edge, cutting off 1/3 of the binarized image in a horizontal direction rightwards from a left boundary, and cutting off 1/3 of the binarized image in the horizontal direction leftwards from a right boundary. The middle region is a rectangular portion in Fig. 9. 1/3 of the binarized image in a direction is merely illustrative and is not intended to limit the disclosure.

S502: a number N_1 of pixels having grayscale values of 1 in a portion, outside the pupil region, of the middle region is counted.

A region composed of the pixels having grayscale values of 1 in the portion, outside the pupil region, of the middle region denotes the colored contact lens region within the middle region.

S503: the proportion is calculated according to a formula N_1/N_T .

The step is to calculate a proportion of the colored contact lens region to the middle region. The proportion is used as the proportion of the pixels having grayscale values of 1 in the portion, outside the pupil region, of the binarized image. Accordingly, the impact of the upper eyelid, the lower eyelid, the eyelash noise, etc. is eliminated.

A colored contact lens detection apparatus 10 for detecting a colored contact lens is provided in an example of the disclosure. As shown in Fig. 10, the apparatus includes: an image acquisition module 100, a first image matrix calculation module 200, a second image matrix calculation module 300, a binarized image calculation module 400, and a colored contact lens determination module 500.

The image acquisition module 100 is configured to acquire an eye image.

The first image matrix calculation module 200 is configured to calculate an average pixel value of the eye image, stretch grayscale values of pixels having grayscale values smaller than the average pixel value in the eye image to a range [0,1], and set grayscale values of pixels having grayscale values greater than the average pixel value to 0, so as to obtain a first image matrix.

The second image matrix calculation module 300 is configured to perform a gradient transformation on the eye image, and normalize a grayscale value of each pixel in an image obtained through the gradient transformation to a range $[0,1]$, so as to obtain a second image matrix.

The binarized image calculation module 400 is configured to perform a matrix addition operation on the first image matrix and the second image matrix, and binarize each pixel in an image obtained through the matrix addition operation according to a set binarization threshold, so as to obtain a binarized image.

The colored contact lens determination module 500 is configured to count a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region, of the binarized image, determine a binarized image having a proportion greater than a set colored contact lens threshold as indicating that no colored contact lens is worn, and determine a binarized image having a proportion smaller than or equal to the set colored contact lens threshold as indicating that the colored contact lens is worn.

According to the disclosure, the colored contact lens is detected according to features that a colored contact lens region has complex textures and a large relative gradient, while an iris normally has a smooth outer circle, and that the colored contact lens region has a smaller pixel value compared to an entire iris region. Firstly, the eye image is acquired. Then, grayscale stretching and the gradient transformation are performed on the eye image individually, and the matrix addition operation and binarization are performed. Finally, whether the colored contact lens is worn is determined according to the proportion of the pixels having grayscale values of 1 in the portion, outside the pupil region, of the binarized image obtained.

According to the disclosure, a dark colored contact lens and a light colored contact lens may be accurately recognized without depending on image samples, the robustness is realized, and various types of colored contact lenses can be recognized.

The eye image acquired by the image acquisition module 100 may be an initial eye image or an image obtained by preprocessing the initial eye image as required. In some examples, the image acquisition module 100 is further configured to preprocess the initial eye image and includes: a preliminary pupil location unit, an image interception unit, and a spot filling unit.

The preliminary pupil location unit is configured to preliminarily locate a pupil from the initial eye image, so as to obtain a pupil position, a pupil radius, an upper eyelid boundary, and a low eyelid boundary.

The image interception unit is configured to intercept the initial eye image by selecting a vertex

of the upper eyelid boundary, a bottom point of the lower eyelid boundary, and two intersections between the upper eyelid boundary and the lower eyelid boundary as interception boundaries individually, so as to obtain an eye region image.

The spot filling unit is configured to detect a spot from the eye region image, and fill, for the eye region image from which the spot is detected, the spot detected from the eye region image through biquadratic interpolation.

In some examples, the colored contact lens determination module 500 includes: a middle region selection unit, a pixel counting unit, and a proportion calculation unit.

The middle region selection unit is configured to select a middle region from the binarized image, and count a total number N_T of pixels in the middle region.

The pixel counting unit is configured to count a number N_1 of pixels having grayscale values of 1 in a portion, outside the pupil region, of the middle region.

The proportion calculation unit is configured to calculate the proportion according to a formula N_1/N_T .

The apparatus according to the example of the disclosure has the same implementation principles and technical effects as those of the foregoing method example. For a concise description, reference may be made to the corresponding contents in the example of the foregoing colored contact lens detection method for the parts not mentioned in the apparatus example. Those skilled in the art can clearly understand that for a convenient and concise description, reference may be made to the corresponding processes in the example of the above colored contact lens detection method for the specific working processes of the foregoing apparatus and units, which will not be repeated herein.

According to the colored contact lens detection method in the above example provided by the description, the service logic may be implemented through a computer program and recorded on a storage medium. The storage medium may be read and executed by a computer, so as to realize the effects of the solution described in the example of the colored contact lens detection method in the description. Therefore, the disclosure further provides a computer-readable storage medium for detecting a colored contact lens. The computer-readable storage medium stores a computer program executable by a processor, where the computer program implements steps in the example of any colored contact lens detection method described above when executed by the processor.

According to the disclosure, a dark colored contact lens and a light colored contact lens may be

accurately recognized without depending on image samples, the strong robustness is realized, and various types of colored contact lenses can be recognized.

The storage medium may include a physical apparatus configured to store information. The information is typically digitized and stored on an electrical medium, a magnetic medium, or an optical medium, etc. The storage medium may include: an electrical information storage apparatus, such as a random access memory (RAM) and a read-only memory (ROM); a magnetic information storage apparatus, such as a hard disk, a floppy disk, a magnetic tape, a magnetic core memory, a magnetic bubble memory, a universal serial bus (USB) flash disk; and an optical information storage apparatus, such as a compact disk (CD) or a digital video disk (DVD). Certainly, there are other readable storage media, such as a quantum memory and a graphene memory.

The above apparatus may further include other embodiments according to the description in the example of the colored contact lens detection method. Reference may be made to the description in the example of the colored contact lens detection method for the particular embodiment, which will not be repeated herein.

The disclosure further provides a colored contact lens detection device. The device may be a stand-alone computer or include an actual operation apparatus using one or more of the methods or one or more of the example apparatuses in the description. The colored contact lens detection device may include at least one processor and a memory storing a computer program, where the processor implements steps in the example of any colored contact lens detection method described above when executing the computer program.

According to the disclosure, a dark colored contact lens and a light colored contact lens may be accurately recognized without depending on image samples, the strong robustness is realized, and various types of colored contact lenses can be recognized.

The above device may further include other embodiments according to the description in the method example or the apparatus example. Reference may be made to the description in the example of the colored contact lens detection method for the particular embodiment, which will not be repeated herein.

An iris recognition method is further provided in an example of the disclosure. As shown in Fig. 11, the method includes S100'-S300'.

S100': a colored contact lens is detected through any colored contact lens detection method described above.

S200': the iris is detected from an eye image, so as to obtain an iris region.

Iris may be detected simultaneously with step S100 in the example of the foregoing colored contact lens detection method or detected independently of S100 in the foregoing example, which will not be limited in the disclosure.

An inner iris boundary (i.e., an outer circle of a pupil) and an outer iris boundary are acquired by detecting the iris, so as to obtain the iris region shown in Fig. 12.

S300': a proportion of pixels having a grayscale value of 1 in the iris region of a binarized image is counted, and for a binarized image having a proportion smaller than a set recognition threshold, the iris is recognized from an eye image.

In the step, a region composed of the pixels having grayscale values of 1 in the iris region of the binarized image is a colored contact lens region within the iris region. The proportion is a proportion of the colored contact lens region within the iris region to the iris region. A large proportion of iris textures are blocked by the colored contact lens when the proportion is high, so that the iris may not be recognized from the eye image. Otherwise, the iris may be recognized from the eye image.

According to the disclosure, the colored contact lens is detected from the eye image, and whether to recognize the iris may be determined according to a colored contact lens detection result. The main thought is as follows: a proportion of the colored contact lens region to an entire iris region is determined through an inner iris boundary location result, an outer iris boundary location result, and a noise template generated. Moreover, whether to recognize the iris from the eye image is determined according to the proportion. Fig. 12 is a schematic diagram of an inner iris boundary location result and an outer iris boundary location result on an iris image in an example of the disclosure. Fig. 13 is a schematic diagram of a noise template in an example of the disclosure.

In some examples, on the basis of the inner iris boundary location result and the outer iris boundary location result in Fig. 12, with reference to the proportion of the pixels having grayscale values of 1 in the iris region in the noise template shown Fig. 13, and the recognition threshold set to 50%, etc, whether to recognize the iris from the eye image may be determined according to the proportion and the recognition threshold. The recognition threshold of 50% is merely illustrative and is not intended to limit the disclosure.

Moreover, during iris recognition, the region of the pixels having grayscale values of 1 in the binarized image is processed as a noise region in a process of extracting an iris feature. In other words, the colored contact lens region in the iris region is processed as the noise region and is not involved in iris feature extraction or feature comparison.

According to the disclosure, the proportion of the colored contact lens region to the iris region is confirmed. Whether to recognize the iris from the eye image is determined according to the proportion. The colored contact lens region is processed as the noise region in the process of recognizing the iris. Accordingly, the accuracy of iris recognition is improved.

The example of the iris recognition method of the disclosure includes the example of the foregoing colored contact lens detection method. For a concise description, reference may be made to the example of the foregoing colored contact lens detection method for the parts not mentioned in the example of the iris recognition method, which will not be repeated herein.

An iris recognition apparatus is further provided in an example of the disclosure. As shown in Fig. 14, the apparatus includes a colored contact lens detection apparatus 10, an iris detection module 20, and a recognition and determination module 30.

The colored contact lens detection apparatus 10 is any colored contact lens detection apparatus 10 in the above example.

The iris detection module 20 is configured to detect an iris from an eye image, so as to obtain an iris region.

The recognition and determination module 30 is configured to count a proportion of pixels having grayscale values of 1 in the iris region of a binarized image, and recognize the iris from the eye image, for a binarized image having a proportion smaller than a set recognition threshold.

When the iris is recognized, a region of the pixels having grayscale values of 1 in the binarized image is processed as a noise region.

The iris recognition apparatus according to the example of the disclosure has the same implementation principles and technical effects as those in the example of the foregoing iris recognition method. For a concise description, reference may be made to the corresponding contents in the example of the foregoing iris recognition method for the parts not mentioned in the apparatus example, which will not be repeated herein.

In the example of the iris recognition method provided in the description, the service logic may be implemented through a computer program and recorded on a storage medium. The storage medium may be read and executed by a computer, so as to realize the effects of the solution described in Example 5 of the description. Therefore, the disclosure further provides a computer-readable storage medium for recognizing an iris. The computer-readable storage medium includes a memory configured to store an instruction executable by a processor, where the instruction

implements steps in the example of the iris recognition method when executed by the processor.

The above apparatus may further include other embodiments according to the description in the example of the iris recognition method. Reference may be made to the description in the example of the colored contact lens detection method for the particular embodiment, which will not be repeated herein.

The disclosure further provides an iris recognition device. The device may be a stand-alone computer or include an actual operation apparatus using one or more of the methods or one or more of the apparatus examples in the description. The iris recognition device may include at least one processor and a memory storing a computer-executable instruction, where the processor implements steps in the example of any one or more of the above methods for recognizing irises when executing the computer-executable instruction.

The above device may further include other embodiments according to the description in the method example or the apparatus example. Reference may be made to the description in the example of the colored contact lens detection method for the particular embodiment, which will not be repeated herein.

It should be noted that the above apparatus or system in the description may further include other embodiments according to the description in the relevant method example. Reference may be made to the description in the method example for the particular embodiment, which will not be repeated herein. Each example in the description is described in a progressive way. Reference may be made to one another for the same or similar parts of the examples. Each example is primarily described in terms of differences from other examples. Especially, for the examples of the type hardware+program and the example of the type storage medium+program, since these example are basically similar to the method example, their descriptions are simple, and reference may be made to the description in the method example for the relevant parts.

The specific examples in the description are described above. Other examples fall within the scope of the appended claims. In some cases, the actions or steps recited in the claims may be performed in an order different from those in the examples and still realize the desired results. Also, the processes depicted in the accompanying figures do not necessarily require the specific order shown or a successive order to realize the desired results. Multitasking and parallel processing are also possible or may be advantageous in some embodiments.

The system, apparatus, module, or unit set forth in the above examples may be specifically implemented by a computer chip or entity or a product having a certain function. A typical

implementation device is a computer. Specifically, the computer may be, for example, a personal computer, a laptop computer, a vehicle-mounted human-computer interaction device, a cellular phone, a camera phone, a smart phone, a personal digital assistant, a media player, a navigation device, an email device, a game console, a tablet computer, a wearable device, or a combination of any ones of these devices.

For a convenient description, the above apparatuses are divided into various modules by function, so as to be described separately. Certainly, when one or more apparatuses in the description are implemented, the function of each module may be implemented in one or more pieces of software and/or hardware. Alternatively, the modules implementing the same function may be implemented by a combination of a plurality of sub-modules or sub-units. The above apparatus examples are merely illustrative. For example, The units are divided merely by logic function. Other division methods may be employed during practical implementation. For example, a plurality of units or components may be combined or integrated into another system. Alternatively, some features may be omitted or may not be executed. Further, mutual coupling, direct coupling, or communication connection shown or discussed may be indirect coupling or communication connection through some interfaces, apparatuses, or units in an electrical or mechanical manner, etc.

Those skilled in the art will also understand that except for implementing a controller by computer-readable program codes only, it is entirely possible to logically program the steps of the method, so that the controller implements the same function in a form of a logic gate, a switch, an application-specific integrated circuit, a programmable logic controller, an embedded microcontroller, etc. Therefore, such a controller can be deemed as a hardware component, and apparatuses included in the controller and configured to implement various functions can also be deemed as structures in the hardware component. Or further, the apparatuses configured to implement various functions can be deemed as software modules for implementing the methods and the structures in hardware component.

The disclosure is described with reference to flowcharts and/or block diagrams of the methods, devices (systems), and computer program products according to the examples of the disclosure. It should be understood that each flow and/or block in the flowcharts and/or the block diagrams and combinations of the flow and/or the block in the flowcharts and/or the block diagrams can be implemented by the computer program instructions. These computer program instructions can be provided for a processor of a general-purpose computer, a special-purpose computer, an embedded processing machine, or another programmable data processing device to produce a machine. Therefore, the instructions executed by the processor of the computer or another programmable data processing device produce an apparatus configured to implement the functions specified in one

or more flows in the flowcharts and/or one or more blocks in the block diagrams.

These computer program instructions can also be stored in the computer-readable memory that can guide the computer or another programmable data processing device to work in a specific way. Therefore, the instructions stored in the computer-readable memory produce a product including an instruction apparatus. The instruction apparatus implements the functions specified in one or more flows in the flowcharts and/or one or more blocks in the block diagrams.

These computer program instructions can also be loaded onto the computer or another programmable data processing device. Therefore, a series of operation steps are executed on the computer or another programmable device to generate computer-implementable processing. The instructions executed on the computer or another programmable device provide steps configured to implement the functions specified in one or more flows in the flowcharts and/or one or more blocks in the block diagrams.

In a typical configuration, a calculation device includes one or more central processing units (CPUs), an input/output interface, a network interface, and a memory.

It should also be noted that the terms “comprise”, “include”, “encompass”, or their any other variations are intended to cover non-exclusive inclusion. Therefore, a process, method, product, or device including a series of elements further includes other elements that are not explicitly listed except for those elements, or further includes elements inherent to such a process, method, product, or device. Without more restrictions, the element defined by the sentence “comprise a ...” and “include a ...” does not exclude the existence of other identical elements in the process, method, or device including the element.

Those skilled in the art should understand that one or more examples in the description may be provided as the method, system, or computer program product. Therefore, one or more examples in the description may be full hardware examples, full software examples, or software and hardware combined examples. Moreover, one or more examples in the description may employ a form of a computer program product that is implemented on one or more computer-available storage media (including, but not limited to, a disk memory, a compact disk read-only memory (CD-ROM), an optical memory, etc.) that encompass computer-available program codes.

One or more examples in the description may be described in the general context of the computer-executable instruction, such as a program module, executed by the computer. Generally, the program module includes routines, programs, objects, components, data structures, etc. that execute specific tasks or implement specific abstract data types. One or more examples in the

description may also be practiced in a distributed calculation environment where tasks are executed by remote processing devices connected through a communication network. In the distributed calculation environment, the program module can be positioned in local and remote computer storage media including storage devices.

Each example in the description is described in a progressive way. Reference may be made to one another for the same or similar parts of the examples. Each example is primarily described in terms of differences from other examples. Especially, since being basically similar to the method example, the system example is simply described, and reference may be made to the description in the method example for the relevant parts. In the description, the descriptions with reference to the terms “an example”, “some examples”, “an instance”, “specific instances”, or “some instances”, etc., mean that a specific feature, structure, material, or characteristic described in connection with the example or instance falls within at least one example or instance in the description. In the description, the illustrative expressions of the above terms do not indicate the same example or instance necessarily. Moreover, the specific feature, structure, material, or characteristic described can be combined in any one or more examples or instances in a suitable way. In addition, those skilled in the art can integrate and combine different examples or instances and features in different examples or instances described in the description without contradiction.

Finally, it should be noted that the above examples are merely the particular embodiments of the disclosure and are intended to describe the technical solutions of the disclosure instead of limiting the disclosure, and the scope of protection of the disclosure is not limited thereto. Although the disclosure has been described in detail with reference to the foregoing examples, it should be understood by those of ordinary skill in the art that those skilled in the art can still make modifications to the technical solutions described in the foregoing examples, readily conceive of variations, or make equivalent replacements to some technical features within the technical scope disclosed in the disclosure. These modifications, variations, or substitutions do not deviate the essence of the corresponding technical solutions from the spirit and scope of the technical solutions in the examples of the disclosure, and should fall within the scope of protection of the disclosure. Therefore, the scope of protection of the disclosure should be defined by the scope of protection of the claims.

Claims

1. A colored contact lens detection method, comprising:

acquiring an eye image;

calculating an average pixel value of the eye image, stretching grayscale values of pixels having grayscale values smaller than the average pixel value in the eye image to a range [0,1], and setting grayscale values of pixels having grayscale values greater than the average pixel value to 0, so as to obtain a first image matrix;

performing a gradient transformation on the eye image, and normalizing a grayscale value of each pixel in an image obtained through the gradient transformation to a range [0,1], so as to obtain a second image matrix;

performing a matrix addition operation on the first image matrix and the second image matrix, and binarizing each pixel in an image obtained through the matrix addition operation according to a set binarization threshold, so as to obtain a binarized image; and

counting a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region, of the binarized image, determining a binarized image having a proportion greater than a set colored contact lens threshold as indicating that no colored contact lens is worn, and determining a binarized image having a proportion smaller than or equal to the set colored contact lens threshold as indicating that the colored contact lens is worn.

2. The colored contact lens detection method according to claim 1, wherein the acquiring an eye image comprises:

preliminarily locating a pupil from an initial eye image, so as to obtain a pupil position, a pupil radius, an upper eyelid boundary, and a low eyelid boundary;

intercepting the initial eye image by selecting a vertex of the upper eyelid boundary, a bottom point of the lower eyelid boundary, and two intersections between the upper eyelid boundary and the lower eyelid boundary as interception boundaries individually, so as to obtain an eye region image; and

detecting a spot from the eye region image, and filling, for the eye region image from which the spot is detected, the spot detected from the eye region image through biquadratic interpolation.

3. The colored contact lens detection method according to claim 1 or 2, wherein the counting a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region, of the binarized

image comprises:

selecting a middle region from the binarized image, and counting a total number N_T of pixels in the middle region;

counting a number N_1 of pixels having grayscale values of 1 in a portion, outside the pupil region, of the middle region; and

calculating the proportion according to a formula N_1/N_T .

4. The colored contact lens detection method according to claim 1, wherein the binarization threshold is 0.6.

5. The colored contact lens detection method according to claim 1, wherein the colored contact lens threshold is 0.8.

6. The colored contact lens detection method according to claim 2, wherein the preliminarily locating a pupil from an initial eye image, so as to obtain a pupil position, a pupil radius, an upper eyelid boundary, and a low eyelid boundary comprises:

preliminarily locating the pupil from the initial eye image through an edge detection operator and edge gradient binarization detection, so as to preliminarily determine the pupil position, the pupil radius, the upper eyelid boundary, and the lower eyelid boundary.

7. The colored contact lens detection method according to claim 3, wherein the middle region is an image obtained by cutting off 1/3 of the binarized image in a vertical direction downwards from an upper edge, cutting off 1/3 of the binarized image in the vertical direction upwards from a lower edge, cutting off 1/3 of the binarized image in a horizontal direction rightwards from a left boundary, and cutting off 1/3 of the binarized image in the horizontal direction leftwards from a right boundary.

8. A colored contact lens detection apparatus, comprising:

an image acquisition module configured to acquire an eye image;

a first image matrix calculation module configured to calculate an average pixel value of the eye image, stretch grayscale values of pixels having grayscale values smaller than the average pixel value in the eye image to a range [0,1], and set grayscale values of pixels having grayscale values greater than the average pixel value to 0, so as to obtain a first image matrix;

a second image matrix calculation module configured to perform a gradient transformation on the eye image, and normalize a grayscale value of each pixel in an image obtained through the gradient transformation to a range [0,1], so as to obtain a second image matrix;

a binarized image calculation module configured to perform a matrix addition operation on the first image matrix and the second image matrix, and binarize each pixel in an image obtained through the matrix addition operation according to a set binarization threshold, so as to obtain a binarized image; and

a colored contact lens determination module configured to count a proportion of pixels having grayscale values of 1 in a portion, outside a pupil region, of the binarized image, determine a binarized image having a proportion greater than a set colored contact lens threshold as indicating that no colored contact lens is worn, and determine a binarized image having a proportion smaller than or equal to the set colored contact lens threshold as indicating that the colored contact lens is worn.

9. The colored contact lens detection apparatus according to claim 8, wherein the image acquisition module comprises:

a preliminary pupil location unit configured to preliminarily locate a pupil from an initial eye image, so as to obtain a pupil position, a pupil radius, an upper eyelid boundary, and a low eyelid boundary;

an image interception unit configured to intercept the initial eye image by selecting a vertex of the upper eyelid boundary, a bottom point of the lower eyelid boundary, and two intersections between the upper eyelid boundary and the lower eyelid boundary as interception boundaries individually, so as to obtain an eye region image; and

a spot filling unit configured to detect a spot from the eye region image, and fill, for the eye region image from which the spot is detected, the spot detected from the eye region image through biquadratic interpolation.

10. The colored contact lens detection apparatus according to claim 8 or 9, wherein the colored contact lens determination module comprises:

a middle region selection unit configured to select a middle region from the binarized image, and count a total number N_T of pixels in the middle region;

a pixel counting unit configured to count a number N_1 of pixels having grayscale values of 1 in a portion, outside the pupil region, of the middle region; and

a proportion calculation unit configured to calculate the proportion according to a formula N_1/N_T .

11. A computer-readable storage medium, storing a computer program executable by a processor, wherein the computer program implements steps of the colored contact lens detection

method according to any one of claims 1-7 when executed by the processor.

12. A colored contact lens detection device, comprising at least one processor and a memory storing a computer program, wherein the processor implements steps of the colored contact lens detection method according to any one of claims 1-7 when executing the computer program.

13. An iris recognition method, comprising:

detecting a colored contact lens through the colored contact lens detection method according to any one of claims 1-7;

detecting the iris from an eye image, so as to obtain an iris region; and

counting a proportion of pixels having grayscale values of 1 in the iris region of a binarized image, and recognizing the iris from the eye image for a binarized image having a proportion smaller than a set recognition threshold.

14. The iris recognition method according to claim 13, wherein the recognizing the iris from the eye image comprises:

processing a region of the pixels having grayscale values of 1 in the binarized image as a noise region.

15. An iris recognition apparatus, comprising:

the colored contact lens detection apparatus according to any one of claims 8-10;

an iris detection module configured to detect the iris from an eye image, so as to obtain an iris region; and

a recognition and determination module configured to count a proportion of pixels having grayscale values of 1 in the iris region of a binarized image, and recognize the iris from the eye image for a binarized image having a proportion smaller than a set recognition threshold.