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Image Processing Using Color and Object Information for Wireless Capsule Endoscopy

Jin-Hee Park, Yong-Gyu Lee, and Gilwon Yoon

***Abstract*—**Wireless capsule endoscopy provides real-time images in the digestive tract. Capsule images are usually low resolution and are diverse images due to travel through various regions of human body. Color information has been a primary reference in predicting abnormalities such as bleeding. Often color is not sufficient for this purpose. In this study, we took morphological shapes into account as additional, but important criterion. First, we processed gastric images in order to indentify various objects in the image. Then, we analyzed color information in the object. In this way, we could remove unnecessary information and increase the accuracy. Compared to our previous investigations, we could handle images of various degrees of brightness and improve our diagnostic algorithm.

***Keywords*—**Capsule Endoscopy, HSV model, Image processing, Object Identification, Color Separation.

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I. Introduction

WIRELESS capsule endoscopy is a method that views the intestinal canal without having any connections such as electrical wires or tubes [1]. Capsule images are obtained from a swallowed capsule. It travels in the gastrointestinal tract through vermicular movements. It takes at least 7 ~ 8 hours and produce numerous images. It is impractical for a physician to examine images in real time since. Therefore, a computer algorithm that can supply with diagnostic information on potential abnormality can save time and efforts of a physician [2], [3]. We have reported previously on the image processing methods that determined bleeding [4]-[6]. These algorithms were based on optical characteristics of blood. Fig. 1 illustrates the overall flow chart. RGB color information was processed in order to obtain statistical features of blood. Potential blood pixels were once again verified whether they were in a congregational region since only a few pixels did not form bleeding region.

However, this method was highly dependent on RGB information. We found that the accuracy of detecting bleeding regions became lower for dim images or images with a lot of noises. Table I shows this phenomenon. Sensitivity dropped from 79% to 22% while brightness became from 0.8 to 0.2. Our definition of accuracy dropped from 89% to 9.5%. Our accuracy was defined as the product of sensitivity and specificity. Brightness was defined as follows:

$$Brightness = \sqrt{R^2 + G^2 + B^2} \quad (1)$$

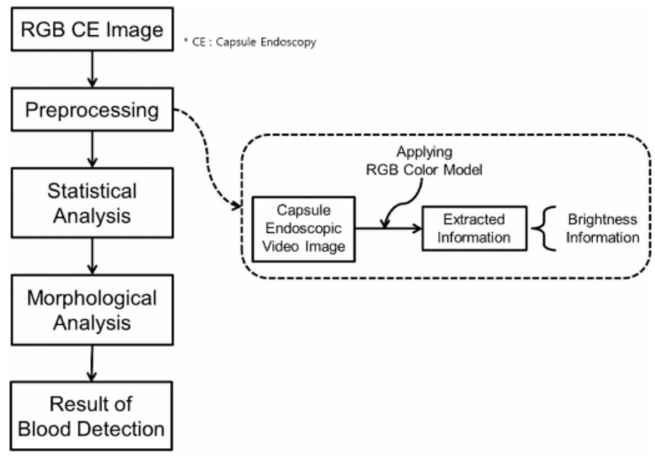

Fig. 1 Diagram of our previously reported algorithm

TABLE I
Accuracy and Sensitivity According to Brightness

Characteristics							
Brightness (0-1)	0.2	0.3	0.4	0.5	0.6	0.7	0.8
Accuracy (%)	9.5	10.2	20.8	39.6	46.7	66.7	89
Sensitivity (%)	22	26.2	30	32.2	42.5	59.8	79

In this study, we investigated on an improved algorithm for the purpose of reducing the influences of low brightness and noises in capsule endoscopy.

II. Image Analysis

Our proposed algorithm was based on color separation with respect to hue, saturation and value. Then, we composed the HSV color model. In addition, we introduced the identification of objects in one image. This object identification provides not only physiological information but also the references on different brightness according to the distance.

For object identification, in the first place, we detected the outlines or the edges of objects in the image. The block diagram in Fig. 2 illustrates this concept. In other words, we utilized color information in separated local regions inside the image. The image contains various shapes and sizes and we believe that such identification provides useful information in determining bleeding regions.

J. H. Park is with the Seoul National University of Science and Technology, Seoul, Korea (e-mail: jinheepark@seoultech.ac.kr).

Y-G Lee is with the Seoul National University of Science and Technology, Seoul, Korea (e-mail: yglee@seoultech.ac.kr).

G. Yoon is also with the Seoul National University of Science and Technology, Seoul, Korea (Corresponding author; phone: 82-2-970-6419; fax: 82-2-979-7903; email: gyoon@seoultech.ac.kr).

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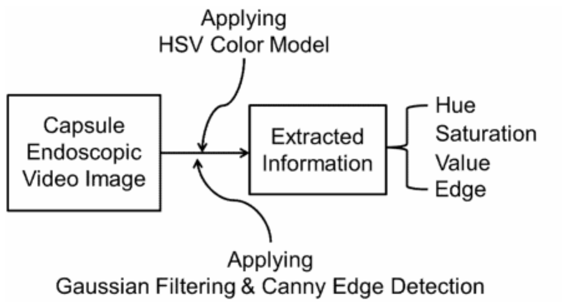

Fig. 2 Block diagram of our proposed image analysis method

A. Color Separation

Generally, the RGB color model has a parameter of brightness. It may not be very effective in analyzing the images under illumination which are often observed in capsule endoscopy. As shown in Fig. 3, we introduced the HSV color model based on Hue (H), Saturation (S) and Value (V) for the purpose of reducing the dependency on brightness. A color is given with H between 0° and 360°, S and V. S and V have any value between 0 and 1. In our modeling, we had 6 H's, 5 S's and 5 V's which makes a total of 150 divisions illustrated in Fig. 3. 150 divisions can be utilized not only for predicting blood but also for object identification.

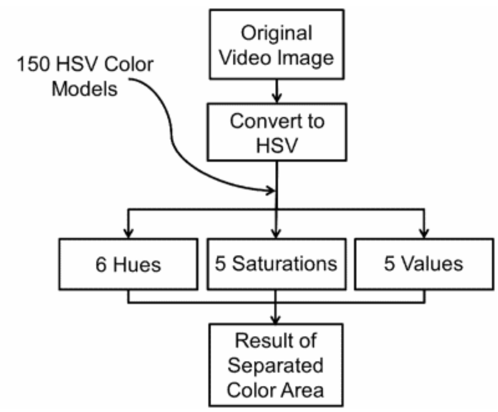

Fig. 3 Flow chart of color separation

B. Edge Detection for Objective Segmentation

Often distal pixels, wrinkles in the digestive duct or the outline of an object have relatively low intensity. Therefore, color processing may be not very effective or reliable. An additional measure is recommended.

Edge detection has been applied for finding out outlines [7]-[10]. The outlines are useful in determining the shapes of digestive duct, bleeding regions and abnormalities. Abnormality includes benign or malignant cancers, ulcer and inflammation etc.

We used an edge detection that was proposed by John F. Canny. It was reported that this method as the first derivative edge detection using the Gaussian function was effective in image processing [11]. This method converts an image into that of gray scale and removes noises through Gaussian filtering. In order to detect edges in the horizontal, vertical and diagonal directions, M_x and M_y in (2) were applied to the blurred or filtered image into the vertical and horizontal directions. Then, we computed the gradient magnitude (M) and the angle of the gradient (Θ) defined in (3). The gradient would give information on edge direction. Finally, outlines are obtained through non-maximum suppression and hysteresis threshold.

$$M_x = \begin{vmatrix} -1 & 0 & +1 \\ -2 & 0 & +2 \\ -1 & 0 & +1 \end{vmatrix} * I_{blur} \quad M_y = \begin{vmatrix} -1 & -2 & -1 \\ 0 & 0 & 0 \\ +1 & +2 & +1 \end{vmatrix} * I_{blur} \tag{2}$$

$$M = \sqrt{M_x^2 + M_y^2}$$
$$\Theta = \arctan\left(\frac{M_y}{M_x}\right) \tag{3}$$

Once we applied the algorithm described in the above, the outlines of objects appeared. However, numerous wrinkles in the digestive duct or large objects showed up as they were. We modified the process by adding the Gaussian filtering before edge detection. Consequentially, we applied the Gaussian filter twice. We could remove most unnecessary isolated edges. Isolated edge could behave as error in object segmentation for some images. This influence could be minimized by opening & erode function.

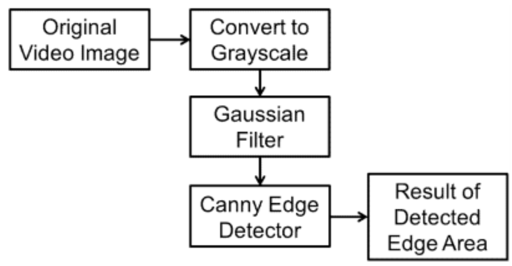

Fig. 4 Flow chart of the modified edge detection

III. Results

We used a total of 20 images where 10 images had bleeding spots and 10 images were normal. We applied our algorithm described in the previous section. Fig. 5 shows the results for a normal image. Fig. 5(a) is a capsule image. Fig. 5 (b) is after color separation based on our 150 HSV color model. Fig. 5 (c) is the result of Gaussian filtering and Canny edge detection. Figs. 5 (d) and (e) are the images after performing opening & erode function in order to minimize isolated edges. Fig. 5 (e) shows completely black which means that there is no bleeding region.

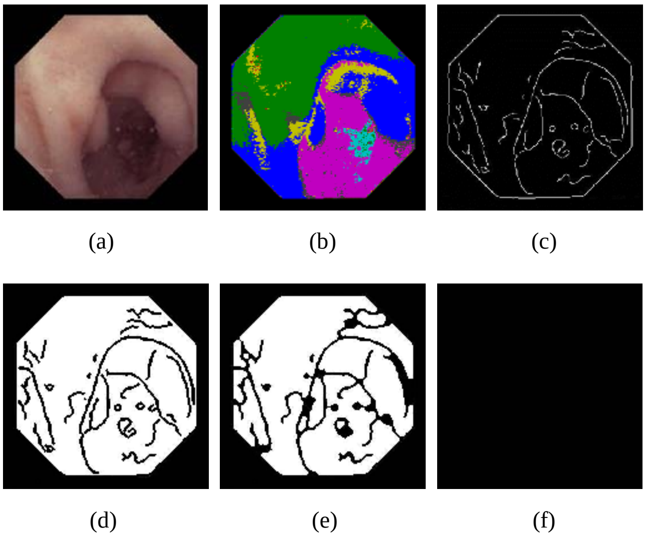

Fig. 5 Image processing for a capsule image with no bleeding sites; (a) original image, (b) color separation by the150 HSV color model, (c) edge detection, (d) image after performing erode function, (e) image after performing opening function, (f) determination of bleeding ('black' indicates no bleeding)

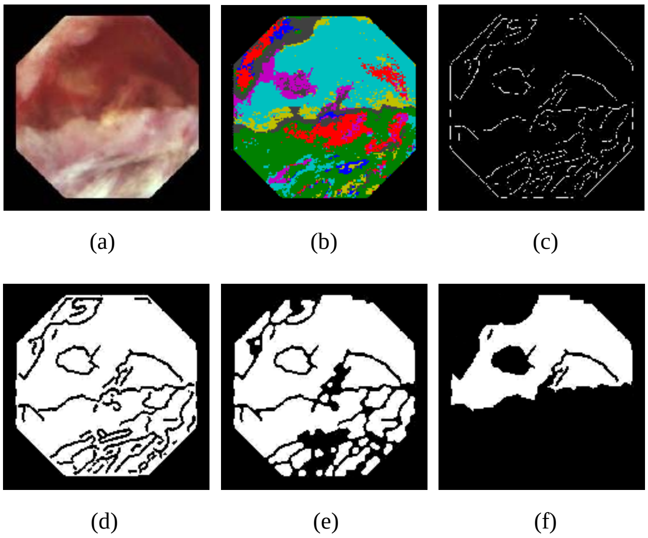

Fig. 6 Image processing for a capsule image with bleeding sites; (a) original image, (b) color separation by the150 HSV color model, (c) edge detection, (d) and (e) processed images after performing opening & erode function, (f) determination of bleeding ('white' indicates blood)

Fig. 6 is a case where there is bleeding. The steps follow the same routines described for Fig. 5. White area in Fig. 6 (f) indicates blood.

IV. Conclusion

We reported the improvements of image processing algorithm for detecting bleeding sites in capsule images. Most previous studies have utilized only color information in determining bleeding or other abnormalities. However, object identification or geometries in the image can provide useful information since regions in different distance shows different brightness. Furthermore, identification of local objects such as bump, winkles, air bubbles, inflammation area and other help the steps associated with color separation process since we can perform color analysis for each local region.

We applied the 150 HSV color model for color separation and identified local regions using edge detection. We successfully tested our algorithms with the existing capsule images.

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Jin-Hee Park was born in Seoul, South Korea (1987) and received her B.S. degree in electronics and information engineering from Seoul National University of Science and Technology, Seoul, South Korea (2012). She is currently a M.S. student at Seoul National University of Science and Technology and engages in biomedical engineering.

Yong-Gyu Lee was born in Seong-nam, South Korea (1984) and received his B.S. degree in electronics and information engineering from Seoul National University of Science and Technology, Seoul, South Korea (2010). He is currently a M.S. student at Seoul National University of Science and Technology and engages in biomedical engineering.

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Gilwon Yoon received his B.S. in Electrical Engineering from Seoul National University, Seoul, Korea in 1977 and M.S. and Ph.D. in Electrical and Computer Engineering from the University of Texas at Austin, U.S.A. in 1982 and 1988 respectively. He worked at Samsung Advanced Institute of Technology, Korea between 1992 and 2003. He is with Seoul National University of Science and Technology since 2003.

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