Wireless Micro-Ball Endoscopic Image Enhancement Using Histogram Information

Abdolrahman Attar, Xiang Xie, Chun Zhang, Zhihua Wang, Shigang Yue

***Abstract*—Wireless endoscopy systems is a new innovative method widely used for gastrointestinal tract examination in recent decade. Wireless Micro-Ball endoscopy system with multiple image sensors is the newest proposed method which can make a full view image of the gastrointestinal tract. But still the quality of images from this new wireless endoscopy system is not satisfactory. It's hard for doctors and specialist to easily examine and interpret the captured images. The image features also are not distinct enough to be used for further processing. So as to enhance these low-contrast endoscopic images a new image enhancement method based on the endoscopic images features and color distribution is proposed in this work. The enhancement method is performed on three main steps namely color space transformation, edge preserving mask formation, and histogram information correction. The luminance component of CIE Lab, YCbCr, and HSV color space is enhanced in this method and then two other components added finally to form an enhanced color image. The experimental result clearly show the robustness of the method.**

I. INTRODUCTION

There are many diseases in the gastrointestinal (GI) tract that if easy observation can be provided they may be diagnosed and cured. The traditional detection methods such as endoscopy, ultrasound, and computed tomography (CT) scan have demonstrated great values in diagnosing digestive diseases. However, the main body of the GI tract, small intestine, is not accessible by the traditional endoscopy devices [1, 2].

Wireless Capsule Endoscopy (WCE) is a technological innovation that help physicians to observe the patient GI tract in a comfortable and efficient way. It helps to see inside of the patient colon, small bowel and other parts of the digestive system [2, 3]. Recently, our research team has proposed a wireless Micro-Ball endoscopy system (Fig. 1) with multiple image sensors that can make full view of GI tract possible [4, 5].

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Figure 1. The new wireless Micro-Ball endoscopy.

By observation of images from GI tract, it can be seen that they are rather low contrast and sometimes even difficult to review contents of the images. So we come to the conclusion that it is necessary to enhance the endoscopic images. It helps both physicians and image engineers so that physicians can interpret images easier and engineers can use it for further processing e.g. automatic disease detection or image registration for creating 2D map of GI.

In this paper, an endoscopic image enhancement method using histogram information is designed. It works in three main steps. It first transforms the original image, captured by the endoscopy system, to a different color space. Then luminance component of the image is smoothed and normalized in a way that it still follows the input image general histogram pattern. Finally a new edge mask is applied to the new image to amplify its object features and details.

The remainder of the paper is organized as follows: Section II, wireless micro-ball endoscopic images features are discussed. In Section III, an endoscopic image enhancement method is proposed. Experimental results are analyzed in Section IV and Section V concludes the paper.

II. WIRELESS MICRO-BALL ENDOSCOPIC IMAGE ANALYSIS

There is an important problem with the current wireless endoscopic images, which is the quality. Their quality are not as good to be easily examined by the physicians or exploited for further use such as image registration, image understanding, etc.

Bad imaging conditions such as low illumination and complex circumstances in the GI tract, high compression ratio, limitations in power consumption, short-focal-length camera, communication bandwidth, and storage device all affect the image quality [6].

Wireless endoscopic images have their own characteristics compared to other kinds of natural images. The characteristics of GI tract images will be analyzed in spatial domain and frequency domain respectively. To this aim, we first transform the color endoscopic images from RGB color space to gray scale. In this work, the transformation is done by getting the red, green, and blue values of a pixel, using following equation (1) to turn those numbers into a single gray value, and replacing the original red, green, and blue values with the new gray value.

$$M_{ij}=\alpha R_{i,j}+\beta G_{i,j}+\gamma B_{i,j} \qquad (\alpha+\beta+\gamma=1) \qquad (1)$$

Where M is the new gray value, i, j are pixel coordinates in the width and height dimensions, and α, β, γ are constant numbers which affect the image contrast. In our experiments, aiming at a better representation of the images and considering gastrointestinal tract image color distribution, the empirical values for $\alpha, \beta,$ and γ are 0.33, 0.62, and 0.05 respectively. Now, spatial and frequency domain analysis is applied to the new gray scale images.

A. Spatial Domain

An image histogram offers a graphical representation of intensity distribution in a digital image. By viewing the image histogram, the frequency of appearance of the different intensities contained in the image can be understood. By observing a large number of histograms of GI tract images, we can see that the gray distribution of this kind of images concentrates in a certain range of intensities and the contrast is relatively low. The histogram shows us that the image contains only a fraction of the total range of gray levels. Theoretically, an image is considered to be more informative if its histogram resembles a uniform distribution.

B. Frequency Domain

The frequency domain analysis for GI tract images and natural images are also made. The number of high frequency components for GI tract images are much smaller than that of natural images. It means that the features of GI tract images are not distinct and it may bring challenges both for medics to interpret the images and engineers to process them.

Fig. 2 shows the spatial domain and frequency domain analysis of a natural image compared with two typical image of GI tract.

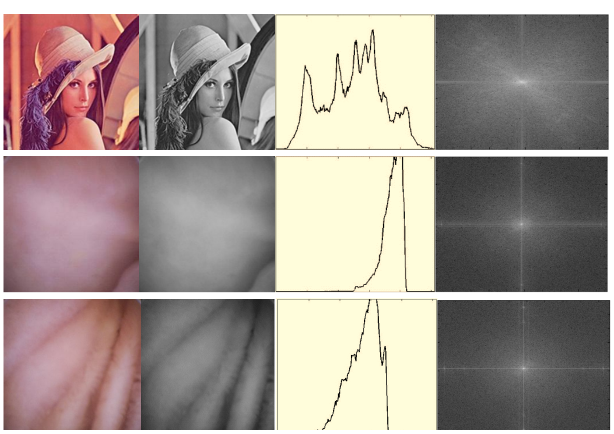

Figure 2. Spatial domain and frequency domain analysis.

III. PROPOSED METHOD

In order to make the features of GI tract images more distinct and easier to be examined by experts, a proper image enhancement method using histogram information is designed. The method is formed of three main steps; Color space transformation, edge preserving mask formation, and histogram information correction.

A. Color Space Transformation

A color space is a method by which we can specify, create and visualize color. There are a lot of color spaces but the following stand out: RGB, CIE Lab, YCbCr, and HSV.

RGB color model is the most convenient and popular model so that many devices use RGB color space for capturing and processing images. RGB is an additive color model which combines the three main colors (red, green and blue) to produce the full gamut (precise distribution of how the multiple channels of the color model are interpreted) of colors. Our new Wireless Micro-Ball system also use this color space.

By applying the new endoscopic image enhancement method on RGB color space, the chromaticity of image changed significantly. Since both luminosity and chromaticity of the image are represented on the same component in the RGB color model, it is not possible to increase the luminosity with having no change in chromaticity. In order to ensure that the chromaticity of the image is not affected, the luminosity of the image must be first separated before enhancement. In this work we examine the CIE Lab, YCbCr and HSV color space to determine which color space provides the best contrast enhancement while preserving the original chromaticity as much as possible. Chromaticity is completely separated in both CIE Lab and YCbCr color spaces. It can be seen later, by applying the new method to these channels, L and Y, the contrast of the image can be increased without changing the chromaticity of the image. For enhancement in the HSV color space the component V is separated and then the method is applied. As HSV color space does not completely separate chromaticity from luminosity, some changes in chromaticity may be seen.

As different color spaces transformation formulas are one of the most widely used equation in the field of image processing, it is not discussed and illustrated here. Fig. 3 shows the luminance components L, Y, and V of a sample image.

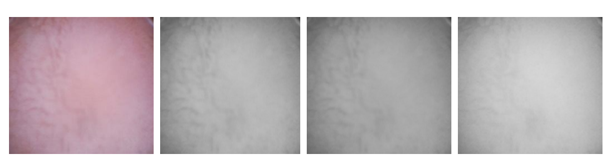

Figure 3. Left to right, the luminance components L, Y, and V.

B. Edge Preserving Mask Formation

As discussed earlier, the endoscopic images objects are not clear enough and affected to some extent by noise. In this section, by using an appropriate filter, features of interest in images are accentuated.

We use the simplest, most studied and most widely used nonlinear filter, the Moving Median Filter. It is operated on each pixel separately and by taking into account the values of neighboring pixels changes a pixel's value. It replaces each pixel by the median of pixels values in a square window centered on that pixel. The median of a set of numbers can be found by arranging all the observations from lowest value to highest value and picking the middle one. For a filter of n-pixels window which has been ascending sorted, the output is (2):

$$median = \begin{cases} f((n+1)/2) \ ; \ n = 2k+1 \\ mean(f(n/2), f((n/2)+1)) \ ; \ n = 2k \end{cases} \quad (2)$$

Where f is the value of pixel and k equals to $1, 2, 3, \ldots, N$. So Moving Median Filter is applied to luminosity image. Fig. 4 b is a display of the output from a *5*x*5* moving median filter. Each pixel has been replaced by the median of pixel values in a *5*x*5* square, or window centered on that pixel. Then the output from the moving median filter is subtracted from the original luminance channel, the result is shown in Fig. 4 c. Finally, the difference image is applied to the output image of section C.

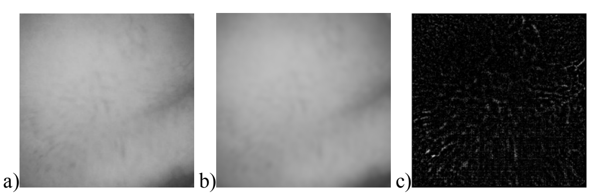

Figure 4. Application of moving median filter to luminance component of an endoscopy image. (a) original image, (b) filtered image, (c) difference image.

C. Histogram Information Correction

Image contrast is fine when the histogram represents a uniform plot covering almost all of the gray levels. Otherwise, if the grey levels are concentrated on the left side of the histogram, the image has overall dark appearance, if the grey levels are concentrated on the right side then the resulting image has bright characteristics, and if the grey levels occurred in the middle of gray scale the image would appear murky. In section II was shown that the endoscopic images histograms belong to third group.

So the endoscopic images gray values need to be manipulated to have a clearer representation of gastrointestinal tract. The contrast of an image is altered to change the intensity distribution of the image and yield an intensity histogram with a desired shape.

Let suppose dynamic range for the intensity varies from 0 (black) to *L-1* (white), h_i is the number of pixels having the *i-th* intensity bin, N is the total number of pixels, $H(I)$ defined in equation (3) is histogram of image I.

$$H(I) = \{h_i\}, \ \sum_{i=0}^{L-1} h_i = N \quad (3)$$

In order to enhance the contrast of a color image and to reveal the image details, we need to preserve the intensity distribution ratio of the original image. So we first apply the one dimension Gaussian filter by equation (4) to obtain the smooth format of image histogram.

$$G(x)=(2\pi\sigma^2)^{-0.5}.exp(-x^2/2\ \sigma^2) \quad (4)$$

After that 70% (empirically obtained) high occurred values are preserved and the rest is clipped from histogram so as to redistribute equally among all histogram bins. Then by transform function in equation (5) the image values are normalized. The new image is said to have the standard normal distribution while follows the original image histogram pattern.

$$Z=(x-\mu).\sigma^{-1} \quad (5)$$

Where σ is the standard deviation and μ is mean. Fig. 5. a, b, c, and d show the original image histogram, smoothed histogram by Gaussian filter, clipped histogram, and normalized histogram, respectively. Comparing Fig.5 c and d, it is clear that there is a shift from right to left. This shift is considered as a dynamic parameter to not abruptly change the image intensity distribution.

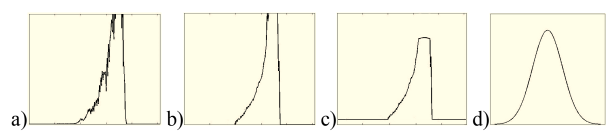

Figure 5. Image histogram. a) original image b) after Gaussian filter c) after clip limit d) after normalization.

IV. EXPERIMENTAL RESULT

The proposed method is used to emphasize endoscopic images objects so as to help visualization and interpretation of images, and can also be used as a precursor to further endoscopic image processing, such as registration and segmentation. Experiments were conducted to verify the proposed approach. A collection of 500 various test images of different part of GI tract from our own data base was chosen. All images histogram were precisely scrutinized. Color distribution and features of the images were considered to set different parameters such as edge preserving mask window size, clip limit percentage, and shift parameter. The method was performed on different component of RGB and luminance component of CIE Lab, YCbCr, and HSV.

Performance of the method is measured using a six component measurement index for contrast and texture. These measurement index include Mean, Standard Deviation, Smoothness, Third Moment, Uniformity, and Entropy (equations are available with explanation and details in [7]). Table I shows the average value of mentioned metrics for original endoscopic images (O) and enhanced images (E). For all indices except uniformity a higher score represents greater amounts of texture.

TABLE I. MEASUREMENT INDEX FOR CONTRAST.

Measurement		RGB	CIELab	YCbCr	HSV
Mean	*O*	80.23	100.12	113.49	95.11
	E	89.98	120.11	132.01	102.13
Standard Deviation	*O*	42.01	69.89	79.93	70.14
	E	50.10	80.49	92.23	82.05
Smoothness	*O*	0.009	0.073	0.076	0.065
	E	0.023	0.090	0.098	0.084
Third Moment	*O*	0.198	0.423	0.010	1.761
	E	0.211	0.531	0.012	1.922
Uniformity	*O*	0.086	0.073	0.059	0.060
	E	0.022	0.021	0.028	0.024
Entropy	*O*	4.11	4.09	4.10	4.12
	E	4.81	4.99	4.98	4.85

From the table it is clear that algorithm has a good effect on contrast. All demonstrate higher measures of contrast and texture when compared to the original image.

Furthermore, keypoint analysis of the data set before and after enhancement has been done so as to show effect of the new algorithm on making the image features more distinct. Keypoint extraction is a basic issue and has many applications like 3D reconstruction or creating 2D map of GI tract. There are different kinds of features considered as keypoint, such as points, straight lines, curves, edges, etc. Aiming at detecting such features a low contrast image cannot help much. So, higher number of keypoints signifies higher image quality.

There are several functions allowing to extract keypoints from images. Here, two famous feature extractor are used to count number of keypoints: Speeded-Up-Robust-Features (SURF) and Difference-of-Gaussians (DoG) [8].

Table II shows the average number of keypoints obtained from SURF and DoG methods for original endoscopic images (O) and enhanced images (E).

TABLE II. MEASUREMENT INDEX FOR NUMBER OF KEYPOINTS.

Measurement		RGB	CIELab	YCbCr	HSV
SURF	*O*	207	187	162	198
	E	520	643	598	571
DoG	*O*	211	199	160	170
	E	601	712	588	596

The experimental results shown in Table II illustrate that the new enhancement method has increased the quality of wireless Micro-Ball endoscopy images. Average number of keypoints have been increased noticeably, therefore, it is said the new enhanced data set is more applicable.

Also as Fig. 6 shows the quality of endoscopic images has significantly improved and the features are now more distinct.

V. CONCLUSION

A new color image quality enhancement method was proposed for wireless endoscopy images. The method improves the contrast of the image while preventing it from being over enhanced. The features of the image as visually was shown has been improved a lot and features have been more distinct. Statistical analysis was also performed over the endoscopy image data set and the results showed its positive effect on image contrast.

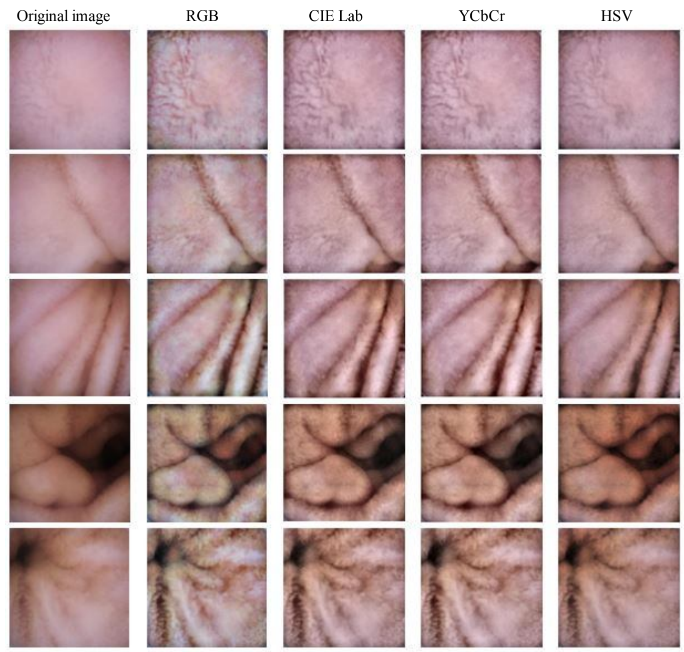

Figure 6. Three different endoscopic images enhanced by the proposed method on RGB, CIE Lab, YCbCr, and HSV color space, respectively.

REFERENCES

[1] B. Li, M. Q.-H. Meng, and L. Xu, "A Comparative Study of Shape Features for Polyp Detection in Wireless Capsule Endoscopy Images," 31st Annual International Conference of the IEEE EMBS, Minneapolis, Minnesota, USA, September 2-6, 2009.

[2] V. B. S. Prasath, I. N. Figueiredo, P. N. Figueiredo, K. Palaniappan, "Mucosal Region Detection and 3D Reconstruction in Wireless Capsule Endoscopy Videos Using Active Contours," 34th Annual International Conference of the IEEE EMBS San Diego, California USA, 28 August - 1 September, 2012.

[3] Y. Fan, M. Q.-H. Meng, B. Li, "A Novel Method for Informative Frame Selection in Wireless Capsule Endoscopy Video," 33rd Annual International Conference of the IEEE EMBS Boston, Massachusetts USA, August 30 - September 3, 2011.

[4] D. Wang, X. Xie, G. Li, Y. Gu, Z. Yin, Z. Wang, "Research on 2D Representation Method of Wireless Micro-Ball Endoscopic Images," 34th Annual International Conference of the IEEE EMBS San Diego, California USA, 28 August - 1 September, 2012.

[5] Y. Gu, X. Xie, Z. Wang, G. Li , T. Sun, N. Qi, C. Zhang, Z. Wang "A new globularity capsule endoscopy system with multi-camera", Biomedical Circuits and Systems Conference, 2009.BioCAS 2009, IEEE, pp. 289-292.

[6] B. Li, M. Q.-H. Meng, "Wireless capsule endoscopy images enhancement using contrast driven forward and backward anisotropic diffusion," IEEE International Conference on Image Processing, ICIP, San Antonio, TX, 2007.

[7] M. K. Monaco, "Color Space Analysis for Iris Recognition," M.S. thesis, Dept. of Computer Science and Elect. Eng., West Virginia Univ., West Virginia, 2007.

[8] T. Tuytelaars and K. Mikolajczyk, "Local Invariant Feature Detectors: A Survey," Foundations and Trends in Computer Graphics and Vision, 2007.