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Generating Lambertian Image by Removing Specular Reflection Component and Difference of Reflectance Factor Using HSV

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Abstract: When Lambertian image is assumed to recover the 3-D shape from endoscope image under the assumption of a point light source and perspective projection, the image is converted to a Lambertian image *a priori* in general. The aim of this paper is to reduce this calculation cost and to improve the accuracy of results by the equalization of reflectance using brightness value V and classification of the hue H. Both of H and V are obtained by HSV conversion from the original RGB image. The effectiveness of the proposed method was evaluated through the experiments using simulation image and actual endoscope image.

1. Introduction

It is important to recognize polyp using endoscope in the medical diagnosis. However, information for the polyp obtained from an endoscope image is limited and even in the case of diagnosis by the medical doctor, and recognition of polyp is sometimes difficult. Therefore, some shape recovery methods to support the diagnosis of endoscope image have been proposed.

Paper [1] [2] have been proposed for shape recovery from endoscope image. The paper [1] uses both of optical constraint and geometrical constraint to optimize gradient parameters to recover the depth. Based on the obtained gradient parameters by optimization, the method calculates depth using optical constraint equation again. The paper [2] uses VBW model [3] which calculates the depth by Hamilton-Jacobi equation [4] which combined Prados model [5] and Faugeras model [6]. Original intensity obtained from an endoscope image used in the calculation of the optical constraint equation is assumed to be Lambert reflectance in [1] [2]. However, the original intensity obtained from an endoscope image is not Lambertian but includes specular reflection component and different textures by blood vessels with difference reflectance factors.

Paper [7] has been proposed for removing specular reflection component of endoscope image. The paper [7] removed specular reflection component by the following procedures. It gets RGB minimum value V of each pixel by Eq.(1). L is image, i is channel of RGB, (x,y) is coordinate.

$$V_{\min}(x, y) = \min_i\{L_i(x, y)\} \tag{1}$$

Threshold T_v is obtained by Eq.(2) which calculates average μ_v and standard deviation σ_v.

$$T_v = \mu_v + 0.5\sigma_v \tag{2}$$

Offset $\tau(x, y)$ is obtained by Eq.(3) using threshold T_v.

$$\tau(x, y) = \begin{cases} T_v & \text{if } V_{\min}(x, y) > T_v \\ V_{\min}(x, y) & otherwise \end{cases} \tag{3}$$

The Specular reflectance region is extracted by difference of $V_{\min}$ and offset $\tau(x, y)$. Finally, obtained specular reflection region is interpolated by inpainting. Although paper [7] can remove the specular reflection component, it does not use processing of reflectance equalization.

While paper [8] has been proposed for remove specular reflectance component and reflectance equalization of endoscope image. The method extracts the specular reflection region by logical OR operation between mask image which is obtained from normalized RGB using grayscale value and mask image obtained from the variation of value by Median filter. The reflectance is equalized using mean-shift-clustering. Mask image generating and reflectance equalization processing are as follows. RGB components of the input image are converted to normalized RGB by Eq.(4).

$$[Rn_{(i,j)}, Gn_{(i,j)}, Bn_{(i,j)}] = \frac{[R_{(i,j)}, G_{(i,j)}, B_{(i,j)}]}{Y_{(i,j)}} \tag{4}$$

$[Rn, Gn, Bn]$ is normalized RGB value,$[R, G, B]$ is RGB component of input image, Y is grayscale value, (i, j) is image coordinate. The region that $[Rn, Gn, Bn]$ becomes close to (1,1,1) is regarded as a specular reflection region when the white light source is used. The paper [8] uses Eq.(5) for the reflectance equalization.

$$\frac{C_1}{C_2} = \frac{E_1}{E_2} \rightarrow C_1 = C_2\frac{E_1}{E_2} \tag{5}$$

C is reflectance for each cluster, and E is the intensity value of images. Eq.(5) clusters each reflectance. Eq.(5) clusters each reflectance and it absorbs C_2 to C_1. However, there is a problem that the clustering result depends on the initial point because initial point is selected at random when the clustering process begins. In this sense, multiple clustering makes it possible to get the stable result by taking average of those trials. Specular reflection region is extracted from the uniform reflectance image by absorbing reflectance and removed region is interpolated by Bi-cubic interpolation from the intensities atthe surrounding points.

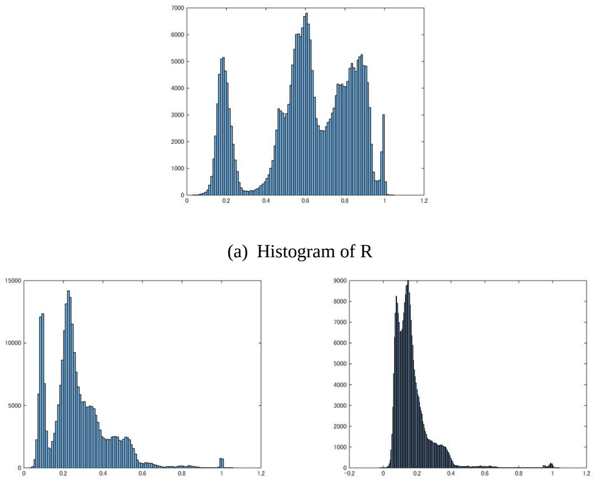
Actually the mask image using the RGB components cannot detect specular reflection region with high accuracy since endoscope images contain almost R components in the whole image. Further, when Mean-shift-clustering is applied for classification of reflectance factors to generate a uniform reflectance factor, the result does not become stable due to the randomness of initial point according to Mean-shift-clustering. Paper [8] performs these procedures repeatedly to obtain stable result. The problem is that this methods costs much computation time.

So this paper proposes a new method to improve the detection of specular reflection region by generating mask images which derive from the RGB except R component. In addition, this paper reduces the calculation cost and improves accuracy and stability of the result by equalizing processing using H (Hue) value from the histogram and using V (Value).

2. Proposed Method

2.1 Detection of specular reflectance region

This paper tries to detect specular reflection region using Fast Fourier Transform (FFT). FFT is used to obtain the contour of the specular reflection region. Subsequently, the region corresponding to inside the contour is detected using threshold for each of RGB components. The problem is that it is difficult to detect the specular reflection component using R component since the endoscope image and the specular reflectance area are mostly composed by R. Since R components take high values as shown in the distribution of Fig.1, it is difficult to separate the specular reflection and high values from the R component. Therefore, the method detects the specular reflection component using the color component which has the lowest value as the sum of whole intensities. B or G component is used to extract the specular reflection component.



(a) Histogram of R

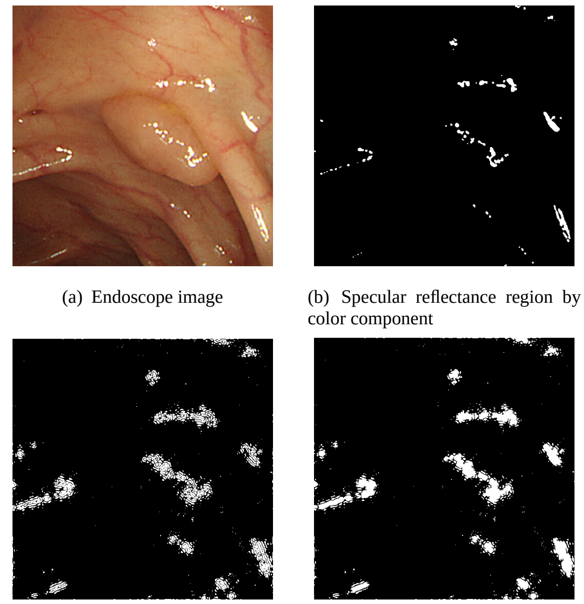
(b) Histogram of G

(c) Histogram of B

Figure 1. RGB histogram of endoscope image

Expansion process and logical OR operation are apply to the extracted two candidate specular reflection regions and mask image is generated. When the specular reflection component exists around the polyp edge, interpolation is done by taking sum of 8 neighboring points based on the filter of weighted distance to remain the polyp edge information with remaining the edge information.

Examples of the mask image generated by the proposed method are shown in Fig.2. Fig.2(a) shows the endoscope image which contains the specular reflectance region. Fig.2(b) shows the mask image which is obtained from color components except R component. Fig.2(c) shows the mask image which is obtained based on the high frequency component taken by FFT. Fig.2(d) shows the mask image which is obtained by taking logical OR of Fig.2(b) and Fig.2(c).



(a) Endoscope image

(b) Specular reflectance region by color component

(c) Specular reflectance region by high frequency component

(d) Mask image by (b) and (c)

Figure 2. Extaction of specular reflection region

2.2 Equalization of reflectance

Endoscope image has multiple colors based on the textures on the surface. The original image has many colors and color is affected to the reflectance factor. Since the original image has many reflectance factors, it is important to convert a different reflectance factor to the uniform reflectance factor in the whole image to recover the shape with the assumption of uniform Lambertian reflectance. This paper performed equalization processing of reflectance factors using brightness value V and classification of each reflectance using histogram of hue H.

Suppose there is the difference of RGB color at near two points where the surface gradient and depth are assumed to be almost the same, this difference should be caused from that of reflectance factor. While brightness value V is converted based on the maximum value of RGB. This assumption leads to the result that two points should have almost the equal V if these points have almost the same surface gradients and depth. Procedures of the proposed method are shown in Fig.3.

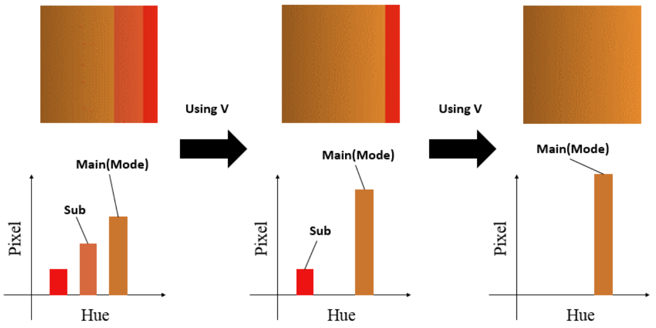


Figure 3. Procedures of proposed method

First, the method selects the mode in the histogram of H and takes it as a main class. Second, the nearest bin to the main class is taken to be the sub class. Then, the subclass are assimilated to the main class using V ratio. V ratio is obtained from neighboring pixels of image in the main class and subclass. Also, pixels except the adjacent pixels of subclass are assimilated to main class using nearest V ratio from an interesting point. Finally, reflectance of image is uniformed by performing the same processing to all subclasses.

Reflectance equalization processing of proposed method can be represented as the Eq.(6) of iterative summation according to the iterative processing.

$$\begin{aligned} H_0 &= H_{main\_start} \\ H_{main\_end} &= (((H_0 + f(H_0, H_1, 1)H_1) + f(H_0, H_2, 2)H_2) \\ &\quad +\ldots\ldots) + f(H_0, H_{n-1}, n-1)H_{n-1} \\ &= \sum_{i=1}^{n-1} f(H_0, H_i, i)H_i \end{aligned} \tag{6}$$

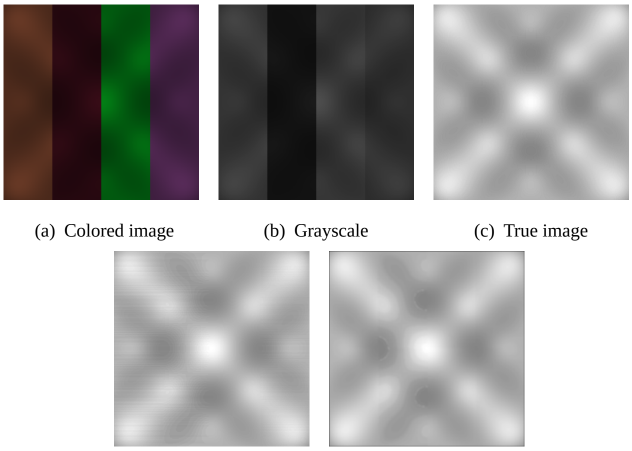
$$f(H_0, H_i, num) = \frac{\sum_{j=1}^{num-1} f(H_0, H_j)H_j}{H_i}$$

H_{main_start} is the main class before equalization processing. H_{main_end} is the main class after equalization processing. H_i is subclass. n is the number of H histogram bins. num is total of processed interesting subclass.

3. Experiments

3.1 Experiment using simulation image

Simulation images generated for concave convex curved surface are shown in Fig.4(c). This image shows a uniform Lambertian image. Fig.4(a) shows an image which added different color reflectance factors. Fig.4(b) shows a corresponding grayscale image of Fig.4(a). The error between true intensity and result by paper [8] (previous method) is shown in Table 1 in this simulation. Here, intensity value takes 0 to 255



(a) Colored image (b) Grayscale (c) True image

(d) Result:Prop. (e) Result:Prev.

Figure 4. Simulation images

Table 1. Previous method error for each number of iterations

Count	10	20	**30**	40	50
Max	26.938	12.353	**10.519**	11.167	10.154
Ave	11.031	4.1856	**2.9042**	3.4065	3.2798
Count	60	70	80	90	100
Max	13.219	11.873	10.863	13.066	12.659
Ave	4.0528	3.6205	3.0219	3.5035	3.6588

Table 2. Standard deviation of results error

	Max	Ave
Proposed	1.785e-14	2.232e-16
Previous	1.242	0.415

and both methods are compared by average error and maximum error. Also, the error of standard deviation is compared with the previous method and the result is shown in Table 2. The standard deviation value is calculated by performing 100 times in both methods.

From these results, it is shown that result improves stability in comparison with the previous method. In the evaluation, the average error of the proposed method was 1.479 and the maximum error was 9.690. Processing time was about 4.4 seconds. While the best result of the previous method is shown below. When the process was repeated with 30 iterations, the average error of the previous method [8] was 2.9042 and the maximum error was 10.519, where 5 clusters are generated and processing time was 10.9 seconds. It is confirmed that the proposed method also reduced the error in comparison with the previous method. Processing time of the proposed method and previous method are shown in Table 3.

Furthermore, it is confirmed that the processing time was also reduced.

3.2 Experiment using actual endoscope image

Some images used in experiments is shown in Fig.5.

Processing time increases based on the number of different reflectances included in the image in the previous method.

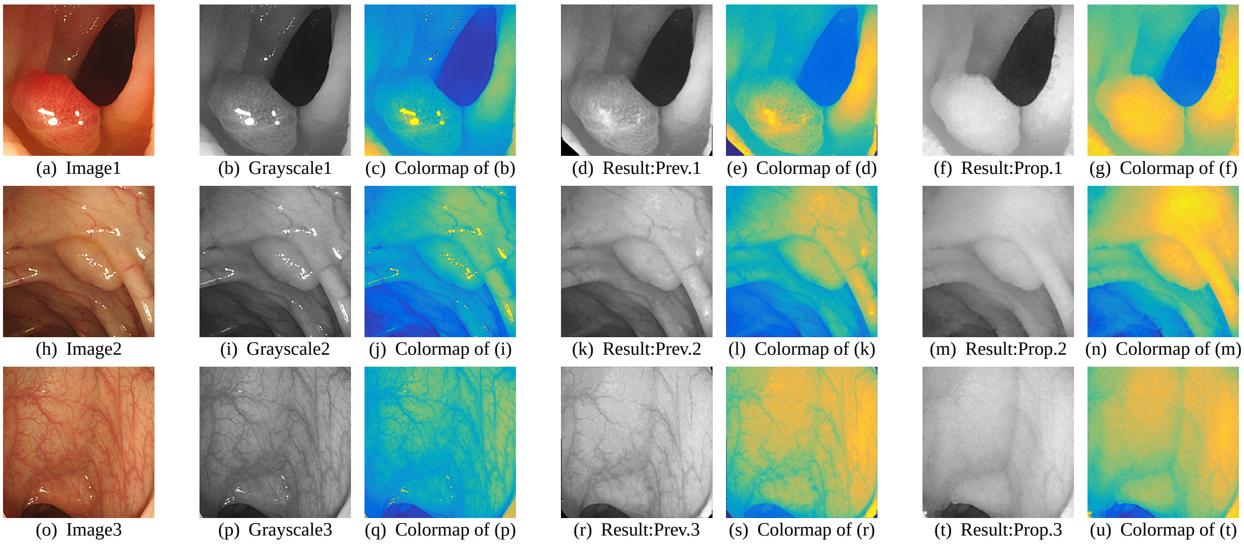


Figure 5. Results for endoscope images

While it is also confirmed that the proposed method gives a stable improvement of result.

Standard deviation of processing time by the proposed method and the previous method for original image is shown in Table 4. From these standard deviations, the proposed method can get the result in stable processing time.

Table 3. Processing time(min.) of each method

	Image1(a)	Image2(h)	Image3(o)
Proposed	0.465	0.488	0.545
Previous	220.38	178.70	128.22
No. of clusters	448	293	236

Table 4. Standard deviation of processing time

	Image1(a)	Image2(h)	Image3(o)
Proposed	0.154	0.165	0.0870
Previous	10.876	13.657	8.397
No. of cluster	5.935	4.291	3.818

Fig.5 shows that the proposed method improved with better result of equalization processing of reflectance factor compared with the previous method. Specular reflection components which the previous method cannot remove were also removed with better accuracy.

4. Conclusion

This paper proposed a method which removes the specular reflection component region and generates Lambertian image by equalization processing of reflectance factor using HSV. The method improves the generated resulting image with better accuracy with small computation time than the previous method. The results are demonstrated using the simulation and the actual experiment and it is confirmed that the method is useful for generating uniform Lambertian image.

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References

[1] K. Tatematsu, Y. Iwahori *et al.*: "Shape from Endoscope Image based on Photometric and Geometric Constraints", *KES 2013*, Procedia Computer Science, Elsevier, Vol.22, pp. 1285-1293, 2013.

[2] Seiya Tsuda, Yuji Iwahori, Yuki Hanai, Robert J. Woodham, M.K. Bhuyan, Kunio Kasugai, "Recovering Size and Shape of Polyp from Endoscope Image by RBF-NN Modification", *IEEE ICIP 2015*, pp.4684-4688, TEC-P31.6, Automated Detection and Tracking in Biomedical Images II, September 29, Tuesday 10:30-12:00 (Poster E), 2015.

[3] O. Vogel, M. Breuß, J. Weickert, "A Direct Numerical Approach to Perspective Shape-from-Shading", *Vision Modeling and Visualiz-ation(VMV) 2007*, pp. 91-100, 2007.

[4] S. H. Benton, "The Hamilton-Jacobi Equation: A Global Approach", *Academic Press*, volume 131, 1977.

[5] E. Prados and O. Faugeras, "A mathematical and algorithmic study of the Lambertian SFS problem for orthographic and pinhole cameras", Technical Report 5005, *INRIA 2003*, 2003.

[6] E. Prados and O. D. Faugeras, "Unifying Approaches and Removing Unrealistic Assumptions in Shape from Shading: Mathematics Can Help", *ECCV04*, 2004.

[7] Shen, Hui-Liang, and Cai, Qing-Yuan, "Simple and efficient method for specularity removal in an image", *Applied optics*, vol48, no.14, pp2711-2719, 2009.

[8] Yuki Shimasaki, Yuji Iwahori *et al.*: "Generating Lambertian Image with Uniform Reflectance for Endoscope Image", *IWAIT2013*, pp.60-65, 2013.