Image Enhancement Using Geometric Mean Filter and Gamma Correction for WCE Images

Shipra Suman[1], Fawnizu Azmadi Hussin[1], Aamir Saeed Malik[1], Nicolas Walter[1], Khean Lee Goh[2], Ida Hilmi[2], and Shiaw hooi Ho[2]

[1] Electrical and Electronic Engineering, Universiti Teknologi PETRONAS, 31750 Tronoh, Perak, Malaysia
[2] Department of Medicine, university of Malaya, 50603, Kuala Lumpur, Malaysia
suman.shipra@ieee.org, {fawnizu,aamir_saeed}@petronas.com.my, {walter.nicolas.pro,klgoh56}@gmail.com, i_hilmi@um.edu.my, shooiho@yahoo.com

Abstract. The application of image enhancement technology to Wireless capsule Endoscopy (WCE) could extremely boost its diagnostic yield. WCE based detection inside gastrointestinal tract has been carried out over a great extent for the seek of the presence of any kind of etiology. However, the quality of acquired images during endoscopy degraded due to factors such as environmental darkness and noise. Hence, decrease in quality also resulted into poor sensitivity and specificity of ulcer and diagnosis. In this paper, a method based on color image enhancement through geometric mean filter and gamma correction is proposed. The developed method used geometric mean filtering to reduce Gaussian noise present in WCE images and achieved better quality images in contrast to arithmetic mean filtering, which has blurring effect after filtration. Moreover, Gamma correction has been applied to enhance small details, texture and contrast of the images. The results shown improved images quality in terms of SNR (Signal to Noise Ratio) and PSNR (Peak Signal to Noise Ratio) which is beneficial for automatic detection of diseases and aids clinicians to better visualize images and ease the diagnosis.

Keywords: Wireless capsule endoscopy (WCE), image enhancement, geometrical means filter, gamma correction.

1 Introduction

Wireless Capsule Endoscopy (WCE) is a recent technique (approved by Food and Drug Administration (FDA) in 2002)[1] that allows clinicians to inspect gastrointestinal (GI) tract. Earlier imaging modalities such as upper gastrointestinal endoscopy, colonoscopy, and push enteroscopy allowed examining the stomach, duodenum, colon and terminal ileum. However, these techniques are long procedures as they require preparation of the patient and are painful. Moreover, most of small intestinal parts could not be observed without performing surgery that is invasive [2, 3]. In 2000, a short paper published in nature [4] introduced an advanced form of endoscopy,

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i.e. WCE, designed by the company Given Imaging® [5]. The apparatus employs remodeling diagnosis process for GI tract and visualizes entire small intestine without sedation, pain or air insufflation. Hence, as the technology is not invasive, it has been promptly adopted by many practitioners and hospitals. Up to now, WCE has been used to detect many diseases [6-8] like small intestinal blooding, Crohn's diseases, ulcers, tumors, vascular lesions and colon cancers. It has also been reported by Given Imaging® that over 1,000,000 patients worldwide have already enjoyed the benefits of this device.

Fig. 1 describes WCE pill-shaped device including short-focal-length CMOS camera, light source, battery and radio transmitter. It is swallowed by the patient after about 12 hours fasting. This miniature device propelled by peristalsis of GI tract begins to work and record images at 2 frames per second while moving forward along the GI tract. At the same time, images are sent to a data recorder attached to the patient's waist wirelessly.

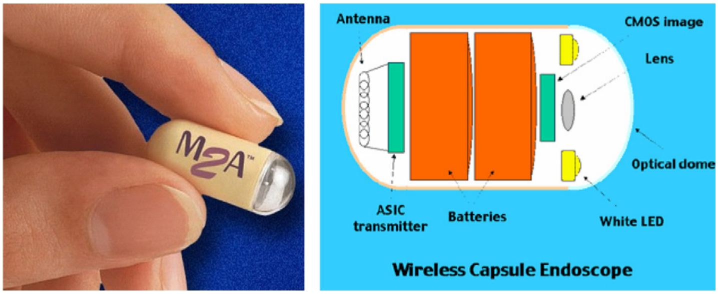

Fig. 1. Wireless capsule endoscopy capsule and its component [9]

The whole inspection process takes about 8 hours, before the image data can be processed. Finally, a physician performs analysis by watching the recorded data in the form of either video or images. However, the diagnosis process is time-consuming due to the huge amount of data (about 50,000 useful images per inspection). Therefore, the diagnosis is not a real-time process, making this situation a potential breakthrough for off-line post processing and computer aided detection.

Although clinical findings on WCE are encouraging, there still remains for a large gap for improving the automation [10]. For example, to reduce the image acquisition time, Olympus has been investigating a new generation of WCE such as self-propel capsule endoscopy [11]. One of the great challenges with the present WCE system is the image's quality. Qualities of WCE images are not ideal due to the following reasons. First, in order to reduce the communication bandwidth and save power, WCE images are not very clear due to high compression ratio [8]. Secondly, though CMOS image sensor has advantages of low power consumption and superior integration, the image quality it produced is not as good as that of CCD imagers [12]. Furthermore, the resolution of WCE image is only 256×256 due to volume limitation of encapsulation, especially power limitation, whereas traditional endoscopy has a superior performance on this aspect since no power limitation exists. Moreover, bad imaging conditions such as low illumination and complex circumstances in the GI tract will further deteriorate the quality of produced images. Finally, the short-focal-length camera pictures a low depth of focus, i.e. effects of depth will produce blurring.

The proposed method aims at enhancing the WCE images in order to improve the low illumination problem, sharpening the blurred parts and reduce the noise.. For the purpose of computer aided design (CAD) to ease the diagnosis of physicians [13], image filtering to reduce noise and gamma correction to enhance contrast of target images has been studied. Moreover, this method focused on local property of WCE images, leading to details enhancement. Results exhibit better performances of enhancement than conventional methods so as to assist diagnosis of physicians.

In the next Section is dedicated to the review of image enhancement techniques for noise removal and contrast enhancement. Methodology will be presented in Section 3 along with qualitative assessment. Section 4 provides experimental results and validation of the proposed methodology for real WCE sequences. Finally, Section 5 concludes the paper and presents future works.

2 Methods for Noise Removal and Contrast Enhancement

Noise removal is the process of removing noise from the image. Noise reduction techniques are conceptually very similar, regardless of the image being processed. However, a prior knowledge of the characteristics of the expected images gives better inference on the type of noise and eases the implementation of noise removal techniques. Mostly, the encountered noise in the acquired data exhibits a Gaussian-like distribution. Gaussian noise is characterized by his additive and zero-mean distribution property. Basically, the zero-mean property of the distribution allows such noise to be removed by locally averaging pixel values [14].

Contrast enhancement techniques improve the perception of objects in the scene by strengthen the brightness difference between objects and background. Contrast enhancements are typically performed as a contrast stretch followed by a tonal enhancement, although these could both be performed in one step. A contrast stretch improves the brightness differences uniformly across the dynamic range of the image, whereas tonal enhancements improve the brightness differences in the shadow (dark), midtone (grays), or highlight (bright) regions at the expense of the brightness differences in the other regions.

2.1 Geometric Mean Filtering

Additive white Gaussian noise is a standard model which is present in WCE images. It is an idealized form of white noise, which is caused by random fluctuations in the signal [15] in color cameras where more amplification is used in blue channel other than green and red channel. While facing Gaussian noise, each pixel of the image will be affected.

Noise is an unavoidable side effect. Fig. 2 describes the filtering process. It separates the red, green and blue channels. It is followed by introducing a gain to compensate the attenuation resulting from the filter. Each filtered channel is then combined to form resulting colored image.

Geometric mean filter replaces the colour value of each pixel with the geometric mean of colour pixel values from a larger region surrounding it, based on filter size (3x3 or 5x5) and yields a stronger filter effect. The geometric mean filter performed better than conventional methods such as arithmetic filters to remove Gaussian type noise and preserve edge features [16].

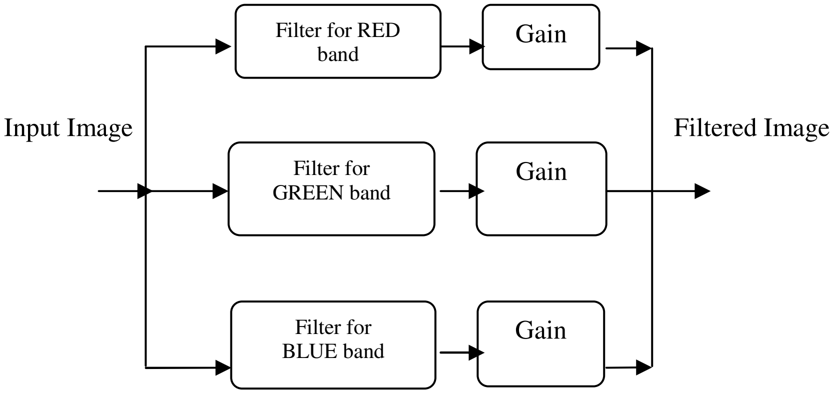

Fig. 2. Filteration of three band separately

Geometric filter is a simplest form of mean filter. Let's S_{xy} represents the set of coordinates in a sub-image window (neighborhood) of size m x n where m and n are equal, centered at point (x, y). The local image function f(x, y) is filtered image and g(s,t) is input image. In Geometric mean filter each restored pixel is given by the product of the pixels in the sub-image window, raised to the power 1/m×n as described in (1).

$$f(x, y)=[\pi(s,t)\epsilon\ Sxy\ g(s,t)]^{1/mn} \quad (1)$$

The purpose is to produce more objective images (ideally noiseless) for particular application than the original images and hence, increase the accuracy of further algorithms, making them more similar to the characteristics of human visual recognition system.

2.2 Gamma Correction

For color space transformation, the absolute separation between chrominance and luminance components is not achievable due to the cross talk of colour channels, i.e. colors are correlated. Compared to the above methods, gamma correction method has some advantages to overcome the effects of light distortion. However, it is often difficult to select suitable gamma values without a prior knowledge about illumination and the texture details are often lost because of over correction [17, 18]. Moreover, the varieties of images greatly challenge the performance of the traditional Gamma Correction Model (GCM) in applications.[19]

Gamma correction is a nonlinear operation used to encode the luminance in image systems. Gamma correction can be described for simple model, as follows:

$$V_{out}=AV_{in}^{\gamma} \quad (2)$$

Where V_{in} is the input original image, V_{out} is the output corrected image and *A* is a constant used as a gain. Input and output values are non-negative real values; in the common case of *A* = 1, inputs and outputs are typically in the range 0–1. A gamma value $\gamma < 1$ is sometimes called an encoding gamma and the process of encoding with this nonlinear compressive power-law is called gamma compression; conversely a gamma value $\gamma > 1$ is called a decoding gamma and the application of the nonlinear power-law is called gamma expansion.

3 Methodology

3.1 Image Samples

In this paper, 11 annotated WCE images were taken for pre-processing from http://www.capsuleendoscopy.org website. These images have been labelled by experts to be used as gold standard during analysis. They labelled ulcerated and bleeding areas in each frame. We used these images along with more image samples for validation purpose in further experiment. Fig. 3 shows some samples of WCE images. Image 1 and image 4 have ulcerations highlighted by the blue ellipses whereas image 2 and 3 has bleeding underlined by the yellow ellipses.

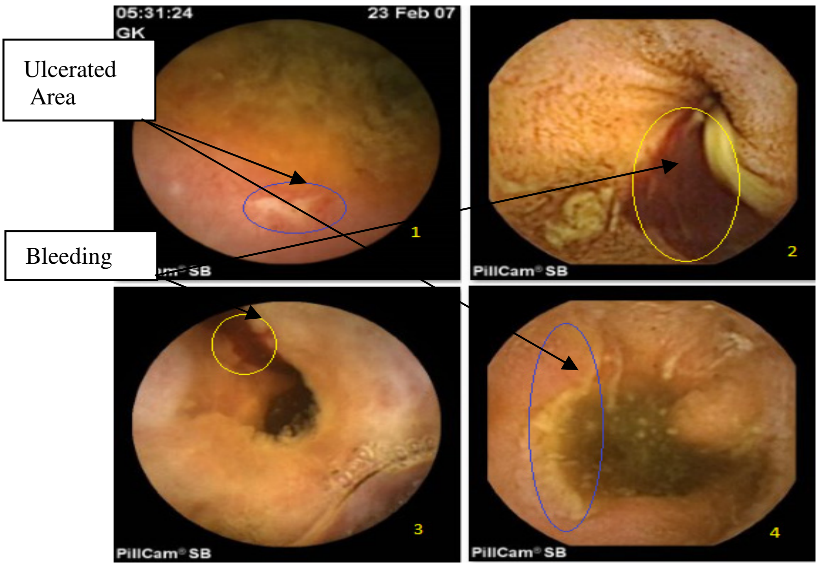

Fig. 3. Sample of WCE images

3.2 Image Enhancement

For image enhancement (see Fig. 4), filters such as geometric, harmonic mean and laplacian have been applied to improve the contrast. These WCE images have Gaussian noise, so mean filters are more suitable to remove this noise. Contrast stretching is performed by gamma correction of images after filtration, according to the method described in Section 2.

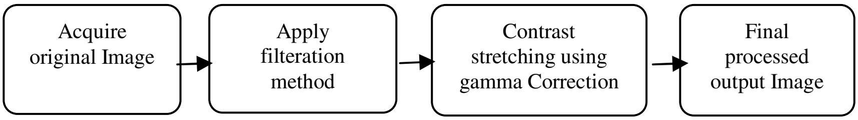

Fig. 4. Flow Chart of Image Enhancement process for WCE Images

3.3 Qualitative Analysis

To measure the quality degradation of an available distorted image with reference to the original image, a class of quality assessment metrics called full reference (FR) is considered. It can perform distortion measure having full access to the original image. The quality assessment metrics are estimated through computation of MSE (mean square error), RMSE (root mean square error), SNR (Signal to noise ratio) and PSNR (peak signal to noise ratio) using their standard formula for imaging.

4 Results and Discussions

Fig. 5 shows SNR and PSNR for the 11 reference images before and after noise removal. Here, SNR_1 illustrate output before filtration and SNR_2 after filtration. One can observe that SNR is increased, showing improvement in the quality of resulting images.

The size of the images used was 576×576 and the noise parameter was compared using SNR and PSNR. The 11 sample images are not taken from only one capsule endoscopy. Hence, the variations depicted in Fig. 5.

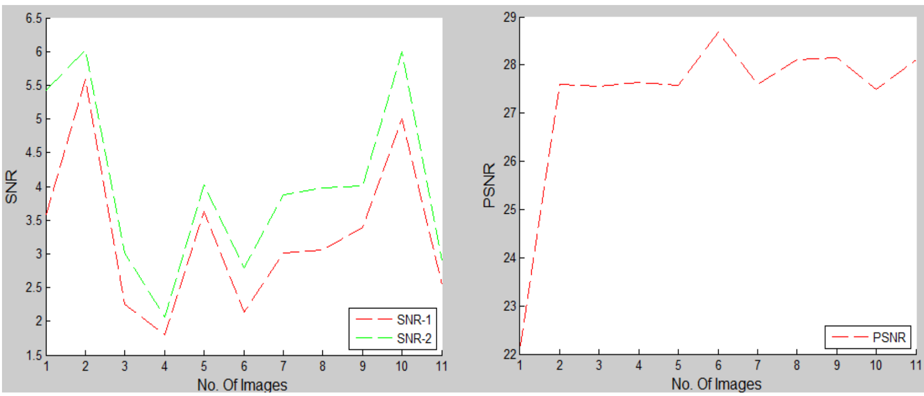

Fig. 5. SNR and PSNR, before (red) and After Filtering (green)

In Fig. 6, we can visualize effects of geometrical mean filtering and gamma correction at experimental level. The image on the left side is original WCE image with noise which is filtered by geometric mean filter to reduce noise and finally gamma correction is used to enhance contrast. Each pixel value has been changed as per suitable procedural filter, leading to more refined output images. If we visualize final images, we can see clearly more erythema patches which are not that clear in original image. Noise reduction also helps to make image quality better. It helps to visualize more villi pattern which can help for more accurate diagnosis.

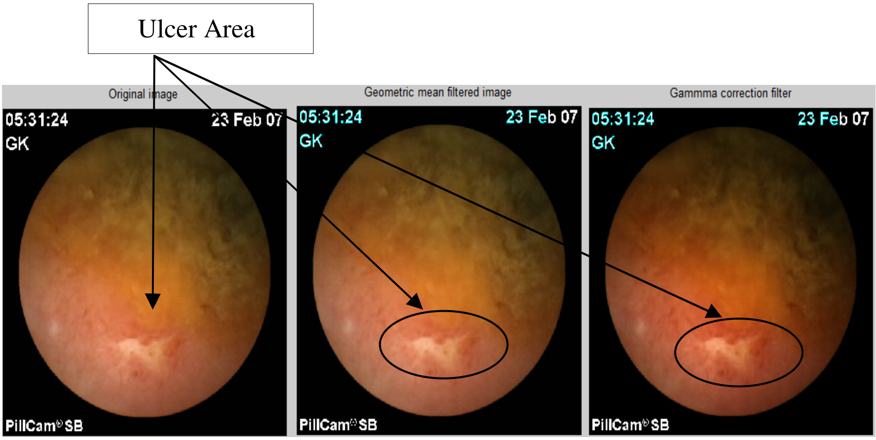

Fig. 6. Original Image (left), Geometric mean filtered image (centre) and gamma corrected image (right)

5 Conclusion

An image enhancement method based on geometric mean filtering and gamma correction has been proposed. Geometrical mean filtering and gamma correction methods contribute enhancement to image smoothing and contrast enhancement. The method tends to lead in more enhanced image quality for WCE images where we can visualize intestinal surface clearly to distinguish between normal and abnormal regions. Outcome of resulting images has been discussed with medical experts from University of Malay Medical Center with positive feedback. Above results show that the enhancement method can filter noise and increase the contrast ratio of the target image which is beneficial for feature extraction, points matching and vision measurement. This result can be further used to detect diseases such as ulcer and bleeding in WCE images using segmentation and classifiers.

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