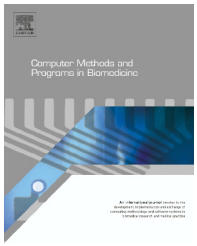
COMPUTER METHODS AND PROGRAMS IN BIOMEDICINE 122 (2015) 341–353

journal homepage: www.intl.elsevierhealth.com/journals/cmpb



Computer-aided gastrointestinal hemorrhage detection in wireless capsule endoscopy videos

*Ahnaf Rashik Hassan, Mohammad Ariful Haque**

Department of Electrical and Electronic Engineering, Bangladesh University of Engineering and Technology, Dhaka 1205, Bangladesh

ARTICLE INFO

Article history:
Received 5 May 2015
Received in revised form
27 August 2015
Accepted 1 September 2015

Keywords:
Wireless capsule endoscopy (WCE)
Bleeding detection
Support vector machine
Normalized Gray Level
Co-Occurrence Matrix

ABSTRACT

Background and objective: Wireless Capsule Endoscopy (WCE) can image the portions of the human gastrointestinal tract that were previously unreachable for conventional endoscopy examinations. A major drawback of this technology is that a large volume of data are to be analyzed in order to detect a disease which can be time-consuming and burdensome for the clinicians. Consequently, there is a dire need of computer-aided disease detection schemes to assist the clinicians. In this paper, we propose a real-time, computationally efficient and effective computerized bleeding detection technique applicable for WCE technology.

Methods: The development of our proposed technique is based on the observation that characteristic patterns appear in the frequency spectrum of the WCE frames due to the presence of bleeding region. Discovering these discriminating patterns, we develop a texture-feature-descriptor-based-algorithm that operates on the Normalized Gray Level Co-occurrence Matrix (NGLCM) of the magnitude spectrum of the images. A new local texture descriptor called difference average that operates on NGLCM is also proposed. We also perform statistical validation of the proposed scheme.

Results: The proposed algorithm was evaluated using a publicly available WCE database. The training set consisted of 600 bleeding and 600 non-bleeding frames. This set was used to train the SVM classifier. On the other hand, 860 bleeding and 860 non-bleeding images were selected from the rest of the extracted images to form the test set. The accuracy, sensitivity and specificity obtained from our method are 99.19%, 99.41% and 98.95% respectively which are significantly higher than state-of-the-art methods. In addition, the low computational cost of our method makes it suitable for real-time implementation.

Conclusion: This work proposes a bleeding detection algorithm that employs textural features from the magnitude spectrum of the WCE images. Experimental outcomes backed by statistical validations prove that the proposed algorithm is superior to the existing ones in terms of accuracy, sensitivity, specificity and computational cost.

* *Corresponding author*. Tel.: +880 1864977369.
E-mail address: arifulhoque@eee.buet.ac.bd (M.A. Haque).

http://dx.doi.org/10.1016/j.cmpb.2015.09.005
0169-2607/

1. Introduction

The classical endoscopic procedure has enabled clinicians to investigate the human gastro-intestinal (GI) tract. Despite being efficacious for the upper (duodenum, stomach and food pipe) and lower part (colon and terminal ileum) of the GI tract, the traditional endoscopy miserably fails to examine the small intestine. The human small intestine is about 8 m long and conventional endoscopy such as Colonoscopy or Esophagogastroduodenoscopy cannot image it satisfactorily. To overcome the limitations of traditional endoscopy, Iddan et al. [1] pioneered the invention of wireless capsule endoscopy (WCE). The WCE system consists of a pill-shaped capsule. The capsule has a built-in video camera, video signal transmitter, light-emitting diode and a battery. It is swallowed by the patient and is propelled forward by peristalsis of human GI tract. It records images as it moves forward along the GI tract and transmits them at the same time using radio frequency. It transmits over the course of about 8 h until its battery runs out. Due to its promising performance for the visualization of human GI tract, U.S. Food and Drug Administration (FDA) approved it in 2001 [2].

1.1. *Problem description*

Manual classification of bleeding and non-bleeding endoscopic video frames has a number of limitations. The power supply of the capsule has limitations which result in low resolution (576×576) of endoscopic video frames. The video frame rate is also low (2 frames/second). Besides, about 60,000 images have to be inspected per examination. It takes an experienced clinician about 2 h which may not be pragmatic in most clinical scenarios. Since the evaluation process is time-consuming and a large volume of images have to be inspected, bleeding detection becomes more subject to human error. So a computer-aided detection (CAD) of bleeding frames can make this monumental task easy for clinicians.

Given Imaging Ltd. [3] designed a software called Suspected Blood Indicator (SBI) for automatic detection of bleeding frames. But SBI demonstrates poor sensitivity and specificity and often fails to detect any kind of bleeding other than that of the small intestine [4]. The software designed by Given Imaging Ltd. allows the physician to view two consecutive frames at the same time. But due to low frame rate, two consecutive frames may not contain the area of interest. Consequently, the clinician has to toggle between images making the evaluation process even more onerous and time-consuming. All the aforementioned problems of manual screening can be eliminated by the use of CAD.

1.2. *Related work*

The previous works on GI hemorrhage detection can roughly be classified as: color based, texture based and color and texture based methods. Color based methods [5–8] basically exploit the ratios of the intensity values of the images in the RGB or HSI domain. Texture based approaches attempt to utilize the textural content of bleeding and non-bleeding images to perform classification [9–11]. It has been reported that the combination of color and texture descriptors exhibit good performance in terms of accuracy [12]. Again, depending on the region of operation, CAD bleeding and tumor detection literature can be categorized into three groups – whole image based [12–15], pixel based [5,6,16] and patch based methods [9,17] as in [7]. Whole image based methods are fast but often fail to detect small bleeding regions. Pixel based methods have to operate on each pixel of the image to generate the feature vectors. As a result, they are computationally very expensive. It can be expected that patch based methods will achieve good accuracy while keeping the computational cost low. However, patch based methods show high sensitivity but low specificity and accuracy. Besides, informative patches need to be identified manually by a clinician which hinders the idea of making the whole process automatic.

Li and Meng [9] put forward a chrominance moment and Uniform Local Binary Pattern (ULBP) based solution to bleeding detection. Yanan Fu et al. [7] came up with a super-pixel and red ratio based solution that was promising in terms of accuracy. But it was reported that this method has a high computational cost and fails to detect images with poor illumination and minor angiodysplasia regions whose hue is similar to normal tissue. Hwang et al. [16] utilized Expectation Maximization Clustering algorithm for CAD of bleeding frames. Some prior works [10,11] employed MPEG-7 based visual descriptors to identify medical events such as blood, ulcer and Crohn's disease lesions. Pan et al. [5] formed a 6-D feature vector using R,G,B,H,S,I values and used probabilistic neural network (PNN) as classifier. Liu et al. [6] proposed Raw, Ratio and Histogram feature vectors which are basically the intensity values of the image pixels and used support vector machine (SVM) to detect GI bleeding. Hegenbart et al. [18] utilized scale invariant wavelet based texture features to detect Celiac disease in endoscopic videos. Using MPEG-7 based visual descriptors, Bayesian and SVM, Cunha et al. [19] segmented the GI tract into four major topographic areas and performed image classification. For a more comprehensive review on computer aided decision support system for WCE videos, [20] can be consulted.

1.3. *Our method*

In this work, we aim to draw inferences (bleeding or non-bleeding) on the spatial domain of an image by extracting features in the frequency domain. Fig. 1 depicts the steps of the proposed scheme. At first, we compute discrete Fourier transform (DFT) of the endoscopic video frames. Afterwards we take the log transform of the magnitude spectrum of the frames. Normalized Gray Level Co-occurrence Matrix (NGLCM) matrix is then constructed to extract features from each log transformed magnitude spectrum. The selected features are computed from NGLCM. The features are then fed into support vector machine classifier to perform classification of the frames.

There are significant distinctions between the proposed approach and previous studies on bleeding detection in the literature. It has also some advantages. Both are described as follows.