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Segmentation of Crohn, Lymphangiectasia, Xanthoma, Lymphoid Hyperplasia and Stenosis diseases in WCE

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Abstract. Wireless capsule endoscopy (WCE) is a great breakthrough for Gastrointestinal (GI) Tract diagnoses which can view the entire gastrointestinal tract, especially the small bowel, without invasiveness and sedation. However, a tough problem associated with this new device is that too many images to be inspected by naked eyes is difficult for physicians, Thus it is essential to find an automatic and intelligent diagnosis method to help physicians. In this paper, a new segmentation algorithm for detection of Lymphangiectasia, Xanthoma, Crohn, and Stenosis in WCE images is proposed. This new approach mainly uses the HSV color space, sigmoid function and canny edge detector. We compare our method with a fuzzy c-mean clustering. We show that sensitivities of the sigmoid function for Lymphangiectasia, Lymphoid hyperplasia, severe Crohn's disease, Xanthoma and ulcerated Stenosis are respectively 89.32%, 91.27%, 95.45%, 87.01%, 97% and sensitivities of the fuzzy c-means clustering with same order are 83.91%, 86.7%, 96.38%, 90.4%, 93.83%. Totally, the sigmoid function is more specific and sensitive, with same accuracy.

Keywords. Wireless Capsule Endoscopy, Disease Detection, Image Segmentation, Sigmoid Function, Fuzzy C-means clustering.

Introduction

Traditional endoscopies cannot reach to the main body of the GI tract, small intestine, due to their cable length and other limitations. A solution to this problem is the wireless capsule endoscopy (WCE), which is invented by Given Imaging in 2000 and can entirely view the small intestine without pain, sedation, and non-invasiveness. After 8 hours, the WCE battery lifetime, the data-recorder is removed and the image data is uploaded to a workstation for offline viewing [1]. The capsule has proved to be an important tool in the diagnosis of obscure Crohn's disease [2], and Celiac disease [3]. Recently, there have been research reports regarding WCE image analysis [4], [5]. In [4], the authors proposed an automatic video segmentation algorithm to discriminate the esophagus, stomach, small intestine, and colon tissue in WCE, using color, texture, and motion information. In [5], a new feature (chromaticity moment) by using of the Tchebichef polynomials and the illumination invariance of HSI color space, was

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proposed to discriminate normal regions and abnormal regions of WCE images. They used the color space and texture features to detect disease in [6]. In [7], the authors developed an adaptive curvature strength diffusion method to enhance WCE images using a new concept of curvature strength. In [8], the authors used the mean-shift algorithm to find centers of candidate regions that may show Crohn's disease inflammation. Then, the system was classified by a trained Support Vector Machine. Accuracy, specificity and sensitivity were reported 87%, 93% and 80% respectively.

In this paper, we propose a new method that segments Lymphangiectasia, Lymphoid hyperplasia, serve Crohn's disease, Xanthoma and ulcerated Stenosis in wireless capsule endoscopy frames. In order to segment these diseases, we convert images from Red Green Blue (RGB) to Hue Saturation Value (HSV), and then a sigmoid filter is used to adjust region. In the last step, we segment the abnormal tissue by using the Canny filter which is able to detect diseased tissues' boundary.

1. Methods

1. 1. Sigmoid function

Sigmoid function is a continuous non-linear function. The name, sigmoid is derived from the fact that the function is ``S'' shaped. Statisticians call this function the logistic function. Using f(x) for the input and with g as a gain, the sigmoid function is

$$f(x) = 1/\ 1 + e^{g(x)} \tag{1}$$

The sigmoid function is a smooth continuous function, its outputs is within the range 0 to 1, and it is easy to deal with it; For better details about this function, refer to [9]. We use a new form of sigmoid with additional parameters in which I (i, j) is the input image without any process, J (i, j) is the output image, Gain is a parameter for changing slope and Cutoff is another parameter to shift data,

$$J(i, j) = 1/1 + e^{\mathrm{Gain}\times(\mathrm{cutoff} - I(i,j))} \tag{2}$$

1.2. Fuzzy C-means clustering

Given a set of n data patterns, $X=x_1 \ldots x_n$, fuzzy c-means (FCM) algorithm minimizes the weighted within group sum of squared error objective function J (u, v) [10]:

$$J = \sum_{j=1}^{N} \sum_{i=1}^{c} u_{ik}^{m} \left|x_j - v_i\right|^2 \tag{3}$$

where x_k is the kth p-dimensional data vector, v_i is the prototype of the centre of cluster i, u_{ik} is the degree of membership of x_k to the ith cluster, m is a weighting exponent on each fuzzy membership, d (x_k, v_i) is a distance measure between object x_k and cluster centre v_i, n is the number of objects and c is the number of clusters. A solution of the objective function J (u, v) can be obtained via an iterative process where the degrees of membership u_{ik} and the cluster centers v_i are updated via:

$$u_{ij} = 1/ \sum_{j=1}^{c} \left(\frac{d_{ik}}{d_{jk}}\right)^{\frac{2}{m-1}} \tag{4}$$

with d_{ik} as the distance between object k and cluster i, d_{jk} as the distance between object k and cluster j,

$$v_i = \frac{\sum_{k=1}^{n} u_{ik}^{m} x_k}{\sum_{k=1}^{n} u_{ik}^{m}}, u_{ik} \in [0\ 1], \sum_{i=1}^{c} u_{ik} = 1\ \forall k, 0 < \sum_{k=1}^{n} u_{ik} < N\ \ \forall i \tag{5}$$

According to the update formula for the cluster prototypes objects with low membership values for that particular cluster have a small contribution to the final position of that particular cluster prototype. This is the general principle on which FCM is based: by weakening membership values of objects that belong to the larger cluster, the contribution of those weakened objects to the cluster centers of the smaller clusters will be small. As a result, the cluster centers of the smaller clusters will not drift to the larger adjacent cluster.

1.3. Proposed Algorithm

An important syndrome of the GI diseases is color of the tissues that changes from red to yellow. In order to improve detection of diseases, we studied normal and abnormal tissue in the HSV color space [11]. Our system (Matlab) is programmed based on this difference. We focus on the Hue at first to omit the normal tissue in the red channel. Then, we focus on the saturation and the value channels to improve the sigmoid function's results. Depending on the hue, the saturation, and the value, we decrease or increase the saturation and the value of image to focus on the interested tissue. Next, we use a sigmoid transform to select light parts in a frame. In the last step, we segment diseases by using the Canny filter [12]. Figure 1 shows the proposed method's algorithm. In our comparative study, we classify frames by using fuzzy c-means clustering into two groups, and then compare the results with the first one. Also, we compare the results with the Canny without using any enhancement and show how this method improve segmentation.

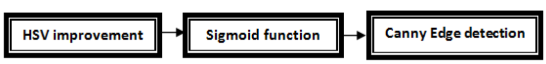

Figure 1. The proposed algorithm.

2. Results

We collected the Given Imaging PillCam SB's videos [13]. We digitize each video into 100 frame, and then reduce the image size which is 576 × 576 to 512 × 512 (omit borders) in the first method. We collected 45 frames of Stenosis disease from 5 patients, 74 frames Crohn diseases of 9 patients, 32 frames of Lymphangiectasia from 5 patients, 27 frames of Lymphoid hyperplasia from 2 patients, 28 frames of Xanthoma from 3 patients. In this study, we focus on disease segmentation, so the Accuracy, Sensitivity and Specificity are important in our work as follow [14].

$$\text{Sensitivity} = \frac{\text{TP}}{\text{TP+FN}}, \text{Accuracy} = \frac{\text{TP+TN}}{\text{TP+FP+FN+TN}}, \text{Specificity} = \frac{\text{TN}}{\text{TN+FP}} \tag{6}$$

where TP, FN, TN, and FP respectively denote the number of pixels in abnormal tissue that are correctly labeled, the number of pixels in abnormal tissue that are incorrectly labeled as normal, the number of pixels in normal tissue that are correctly labeled as normal and the number of pixels in normal tissue that are incorrectly labeled as abnormal. The results are shown in Table 1 and figure 2. The sensitivity sigmoid function's method is 87.76 percent with Gain = 40, Cutoff = 0.5, and sigma = 7 (sigma is canny factor and these factors are fixed in our study) and for the fuzzy c-means clustering is 94.8 percent with same parameters. As Figure 2 shows, before using HSV and sigmoid function, Canny's detector could not segment diseases parts.

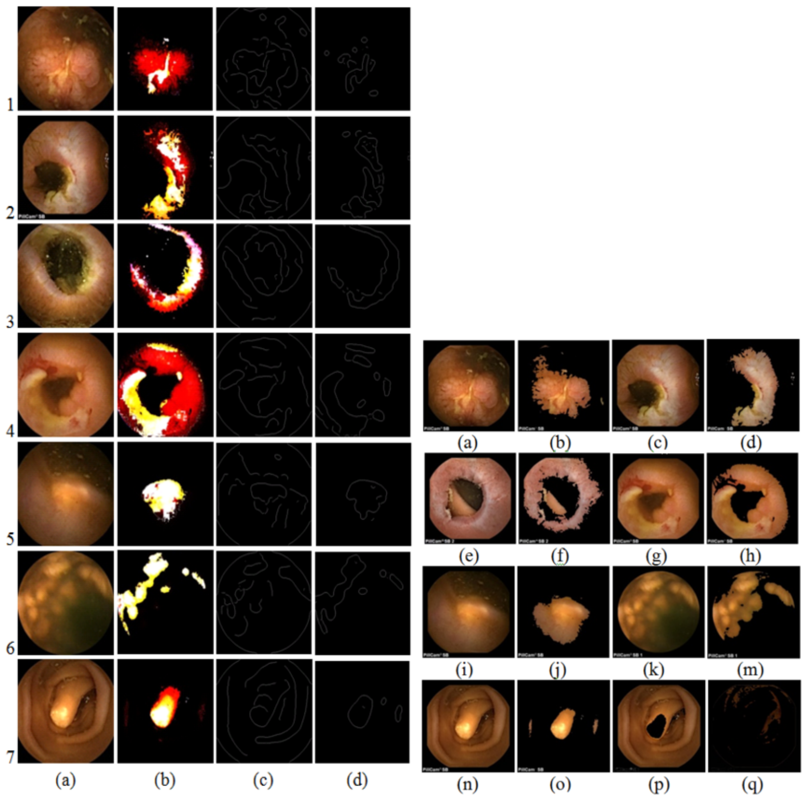

Figure 2. In the left image, rows 1, 2, 3, 4, 5, 6 and 7 show respectively Crohn, Crohn, NSAID and Stenosis, NSAID and Stenosis, Xanthoma, Lymphoid hyperplasia and Lymphangiectasia. In each row, column (a), (b), (c) and (d) show respectively the original image, the RGB image after using sigmoid function, filtered image in column (a) by using the Canny, and filtered image in column (b) by using the Canny. The right image demonstrates eight sample frames and segmented parts using fuzzy c-means.

Comparative method by using fuzzy c-means clustering. In this case, because of borders and dark spaces as illustrated in figure 2 (right image), we classify images to three clusters by using fuzzy c-mean. In order to compare the first method's results, the Canny's edge detector's results and fuzzy c-means clustering, we calculate sensitivity, accuracy and specificity for these algorithms which is demonstrated in Table 1.

3. Discussion

In this paper, we introduced the method to segment abnormal tissues in WCE's frames. The measures show that the proposed method achieves to good sensitivity and accuracy in the detection of lymphoid hyperplasia, Lymphangiectasia, serve Crohn's disease, Xanthoma and ulcerated Stenosis. This is achieved by using the HSV color space, sigmoid function and Canny's edge detector. The proposed method shows better sensitivity, accuracy and specificity than fuzzy c-means with 3 clusters, and also better it improved the Canny edge detector's results. Future research will be directed to investigate automatic detection of normal and abnormal tissues using texture features and the HSV color space. By using the proposed method, we can detect diseases very accurate, so we will illustrate automatic method based on this algorithm by using discriminating features and effective classifiers such as support vector machines or neural networks.

Table 1. In the first three columns, the proposed method's measures are illustrated, in the second three columns, the fuzzy method's measures are illustrated and in the third three columns, the Canny detector's results without any process are illustrated.

Subject	Sensi	Accu	Speci	Sensi	Accu	Speci	Sensi	Accu	Speci
Crohn	89.32	74.95	65.37	83.91	72.08	64.2	31.31	44.49	53.27
Stenosis	91.27	88.67	87.27	86.7	88.99	90.23	19.29	45.1	59
Lymphan	95.45	94.41	94.1	96.38	92.39	91.2	52.71	60.39	62.68
Lymphoid	87.01	81.73	79.71	90.4	76.2	69.2	48.58	64.48	72.31
Xanatoma	97	97.11	97.13	93.83	88.54	87.3	38.12	47.25	49.39

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