Classification of Bleeding Images in Wireless Capsule Endoscopy using HSI Color Domain and Region Segmentation

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Abstract:
Wireless Capsule Endoscopy (WCE) is one of the latest technologies that has evolved in the area of medical endoscopy. The far old endoscopy techniques such as colonoscopy push enteroscopy and intraoperative enteroscopy helped doctors to visualize up to stomach, from the upper part and terminal ileum and colon from the bottom. There exists no method to view most of the small intestine without surgery. WCE is a new technology that enables close examination of the interior portion of the entire small intestine without any surgery. The capsule, small and similar to that of a multi-vitamin capsule has a life expectancy of approximately 8 hours. During that time, it captures around 55,000 images, and transmits the images into a small data receiver worn by the patient on the belt. In spite of this technical revolution in medical history there exists a big drawback. The physician has to spend more than two hours to monitor the WCE video. This drawback has lead to many researchers working on reducing the time assessment of the video.

In this paper, we propose a new method that classifies bleeding images in WCE video using the HSI (Hue, Saturation and Intensity) color domain and region segmentation method. In order to classify the bleeding images, we first convert raw data into HSI color domain since it is closer to human perception than the other color domains. Second, we segment each image into bleeding and non bleeding regions using JEDISON region segmentation algorithm. Finally we classify the segmented images into bleeding and non-bleeding by color threshold technique and rigidness of bleeding region. It is assessed that the sensitivity and specificity of our proposed approach are 70.96% and 97.97%, respectively. The result shows that our effort is to achieve classification of bleeding images with higher accuracy compared to existing algorithm, i.e., Suspected Blood Indicator (SBI) in Given Imaging.

Keywords: Wireless Capsule Endoscopy, Blood Detection, Classification of Bleeding Images

1 Introduction

Wireless Capsule Endoscopy (WCE) has revolutionized the evaluation of the small intestine that is the longest portion of the intestinal tract [1, 9]. The small intestine is thin and narrow as compared to large intestine. Reaching in small intestine with traditional endoscope such as colonoscopy, push enteroscopy and intraoperative enteroscopy is very hard since it is located in between stomach and large intestine. X-ray is one of the options to view the small intestine but even normal X-ray is not the best solution. Most of the small intestine blood loss is caused by abnormal blood vessels that lie within the wall of the small intestine. These abnormal blood vessels called AVMs, arteriovenous malformations, are invisible to standard X-rays. Therefore introduction of this new technology allows the physician, to directly view the entire small intestine. It has been proven invaluable in evaluating obscure gastrointestinal bleeding cancer of the small intestine, unexplained abdominal pain, weight loss and diarrhea.

The capsule, small and similar to that of a multi-vitamin capsule has a life expectancy of approximately 8 hours [1]. During that time, it captures around 55,000 images, and transmits the images into a small data receiver worn by the patient on the belt. In spite of this technical revolution in medical history there exists a big drawback. It takes more than 2 hours for the experienced physician to analyze WCE video. Also, a physician may miss some abnormalities that can be found in one or two images, which may cause a serious problem for patient. Many approaches have been made to analyze these videos and reduce the video assessment time.

In this paper, we propose a new method that classifies bleeding images in WCE video using the HSI (Hue, Saturation and Intensity) color domain [3] and region segmentation method. In order to classify the bleeding images, we first convert raw data into HSI color domain since it is closer to human perception than the other color domains. Second we segment each images into bleeding and non bleeding regions using JEDISON region segmentation algorithm [7]. Finally we classify the segmented images into bleeding and non-bleeding by color threshold technique and rigidness of bleeding region.

The remainder of this paper is organized as follows. The HSI color space conversion is discussed in section 2. Region segmentation for candidate bleeding area and the classification of bleeding images are presented in section 3 and 4, respectively. In section 5, we discuss our experimental results. Finally section 6 represents some concluding remarks.

2 HSI Color Space Conversion

Although color receptors in the human eye (cones) absorb light with the greatest sensitivity in the blue, green and red part of the spectrum, the signals from the cones are further processed in the visual system (Levine, 1985). In the perception process, however, a human can easily recognize basic attributes of color i.e., hue, saturation and intensity (HSI). The hue is a color attribute that describes a pure color and represents the impression related to the dominant wavelength of the color stimulus [3]. The saturation corresponds to relative color purity (lack of white in the color). For example, in the case of a pure color it is equal to 100%. Intensity is brightness. Maximum intensity is sensed as pure white, while minimum intensity as pure black. As a result the HSI model is an ideal tool for developing image processing algorithms based on color descriptions that are natural and intuitive to humans. Therefore, we are going to use HSI color domain by converting the input raw data format, such as RGB, into HSI.

For the HSI conversion we use Kender's Formulation [8] as follows:

$$S = 1 - \frac{3\min(R,G,B)}{R+G+B} \quad (1)$$

$$I = \frac{R+G+B}{3} \quad (2)$$

$$
\begin{aligned}
&\text{If } R > B \text{ and } G > B, && \text{then } H = \frac{\pi}{3} + \tan^{-1}\left[\frac{\sqrt{3}(G-R)}{G-B+R-B}\right] \\
&\text{else if } G > R, && \text{then } H = \pi + \tan^{-1}\left[\frac{\sqrt{3}(B-G)}{B-R+G-R}\right] \\
&\text{else if } B > G, && \text{then } H = \frac{5\pi}{3} + \tan^{-1}\left[\frac{\sqrt{3}(R-B)}{R-G+B-G}\right] \\
&\text{else if } R > B, && \text{then } H = 0
\end{aligned}
\tag{3}
$$

We select only hue color in Equation (3) among three components, since it is easy to represent the semantic of blood, such as reddish bleeding. After the hue component is extracted from each WCE image, we find the initial bleeding pixels that belong to red model. According to the HSI color model, red color spans -30 to 30 degree. In other words, if the hue value of pixel is in that range, it will be considered as the initial bleeding pixel. A group of those pixels are called as *candidate bleeding area*. Figure 1 shows some examples of WCE images. The first column of each figure is the original images, while the second column represents images having candidate bleeding areas. In the output images of candidate bleeding area, dark red color indicates the candidate bleeding area while black color represents non-bleeding. Last column shows the image received after segmentation, which will be discussed in the following section.

3 Region Segmentation for Candidate Bleeding Area

In section 2, we build candidate bleeding areas for each WCE image. As shown in Figure 1, sometimes the pixels that belong to a given range of red cannot form a rigid area, which may cause errors to classify the bleeding images. In order to address the problem, we compute the rigidness of the candidate bleeding area. First, a region segmentation algorithm is applied to the images of candidate bleeding area. Since the goal of image segmentation is to partition an image into disjoint regions which correspond to objects of interest in the images, we can remove such non rigid pixels. Then we compute the rigidness by comparing the number of red pixels in candidate bleeding area with that of the result of region segmentation as follows.

$$
Rigidity = \frac{\#\ of\ \ red\ \ Pixels\ Before\ Segmentation}{\#\ of\ \ red\ \ Pixels\ After\ Segmentation} \tag{4}
$$

For example, the rigidness of Figure 1 (b) and (d) are 1.1 and 0.6, respectively. Since the Figure 1 (d) has very sparse of red pixels we'd better discard from candidate bleeding area.

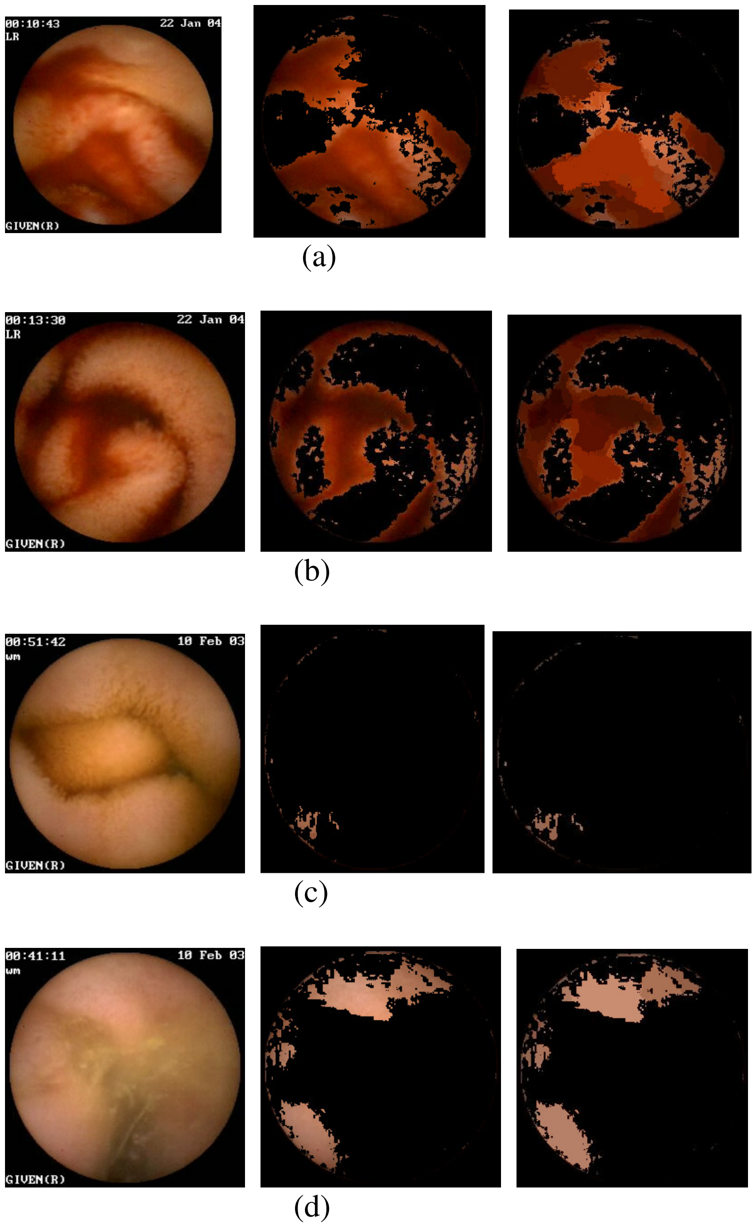
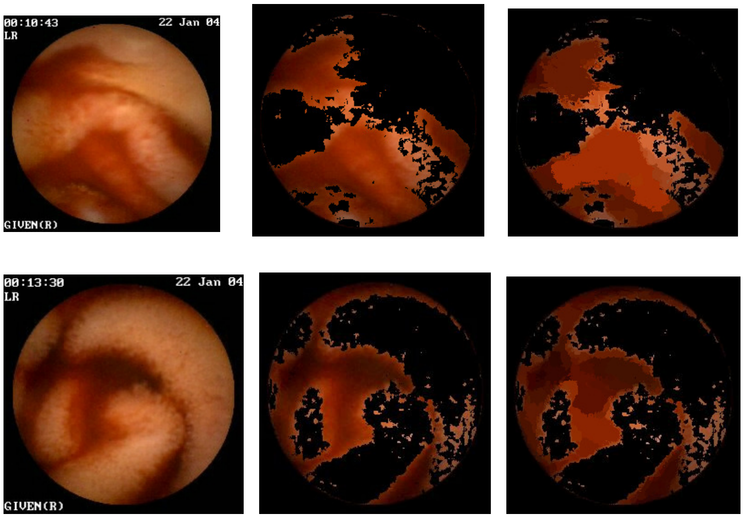


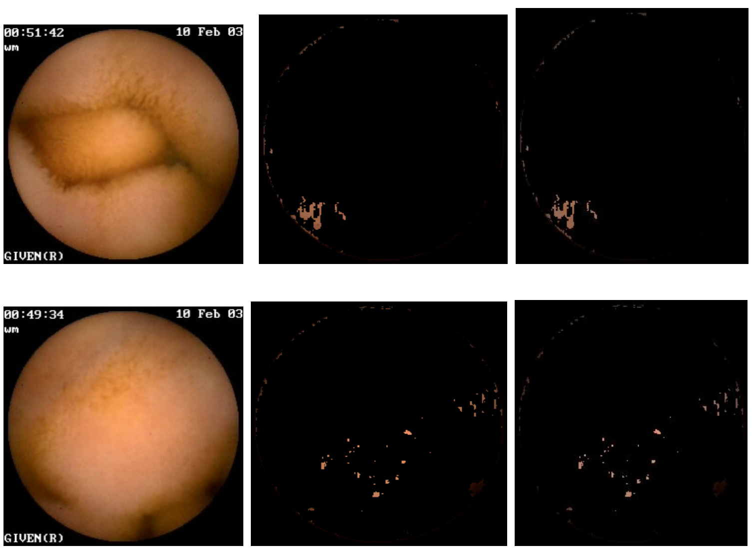
Figure 1. Examples of WCE Images and Candidate Bleeding Areas

4. Classification of Bleeding Images

After we have the images that include the rigid candidate bleeding areas, the final step is to classify the images into bleeding and non-bleeding using threshold technique. We compute the ratio of candidate pixels from the result of region segmentation in the previous section. If the ratio is more than a given threshold value it will be classified as bleeding image. Otherwise it belongs to non-bleeding images. The threshold value can be determined based on the empirical results. In our experiment we are going to use 0.6 that provides the best result of our approach.



(a) Examples of Bleeding Images



(b) Examples of Non-Bleeding Images

Figure 2. Examples of Bleeding and Non-bleeding Images

5. Experimental Results:

In order to assess our proposed approach to classify bleeding images of WCE, we have conducted an experiment based on real WCE images. For the dataset we have chosen 100 images from 10 different WCE videos. The data set include 50 bleeding images and 50 non-bleeding images. When we determine bleeding or non-bleeding images, a Gastroenterologist is involved to confirm the ground truth.

For the evaluation metrics we use *'Sensitivity'* and *'Specificity'* as follows

	Predicted as Positive	Predicted as Negative
Actually Positive	TP	FN
Actually Negative	FP	TN

$$Sensitivity = \frac{\#\ of\ Correct\ Positive\ Predictions}{\#\ of\ Positives} = \frac{TP}{TP+FN}$$

$$Specificity = \frac{\#\ of\ Correct\ Negative\ Predictions}{\#\ of\ Negatives} = \frac{TN}{FP+TN}$$

To find optimal range of red that describe the bleeding of WCE images, we performed several experiments for the different range of red color in Hue model, i.e., -5 to 5 degree, -10 to 10 degree, -15 to 15 degree and -20 to 20 degree. Table 1 shows the result of classification on various ranges of red color. The first column of the table indicates the range of red color in Hue model. The second and third columns of the table represent sensitivity and specificity of the results respectively and last column specifies the rigidity. The rigidity close to 1 is taken as a ideal in our experiments.

Table 1. Result of classification on various ranges of red color

Case	**Sensitivity**	**Specificity**	**Rigidity**
-5 to 5	0.607143	0.9884	7.84431
-10 to 10	0.544102	0.983682	1.68565
-15 to 15	0.709612	0.979704	0.90984
-20 to 20	0.614677	0.939434	0.681068

As you can see in the Table 1, it provides the best result when the range is from –15 to 15 degree. Rigidity close to 1 show that the images are of positive case and other values shows they differ somewhere. So according to Table 1 case number 3 is the best case for classification of bleeding in WCE images. The rigidity in 3^{rd} case is close to 1. The sensitivity and specificity of the proposed approach are 70.96% and 97.97% respectively. Also, the result is better than those of existing approach, such as Suspected Blood Indicator (SBI) by Given Imaging. The sensitivity and specificity of SBI are 72% and 85% respectively. Since our approach uses different color domain, i.e., HSI, and removes some sparse data of bleeding, it outperforms the other to classify the bleeding images.

6. Conclusion and Future works

Since it takes more than two hours for a specialist to examine the entire WCE video, it is crucial to reduce the viewing time. In this paper, we proposed a new technique to classify WCE images into bleeding and non-bleeding. In order to classify the bleeding images, we first convert raw data into HSI color domain since it is closer to human perception than the other color domains. Second we segment each images into bleeding and non bleeding regions using JEDISON region segmentation algorithm. Finally we classify the segmented images into bleeding and non-bleeding by color threshold technique and rigidness of bleeding region. Our result shows 70.96% sensitivity and 97.97% specificity when range of red color is from –15 to 15 degree, which is better than those of Suspected Blood Indicator (SBI) by Given Imaging.

Future works will be directed towards getting better accuracy from the existing algorithm by employing Ontology for WCE Video. Also, we will investigate automatic procedure to classify bleeding images, which includes the threshold value.

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