A Study on the Convergence Algorithm to Identify the Range of Eye congestion

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Abstract: This study studied an algorithm to determine the range of eye congestion with a picture of the bloodshot eyes. After image preprocessing that converts all the skin parts in the red eye photos to black, the color space of the photos was converted to the HSV color space. With the image con-verted to HSV color space, a mask was created by specifying the black and white ranges, and the black was dilated to capture eyelashes and eroded to soften the shape of the object and remove noise more effectively. After combining the black and white masks, a red mask was created with two ranges to identify redness, and then combined to create a single red mask. Finally, an adaptive threshold adaptive mask was created to capture the eyelashes that were not captured by the black mask, and the red mask and adaptive mask were subtracted from the black and white combined mask to create the final combined mask. In the final combined mask, the activated pixel and the total pixel value were calculated to determine the redness range, and then output to get the eye redness range.

Keywords: HSV, Bloodshot eyes, Gaussian blur filter, Adaptive threshold, Mask

1. Introduction

Eye congestion is a condition in which the blood vessels of the conjunctiva, which is a transparent tissue on the sclera, expand or proliferate against the background of the white sclera, and the white pupils appear red, is called eye congestion. The congestion of the eyes means that the conjunctival blood vessels expand or proliferate, and the cause of the expansion or proliferation of blood vessels is caused by the occurrence of infectious and inflammatory diseases and the lack of oxygen supply to the conjunctiva [1].

Eye congestion is a common symptom of numerous eye diseases, including conjunc-tivitis, a disease that causes inflammation in the conjunctiva of the eye, keratitis, a disease that causes inflammation in the cornea of the eye, uveitis, which causes inflammation in the uveolar membrane, which is the middle layer of the eye, glaucoma, which can damage the optic nerve due to increased intraocular pressure, and scleritis, which causes inflam-mation in the sclera of the eye. If the eye congestion is severe, it can cause pain and loss of vision, so it is necessary to visit a hospital for treatment depending on the degree of con-gestion in the eye. In addition, eye congestion is considered one of the initial symptoms in the case of glaucoma, and especially in the case of acute obstructive angle glaucoma, if it is separated as an emergency and treatment is delayed, it can lead to permanent vision loss [2, 3].

In this paper, we intend to develop an algorithm that can finally determine the range of eye congestion by removing the range of sclera and eyelashes by transforming the color space into HSV to identify sclera and eyelashes, and measuring the range of blood vessels that are bloodshot.

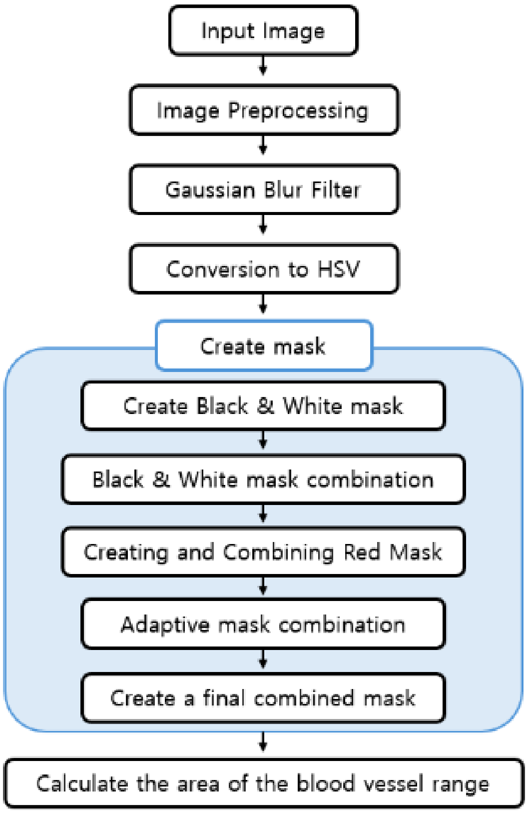


Figure 1. Flow chart for determining the extent of redness in your eyes

2. Algorithm for determining the extent of congestion in the eyes

2.1. Image preprocessing

In the received image, the skin area except for the sclera and red eyes is distinguished by red skin color even after changing to the HSV color space, so the skin part was con-verted to black through image pre-processing to effectively determine the range.

2.2. Gaussian blur

Since most images have noise, we applied Gaussian blur filters after preprocessing the images in this study to reduce noise in the images and emphasize important features.

The Gaussian blur filter is a work of softening the image by replacing the value of each pixel in the image with the Gaussian weighted average of the surrounding pixels, thereby removing small noise and allowing the clear detection of important structures such as blood vessels. The Gaussian blur filter is defined using the Gaussian distribution function (1)

$$G(x,y) = \frac{1}{2\pi\sigma^2}\exp\left(-\frac{x^2+y^2}{2\sigma^2}\right) \quad (1)$$

Here, is the value of the Gaussian function in the coordinates of the kernel, and de-termines the intensity of the blur by the standard deviation of the Gaussian distribution. Using this Gaussian kernel, applying Gaussian blur to the original image is

$$I'(x,y) = \sum_{i=k}^{k} \sum_{j=-k}^{k} I(x+i, y+j) * G(i,j) \quad (2)$$

It is expressed as [4, 5].

2.3. Color space change with HSV

HSV color space is a model developed to overcome complex computational and intu-itive characteristics of RGB color spaces. The abbreviations for HSV represent Hue, satura-tion, and brightness, respectively. H is the type of color measured according to the color wheel from 0° to 360°, and S represents the sharpness or darkness of the color. Finally, V describes the change from the black to the brightest color as the brightness of a color. In this study, specific colors were effectively detected and separated using HSV color space transformation during the image processing [6].

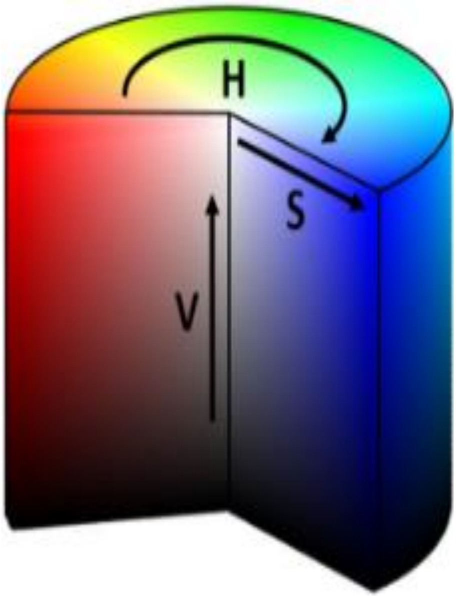


Figure 2. HSV Color Space

The equation for converting RGB values of each pixel in this study into HSV color space values is as follows.

$$H = \begin{cases} 0 & if\ S = 0 \\ \dfrac{60(G-B)}{V - \min(R,G,B)} & if\ V = R \\ 120 + \dfrac{60(B-R)}{V - \min(R,G,B)} & if\ V = G \\ 240 + \dfrac{60(R-G)}{V - min} & if\ V = B \end{cases} \quad (3)$$

$$S = \begin{cases} 0\ if\ V = 0 \\ 1 - \dfrac{\min(R,G,B)}{V} other\ wise \end{cases} \quad (4)$$

$$V = max(R,G,B) \quad (5)$$

Through this process, specific colors are detected, noise is reduced, and HSV color space areas are set as shown in Table 1 to detect two areas: black, which are eyelashes and pupils, white, which is sclera, and red, which is an eye congestion part [7, 8].

Table 1. Range classification based on HSV color space

Color/HSV	Hue	Saturation	Value
Black	0	0	0
White	0	0	100
Red 1	0 ~ 15	50 ~ 100	50 ~ 100
Red 2	165 ~ 180	50 ~ 100	50 ~ 100

2.4. Dilate and Erode

Dilate is a method of expanding objects in an image by expansion. It is done by re-peatedly expanding a specific area of an image, and Erode is a method of reducing objects in an image by erosion. It is done by repeatedly reducing a specific area of an image, such as Dilate [9, 10].

Dilate and Erode are used together to emphasize or remove specific features by changing structural elements of an image in image processing. In this paper, Dilate and Erode operations were applied to detect blood vessels.

2.5. Adaptive threshould

The adaptive threshold is a method of binarizing by dynamically setting a threshold value for each part of an image. This technique dynamically sets a threshold value based on the neighbor value of each pixel, so that it can respond to changes in lighting. In this study, it was used as one of the image pre-processing steps for blood vessel detection, and the vascular structure was emphasized by setting the threshold value using a Gaussian weighted average based on the neighbor value of each pixel [11].

3. Experimental Environment and Process

In this paper, it was built based on the Python programming language and the open source libraries of OpenCV, NumPy, and Matplotlib. The computer specifications are Intel Core i5-10400, 8GB of RAM, and the operating system is Windows 11, 64bit.

In this paper, after changing the color space to HSV, image processing is used to cre-ate a mask by specifying a range of specific colors. Mask is a binarized image used to se-lect or emphasize a specific area, and it is a method of setting pixels in a specific area to '1' and pixel values in the remaining areas to '0' depending on the purpose.

3.1. Black & White mask

Among the Black and White masks, Black was designated as 0, 0, 0 in the order of HSV as a value to distinguish between eyelashes, pupils, and pretreated skin, and White was designated as 0, 0, 100 in the order of HSV as a value to distinguish the scleral part. After that, the two-color masks were combined to create one mask, and as a result, it was confirmed that the black & white range was captured as shown in the right picture in the original left picture of Figure 3.

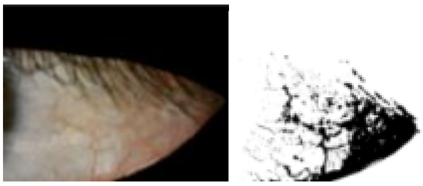


Figure 3. Black & White combined mask

3.2. Red mask

Red mask is a mask to distinguish blood vessels in the red eyes, and two values were designated to clearly capture red, Red 1 was designated as 0-15, 50-100 and 50-100 in the order of HSV, and Red 2 was designated as 165-180, 50-100 and 50-100 in the order of HSV, and the two masks were combined to create one red mask. In the original left picture of Figure 4, the red mask that identified the range of eye congestion as shown on the right was confirmed.

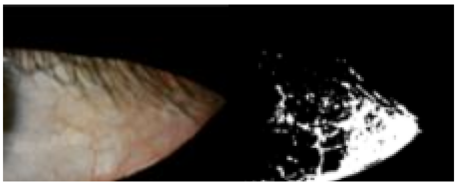


Figure 4. Red combined mask

3.3. Adaptive threshold mask

The adaptive threshold was created to catch the red blood vessels that were not caught in the red mask, and it was confirmed in Figure 5 that the range of fine congestion in the original left picture was captured.

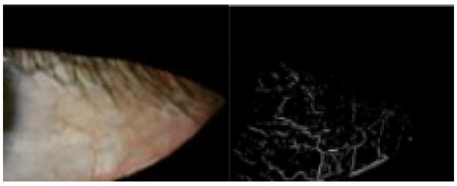


Figure 5. Adaptive threshold combined mask

3.4. Final combined mask

Finally, the combined mask removed the Black & White mask from each of the red mask and adaptive mask measured in the previous step, and then combined the red mask and adaptive mask were combined to derive a final combined mask as shown in the right picture from the original left picture in Figure 6.

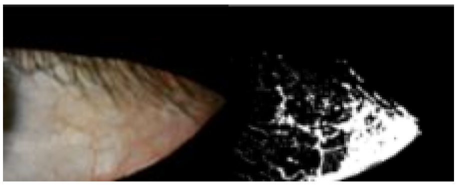
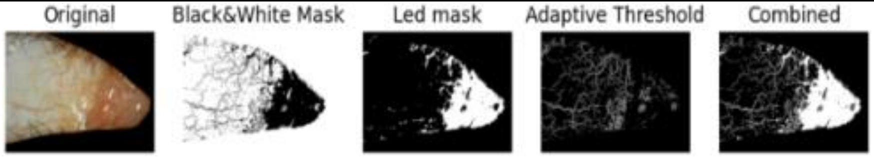
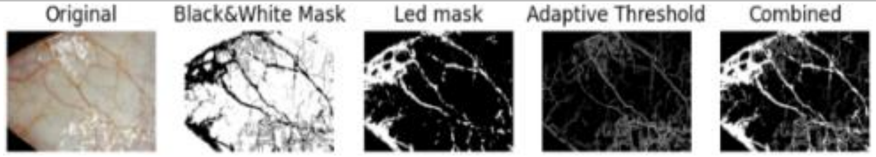
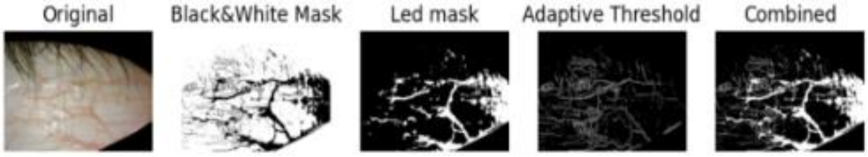


Figure 6. Final combined mask

4. Discussion

Table 2. Overall results and percentages

Picture	Percent (%)
 (a)	19.14%

 (b)	34.49%
 (c)	9.63%
 **(d)**	21.79%
 **(e)**	11.62%
 **(f)**	18.02%
 **(g)**	21.99%

Previously, image processing for analyzing eye redness focused on creating a red mask to detect red areas, but in this study, we focused on applying an adaptive threshold to detect fine redness by applying an adaptive mask. When image processing was performed with photos from different directions as shown in Table 2, the first result was obtained by excluding the black and white mask from the red mask by creating a black and white mask and a red mask, and the second result was obtained by adding an adaptive mask to the first result to detect fine redness. As a result, the first result captured redness as shown in Table 3 first result value, and the second result captured fine redness as shown in Table 3 second result value, resulting in more accurate results. On average, the difference between the first result and the second final result was 4.22%.

Table 3. Result value and error rate

Picture	**First result value (%)**	**Second result value (%)**	**Error rate (%)**
a	14.49%	19.14%	4.65%
b	29.43%	34.49%	5.06%
c	4.26%	9.63%	5.37%
d	15.12%	21.79%	6.67%
e	9.28%	11.62%	2.34%
f	13.95%	18.02%	4.07%

g	20.60%	21.99%	1.39%

5. Conclusions

In order to study an algorithm that can identify the extent of redness with pictures of the red eyes, an image processing technique that can capture the range of redness by applying a Gaussian filter through image preprocessing and converting it into an HSV color space was proposed in this paper. Dilate and Erode image processing techniques were applied to catch eyelashes that are difficult to catch even if the color space is converted to HSV, and light smudging and noise were caught and fine blood vessels were measured by using an adaptive threshold to capture fine parts. As a result of the measurement, photos of lots of redness such as b, d, and g through the process in Figure 7 showed a distribution of more than 20% of the redness range, and photos of not much redness such as c and e showed a distribution of less than 10%. If future research is conducted, it will be conducted by learning the shape of the eyes and applying it so that image processing is possible without pre-processing the skin separately.

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