Abstract—To distinguish small retinal hemorrhages in early diabetic retinopathy from dust artifacts, we analyzed hue, lightness, and saturation (HLS) color spaces. The fundus of 5 patients with diabetic retinopathy was photographed. For the initial experiment, we placed 4 different colored papers on the ceiling of a darkroom. Using each color, 10 fragments of house dust particles on a magnifier were photographed. The colored papers were removed, and 3 different colored light bulbs were suspended from the ceiling. Ten fragments of house dust particles on the camera’s object lens were photographed. We then constructed an experimental device that can photograph artificial eyes. Five fragments of house dust particles under the ochre fundus of the artificial eye were photographed. On analyzing HLS color space of the dust artifact, lightness and saturation were found to be highly sensitive. However, hue was not highly sensitive.

Keywords—Dust artifact, HLS color space, Retinal hemorrhage, and Diabetic retinopathy

I. INTRODUCTION

In Japan, the number of patients with diabetes is increasing along with the rising number of patients with life-style related diseases. According to national research results from the Ministry of Health, Labor, and Welfare in 2005, the number of Japanese patients with diabetes was 16.2 million [1]. They estimated that the number would be 19.0 million in five years. Diabetes is affecting an increasing number of patients, causing complications for eyes, kidneys, and nerves. Many patients with diabetic retinopathy [2] must go to the doctors to prevent blindness [3]-[5]. Early diagnosis is very important [6]; however, detection of small retinal hemorrhages in patients with cloudy ocular media, such as a cataract, is difficult because many hemorrhages are minuscule [7],[8]. Moreover, as shown in Fig. 1, magnified images taken with a fundus camera can be unclear.

A picture taken of several house dust particles flying around in a room would have a number of white spots on it [9],[10]. The flash reflecting from house dust particles causes these white spots. Fig. 2 shows the theory of the creation of these spots. Many of the house dust particles are out of focus, and the flash reflected from the house dust is stronger than that reflected from more distant objects. These white spots are called dust artifacts [11]-[13]. If some dust is on the camera’s object lens, the reflected light from the objects is obscured by dust particles, and black spots appear in the pictures. These black spots are also called dust artifacts.

We investigated the research papers on a dust artifact [16]-[18]. Previously, two methods of image clarification have been explored: deleting dust artifacts from images and removing house dust from parts of the device. However, these studies did not investigate the possible medicinal applications of such image clarification [11], [19]-[23]. On the other hand, one researcher explored image artifacts other than dust artifacts,
using image processing to delete some image artifacts from photographs. And another investigated how the image artifacts enter into the fundus photographs [24]-[26]. No one has theoretically examined the effect of flash photos taken in the presence of airborne dust, nor conducted basic research on the light transparency of house dust particles. The cause of white and black spots on photographs must be determined. We performed a basic experiment to photograph white and black spots and examined their influence on the ability of computers to distinguish small retinal hemorrhages in diabetic retinopathy from dust artifacts. Furthermore, to examine the possible clinical applications of our findings, we performed an experimental involving dust artifact photography using an artificial eye.

Small hemorrhages in diabetic retinopathy are distinguished from dust artifacts by using the color space in a fundus photograph [27]. A dust artifact is caused by the diffused reflection of house dust and covering of flash light. This dust artifact is reflected brightly by diffused reflection and is darkly reflected by covering of light. Therefore, the most important element in the concept of color space is lightness. House dust is reflected by covering of light. Therefore, the most important artifact is reflected brightly by diffused reflection and is darkly reflected by house dust and covering of flash light. This dust artifact is caused by the diffused reflection of house dust particles. The cause of white spots and black spots on photographs must be determined. We performed an experiment using 3 colored light bulbs and a magnifier to investigate the influence of white and black spots.

II. PURPOSE

To apply the concept of HLS color space to ophthalmologic diagnosis, we performed an experiment involving photography of an artificial eye.

III. METHODS

A. Method for distinguishing small retinal hemorrhages from dust artifacts using the HLS color space

The upper side of Fig. 4 shows the division of the fundus image into the hemorrhagic area and the area around the hemorrhage. Paint Shop Pro v. 8.0 was used to visualize the HLS color spaces of these four areas, and the RGB values were transformed from the fundus image to the HLS color space. The hue, lightness, and saturation values ranged from 0 to 255. Hue is the actual color and value is the number assigned on the color wheel (red = zero, yellow = 43, green = 85, cyan = 128, blue = 170, and magenta = 212). Lightness is the brightness of the hue (zero = black, 128 = middle grey, and 255 = white). Saturation is the level of grey added to the hue (zero = very grey and unsaturated and 255 = no grey and fully saturated) [32]. Equation (1) shows the average color space of the hemorrhagic area, $\text{avehm}$, and (2) shows the average color space of the area around hemorrhage, $\text{aveahm}$.

$$\text{Average color space of the hemorrhagic area}$$

$$\text{Average color space of the area around the hemorrhage}$$

$$\text{Average color space of the dust artifact area}$$

$$\text{Average color space of the area around the dust artifact}$$

Fig. 4 The average color space of both the hemorrhagic area and the area around the hemorrhage (up), and the average color space of the dust artifact area and the area around the dust artifact (down)

$$\text{avehm} = \begin{bmatrix} \text{AveH}_{\text{hm}} \\ \text{AveL}_{\text{hm}} \\ \text{AveS}_{\text{hm}} \end{bmatrix}$$

(1)

$\text{aveahm}$

$\text{aveda}$

$\text{aveahm}$

$\text{aveda}$
The lower side of Fig. 4 shows the division of the image between the dust artifact area and the area around the dust artifact. Paint Shop Pro was used to visualize the HLS color spaces of both these areas. (3) shows the average color space of the dust artifact area, aveDa, and (4) shows the average color space of the area around dust artifact, aveada.

\[
\text{aveDa} = \begin{bmatrix}
\text{AveH }_\text{da} \\
\text{AveL }_\text{da} \\
\text{AveS }_\text{da}
\end{bmatrix}
\]  

(3)

\[
\text{aveada} = \begin{bmatrix}
\text{AveH }_\text{ada} \\
\text{AveL }_\text{ada} \\
\text{AveS }_\text{ada}
\end{bmatrix}
\]  

(4)

The hue is generally expressed using 360° of a color circle [31]-[33]. The average degrees of hue related to a hemorrhage are expressed by AveHD_mh and AveHD_amh. The average degrees of the hue related to a dust artifact are expressed by AveHD_da and AveHD_ada. (5) to (8) show these average degrees of hue.

\[
\text{AveHD }_\text{hm} = \frac{\text{AveH }_\text{hm}}{255} \times 360°
\]  

(5)

\[
\text{AveHD }_\text{ahm} = \frac{\text{AveH }_\text{ahm}}{255} \times 360°
\]  

(6)

\[
\text{AveHD }_\text{da} = \frac{\text{AveH }_\text{da}}{255} \times 360°
\]  

(7)

\[
\text{AveHD }_\text{ada} = \frac{\text{AveH }_\text{ada}}{255} \times 360°
\]  

(8)

(9) to (12) show the average color spaces, AveHm, AveAhm, AveDa, and AveAda using the average degrees of hue.

\[
\text{AveHm} = \begin{bmatrix}
\text{AveHD }_\text{hm} \\
\text{AveL }_\text{hm} \\
\text{AveS }_\text{hm}
\end{bmatrix}
\]  

(9)

\[
\text{AveAhm} = \begin{bmatrix}
\text{AveHD }_\text{ahm} \\
\text{AveL }_\text{ahm} \\
\text{AveS }_\text{ahm}
\end{bmatrix}
\]  

(10)

\[
\text{AveDa} = \begin{bmatrix}
\text{AveHD }_\text{da} \\
\text{AveL }_\text{da} \\
\text{AveS }_\text{da}
\end{bmatrix}
\]  

(11)

\[
\text{AveAda} = \begin{bmatrix}
\text{AveHD }_\text{ada} \\
\text{AveL }_\text{ada} \\
\text{AveS }_\text{ada}
\end{bmatrix}
\]  

(12)

\[
\text{DiffH }_\text{hm} = \frac{\text{AveH }_\text{hm}}{255} \times 360° - \frac{\text{AveH }_\text{ahm}}{255} \times 360°
\]  

\[
\text{DiffH }_\text{da} = \frac{\text{AveH }_\text{da}}{255} \times 360° - \frac{\text{AveH }_\text{ada}}{255} \times 360°
\]  

\[
\text{DiffH }_\text{ahm} = \frac{\text{AveH }_\text{ahm}}{255} \times 360° - \frac{\text{AveH }_\text{ada}}{255} \times 360°
\]  

\[
\text{DiffH }_\text{ada} = \frac{\text{AveH }_\text{ada}}{255} \times 360° - \frac{\text{AveH }_\text{ahm}}{255} \times 360°
\]  

\[
\CngL_{\text{hm}} = \frac{1}{\text{AveCngL }_{\text{hm}}} \times \text{AveCngL }_{\text{hm}}
\]  

\[
\CngL_{\text{da}} = \frac{1}{\text{AveCngL }_{\text{da}}} \times \text{AveCngL }_{\text{da}}
\]  

\[
\CngL_{\text{ahm}} = \frac{1}{\text{AveCngL }_{\text{ahm}}} \times \text{AveCngL }_{\text{ahm}}
\]  

\[
\CngL_{\text{ada}} = \frac{1}{\text{AveCngL }_{\text{ada}}} \times \text{AveCngL }_{\text{ada}}
\]  

\[
\text{DiffL }_{\text{hm}} = \frac{1}{\text{AveCngL }_{\text{hm}}} \times \text{AveCngL }_{\text{hm}} - \frac{1}{\text{AveCngL }_{\text{ahm}}} \times \text{AveCngL }_{\text{ahm}}
\]  

\[
\text{DiffL }_{\text{da}} = \frac{1}{\text{AveCngL }_{\text{da}}} \times \text{AveCngL }_{\text{da}} - \frac{1}{\text{AveCngL }_{\text{ada}}} \times \text{AveCngL }_{\text{ada}}
\]  

\[
\text{DiffL }_{\text{ahm}} = \frac{1}{\text{AveCngL }_{\text{ahm}}} \times \text{AveCngL }_{\text{ahm}} - \frac{1}{\text{AveCngL }_{\text{ada}}} \times \text{AveCngL }_{\text{ada}}
\]  

\[
\text{DiffL }_{\text{ada}} = \frac{1}{\text{AveCngL }_{\text{ada}}} \times \text{AveCngL }_{\text{ada}} - \frac{1}{\text{AveCngL }_{\text{ahm}}} \times \text{AveCngL }_{\text{ahm}}
\]  

\[
\text{CngS }_{\text{hm}} = \frac{1}{\text{AveCngS }_{\text{hm}}} \times \text{AveCngS }_{\text{hm}}
\]  

\[
\text{CngS }_{\text{da}} = \frac{1}{\text{AveCngS }_{\text{da}}} \times \text{AveCngS }_{\text{da}}
\]  

\[
\text{CngS }_{\text{ahm}} = \frac{1}{\text{AveCngS }_{\text{ahm}}} \times \text{AveCngS }_{\text{ahm}}
\]  

\[
\text{CngS }_{\text{ada}} = \frac{1}{\text{AveCngS }_{\text{ada}}} \times \text{AveCngS }_{\text{ada}}
\]  

\[
\text{Ev} = \begin{bmatrix}
\text{EvH} \\
\text{EvL} \\
\text{EvS}
\end{bmatrix} = \begin{bmatrix}
\frac{\text{AveDiffH }_{\text{hm}}}{\text{AveCngH }_{\text{hm}}} & 0 & 0 \\
0 & \frac{\text{AveL }_{\text{hm}}}{\text{AveCngL }_{\text{hm}}} & 0 \\
0 & 0 & \frac{\text{AveS }_{\text{hm}}}{\text{AveCngS }_{\text{hm}}}
\end{bmatrix} \times \text{CngDa}
\]  

(16)

B. Fundus photography of the five patients with diabetic retinopathy

Fundus photographs were taken in five patients using the fundus camera Topcon TRC-50EX mydriatic retinal camera with a Nikon digital camera D1x. The image sensor was a 23.7 × 15.6-mm, 12-bit RGB CCD [34]. The file format is JPEG baseline-compliant. The number of recorded pixels is 2000 × 1312. Paint Shop Pro was used to visualize the average color space of the hemorrhagic area, avehm, and the average color space of the area around the hemorrhage, aveahm, in two locations of the photograph.

C. Photography of dust artifacts using three colored light bulbs

In order to investigate the influence of black spots, the experiment was performed using colored light bulb. In the darkroom, three colors of bulbs (yellow, brown, and red) were suspended from the ceiling of the experimental device (Fig. 5). The camera had a dust particle that was 5 × 5 × 5 mm³ on the object lens. Using each color of bulb, 10 fragments of house dust particles were photographed. The distance between the camera’s object lens and the edge of the light bulb was 50 mm. Paint Shop Pro was used to visualize the HLS color spaces of...
the dust artifact area and the area around the dust artifact. We used a FinePix J30 digital camera (Fuji Photo Film Co., Japan) in these experiments. We also used a 1/2.3–in square-pixel charged-coupled device (CCD) with a primary color filter [35]. The file format is Exif 2.2 JPEG (compressed). The number of recorded pixels was 4000 × 3000. Table I shows specifications of the colored light bulbs used in this study.

### Table I

<table>
<thead>
<tr>
<th>Model</th>
<th>GWR110 V60</th>
<th>GWY110 V60</th>
<th>Balloon Color</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maker</td>
<td>TOKI</td>
<td>Kyokko</td>
<td></td>
</tr>
<tr>
<td>Color Cap</td>
<td>Red</td>
<td>Yellow</td>
<td>Brown</td>
</tr>
<tr>
<td>Power</td>
<td>60W</td>
<td>60W</td>
<td></td>
</tr>
<tr>
<td>Voltage</td>
<td>100/110V</td>
<td>100/110V</td>
<td></td>
</tr>
<tr>
<td>Total length</td>
<td>127mm</td>
<td>124mm</td>
<td></td>
</tr>
<tr>
<td>Bulb Sphere</td>
<td>95mm</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**D. Photography of dust artifacts using a magnifier**

In order to investigate the influence of white spots, the experiment was performed using a magnifier. Fig. 6 shows the experimental device. The darkroom had four colors of papers on its ceiling: red, yellow, brown, and black. The distance between the camera’s object lens and the 8-diopter magnifier was 50 mm, and the distance between the magnifier and the ceiling was 485 mm. The magnifier held a dust particle measuring $5 \times 5 \times 5$ mm$^3$. Using a flash and each color of paper, 10 fragments of dust particles were photographed. The magnifier was a Claire Lupe PB60 (Vixen Co.) and its specifications are shown in Table II.

### Table II

<table>
<thead>
<tr>
<th>Specifications of the Magnifier</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lens diameter</td>
</tr>
<tr>
<td>Diophter</td>
</tr>
<tr>
<td>Magnification</td>
</tr>
<tr>
<td>Lens material</td>
</tr>
<tr>
<td>Lens coat</td>
</tr>
<tr>
<td>Frame material</td>
</tr>
</tbody>
</table>

**E. Optical system diagram of the experimental device**

We constructed an experimental device to photograph the fundus of artificial eyes. The optical system of this device was same as that of a fundus camera. Therefore, the optical system of the fundus device was analysed using optical design software (OpTaliX-LT 7.11). Fig. 7 shows an illumination optical system and a photographic optical system, including the distance between lenses and the distance between a lens and a mirror per mm. The device consists of a canon EOS 50D camera with an EF 50 mm f/1.8-2 camera lens, a Speedlite 270EX flash, an object lens with 50-mm focal length and a center thickness of 16 mm, four double-convex lenses with focal lengths of 100 mm and center thicknesses of 10 mm, three aperture stops, a mirror with a hole with 4 mm diameter, another mirror, and an artificial eye. The object lens, four double-convex lenses, and two mirrors are all 50 mm in diameter. Fig. 7 shows the aperture stop equipped with a 13-mm-diameter hole on the right side of the device. The hole in the middle aperture stop was 45 mm in diameter. The aperture stop on the left side of the device was equipped with a 39-mm-diameter hole. Three wires hang a black plate 15 mm in diameter in the center of the hole. The axial distance from eyeground to the image surface is 797.3 mm and that from eyeground to the strobe surface is 858.9 mm.

**F. Artificial eye**

The artificial eye, shown in Fig. 8, consists of a plane-convex lens, a black spacer with a hole 18 mm in diameter, and a hemispherical cup. The plane-convex lens was 20 mm in diameter, with a 4.6-mm center thickness and a 17.4-mm back focal length. The hemispherical cup was 20 mm in diameter with a thickness of 0.5 mm.
The distance from the surface of the plane-convex lens to the eyeground was 22 mm. MgF2 coating was applied to the surface of the plane-convex lens. The hemispherical cup was made of polyethylene terephthalate. Because the fundus color in Fig. 1 resembles ocher, the cup was painted using an ochreous matt color spray (Asahipen Corp., Osaka, Japan). Gold amber was used as ocher.

### G. Experimental device

The experimental device, shown in Fig. 9, was equipped with an illumination optical system and a photographic optical system separated by a mirror with a hole 4 mm in diameter. An MgF2 coating was applied to the surface of all lenses. The image sensor used was a 22.3 × 14.9-mm CMOS sensor [36]. The file format was JPEG, RAW (14-bit Canon original). The number of recorded pixels was 4752 × 3168.

### H. Specimens

We prepared five types of fragments of house dust measuring about 5 × 5 × 5 mm³. Each fragment was set at the central part and artificial eye side on the object lens. Then fragments were photographed one by one. Paint Shop Pro was used to visualize the HLS color space of four areas, as shown in Fig. 4.

### I. Calculation of evaluation space for house dust using HLS data

(16) shows the color space for evaluation (Ev), which is the ratio of change of CngDa to AveCngHm. CngDa is the color space change in the dust artifact area and AveCngHm is the average of the color space change in the hemorrhage area. The greater the absolute values of EvH, EvL, and EvS, the greater the extent to which the HLS color space can be used to distinguish small hemorrhages from dust artifacts. These absolute values must be > 1.0.

### IV. Results

#### A. The changed color spaces of the hemorrhagic area

Fig. 10 shows 10 images of small retinal hemorrhagic areas clipped from 5 fundus photos. Paint Shop Pro was used to visualize both avehm and aveahm from the images. The changed color space of the hemorrhagic areas is CngHm. CngHm was calculated by substituting avehm and aveahm in (5), (6), (9), (10), and (13). Table III shows the average and standard deviation of CngHm.

#### B. Dust artifacts photographed under the colored light bulbs

Fig. 11 shows 30 images of dust artifacts clipped from the photos taken by methods C. Paint Shop Pro was used to visualize both aveda and aveada from 30 images in Fig. 11. Ev was calculated by substituting aveda and aveada for AveDa and AveAda in (7), (8), (11), (12), (14), (15), and (16). If AveHD_ada was near 360°, we changed AveHD_ada to “AveHD_ada – 360°” to maintain the continuity of the color wheel. We used the preceding methods for AveHD_ada in results B and C.
To compare the color spaces of the small hemorrhagic areas with the color spaces of the dust artifact areas, Fig. 12 shows both the averages and the standard deviations of EvL values, obtained from photos taken of dust particles under each color of bulb. The averages are shown as both bar graphs and values, and the standard deviations are shown as lines. According to Fig. 12, the average EvL values were brown 5.7, red 6.4, and yellow 10.0. The average CngL_ad values of all colors were 5.7 times more than the AveCngL_hm values. This shows that \(|CngL_{ad}| > |AveCngL_{hm}|\) was consistently dominant. The lightness can be used to distinguish small hemorrhages from dust artifacts.

According to Table IV, the average EvH values were red −3.3, brown 1.6, and yellow 7.9. The standard deviation of EvH values for brown was a little large. This shows that \(|CngH_{da}| > |AveCngH_{hm}|\) was consistently dominant, except for brown. The hue can be used to distinguish small hemorrhages from dust artifacts, except for brown. Next, the average EvS values were red 0.9, brown −2.8, and yellow −2.2. The standard deviations of EvS values for all colors were large; thus, saturation cannot be used to distinguish small hemorrhages from dust artifacts.

According to Fig. 14, all of EvL values were below zero because AveCngL_hm values were below zero and CngL_ad values were above zero. The absolute values of average EvL were yellow 8.5, brown 11.5, red 14.5, and black 24.0. The greater the absolute values of EvL, the greater the extent to which the HLS color space can be used to distinguish small hemorrhages from dust artifacts. Thus, lightness can distinguish small hemorrhages from dust artifacts.

According to Table V, \(|CngS_{da}|\) values were very large if the background color was black or yellow, and \(|CngS_{da}| > |AveCngS_{hm}|\) held true. Their standard deviations were a little large, but that presented no problem. If the background color is black or yellow, saturation can distinguish small hemorrhages from dust artifacts; however, if the background color is red or brown, saturation cannot distinguish small hemorrhages from dust artifacts because their standard deviations are large. On the other hand, if the background color is black, red or yellow, \(|CngH_{da}| > |AveCngH_{hm}|\) holds true. Their standard deviations were not large, and presented no problem. If the background color is black, red or yellow, hue can distinguish small hemorrhages from dust artifacts; however, when the
background color is brown, the hue cannot distinguish small hemorrhages from dust artifacts because of the large standard deviations.

D. Changed color spaces of the dust artifact area

The ocher fundus of the artificial eye was photographed 5 times with a fragment of house dust set on the central part and artificial eye side of the object lens. Fig. 15 shows 5 images of dust artifact areas.

![Five images of the dust artifact areas clipped from the artificial eye photographs](Image)

E. Evaluation space for house dust on the object lens under the artificial eye photographs

Table VI shows averages and standard deviations of the EvL, EvS, and EvH values. These values are obtained from photographs of dust particles on the object lens. As seen in Table VI, the average CngL_da value was 9.5 times higher than the AveCngL_hm values, indicating that “|CngL_da| > |AveCngL_hm|” was consistently dominant. Therefore, lightness can be used to distinguish small hemorrhages from dust artifacts. In addition, the average CngS_da value was 5.0 times higher than the AveCngS_hm values, indicating that “|CngS_da| > |AveCngS_hm|” was consistently dominant. Thus, saturation can also be used to distinguish small hemorrhages from dust artifacts. However, the average CngH_da value was lower than the AveCngH_hm values, indicating that “|CngH_da| > |AveCngH_hm|” was not consistently dominant. Therefore, it is difficult to distinguish small hemorrhages from dust artifacts on the basis of hue.

![The relation diagram among four background colors](Image)

According to Table VII, the lightness can distinguish hemorrhages from dust artifacts in any of the four states.

According to Table VIII, the saturation possibly had different capabilities for each color. If the background color is yellow, saturation can make the distinction, but not for black spots. In contrast, if the background color is black, saturation can make the distinction only for white spots. If the background color is red or brown, distinguishing the spots on the basis of saturation will be difficult.

V. Discussion

A. The relation among four background colors

Fig. 16 shows the relation of hue to lightness for four of the background colors used in the experiment. In reporting the experimental results in Tables VII to IX, we used “T” if the indices could distinguish hemorrhages from dust artifacts, and “F” if not; we used “M” to indicate that indices could distinguish hemorrhages from dust artifacts with some conditions. For example, if the background color is red or yellow and if the index can distinguish hemorrhages from dust artifacts, then both segments 1 and 4 are “T.” Segment 1 is “M” and segment 4 is “F” if the index can make the distinction when the background color is red but not when the background color is yellow. Segment 1 is “F” and segment 4 is “M” if the index cannot make the distinction when the background color is red, but it can if the background color is yellow. Both segments 1 and 4 are “F” if the index cannot make that distinction when the background colors are either red or yellow.

![The relation diagram among four background colors](Image)

As seen in Table IX, for each color, hue has different capabilities for distinguishing hemorrhages from dust artifacts. If the background color is red, yellow, or black, hue...
can make the distinction. If the background color is brown, distinguishing the spots on the basis of hue will be difficult.

**B. Photographing the artificial eye**

We constructed the experimental device that can photograph artificial eyes. The fundus color of the artificial eye was ochre to resemble the fundus color of diabetic retinopathy. Each specimen was positioned on the central part and artificial eye side of the object lens and was photographed using the experimental device. When HLS color space was analyzed, lightness and saturation were found to be highly sensitive. However, hue was not highly sensitive. Using the experiment involving photography of the artificial eye, data about the eyeball could be obtained. Hence, this experiment was more important than the basic experiment using the magnifier and light bulbs. Further experiments involving changes in fundus color of the artificial eye will be performed in future. Moreover, the specimen size must be small to investigate the optimal size of house dust to be photographed.

**VI. CONCLUSION**

We investigated methods to distinguish small retinal hemorrhages in diabetic retinopathy from dust artifacts using HLS color space. Because an experiment to photograph a dust artifact was required, we constructed an experiment involving colored light bulbs and a magnifier. Dust artifacts were classified into two categories: black spots and white spots. Background colors were red, yellow, brown, and black. In HLS color space, lightness could distinguish hemorrhages from dust artifacts under all conditions; however, hue and saturation could distinguish hemorrhages from dust artifacts only under some conditions.

Furthermore, we constructed an experimental device that can photograph artifical eyes. The experimental device photographed the dust artifact using the artificial eye with an ocherous fundus. Lightness and saturation were found to be highly sensitive. However, hue was not highly sensitive. These methods can automatically distinguish small hemorrhages from dust artifacts using lightness and saturation.

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**REFERENCES**

Naoto Suzuki is earned the necessary credits, but before receiving Ph.D., he left the doctoral course in Graduate School of Engineering, The University of Tokyo, in 2000. He researched on an ophthalmologic device while working with a medical device maker and received Ph.D. from Chiba University in 2007. Since 2009, he has been an assistant professor in Hiroshima International University.