A Colour Rotation Based Detector for Bleeding Gastric Pathologies

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ABSTRACT

Colour is one the distinct features in computer vision systems and can be represented in several colour spaces. The most commonly used is the RGB colour space, since most high-quality cameras used in computer vision systems provide RGB signals, for example endoscopic capsule cameras. This work describes a computer vision algorithm intended to assist the physician in the diagnosis of endoscopic diseases, such as gastrointestinal bleeding, using a colour space rotation-based method. This algorithm modifies the images RGB representation channels in such way that the bleeding information can be effectively enhanced in a single channel. Tests in endoscopic images were performed and results have shown that the proposed colour-based rotation approach successfully increases the detection of bleeding regions in endoscopic images, corroborating the usefulness in physician diagnosis assistance.

1. Introduction

Wireless Capsule Endoscopy (WCE) is a recent diagnosis process in which the patient, under medical supervision, swallows a small colour high-resolution camera device with a capsule shape that is propelled by peristalsis through the gastrointestinal (GI) tract [ASV04]. These devices have a system of lens and an image emitter, which are collected in a recorder device that the patient transports on its cincture [ASV04; GA03]. The main advantage of using these devices arises from the possibility of examination of the entire GI tract, against traditional endoscopy, which only allows examining the extremities of gastric tract. A major drawback of WCE technology is the time consuming needed to inspect and diagnosis by the physician, since a single diagnosis examination has about 50.000–60.000 images (these devices capture 2 frames per sec) obtained from 7 to 8 hours long exam videos [BMK05; GA03]. The videos usually are reviewed, at speeds between 5 to 40 images per second which corresponds to 180 to 45 minutes, respectively, to obtain the results. This can be a strong time-limitation for the physician to uninterruptedly review each video for about 3 hours. Moreover, the facts of the abnormalities can be presented in a reduced number of images (that can be easily missed when reviewing the videos at 40 images per second) and that sometimes some abnormalities can be imperceptible by naked eyes, also condition this diagnosis process. All these issues contribute to increase the difficulty of diagnosis task, even to experienced physicians.

It is clear that different diseases have different symptoms and consequently different distributions (size, colour, shape, patterns, etc), even the same disease can present meaningful variations. Bleeding is one of the most common symptoms of disease found in GI tract. It is easily understandable that colour is an important feature in GI diseases diagnosis. These matters contributed and stimulated the development of computer-assisted systems to improve the physicians diagnosis process.

Several techniques have been reported in the literature addressing GI disease detection. Colour adaptation was proposed [BMK05] and makes use of a colour reference of the image. This adaptation is performed by a cone response transform and the colour reference is obtained by a neural network (NN). In addition, MPEG-7 visual descriptors, namely Scalable Color and Homogeneous Texture are used to extract features or detect events that allow discriminating between normal and abnormal tissues (polyp, bleeding or ulcers) [CC06]. From this proposal a new approach to segment the GI tract into four different topographic zones – entrance, stomach, small intestine and large intestine – was presented using support vector machines (SVMs) [CCC08]. Additionally, colour spectrum transformation method [JKL*08] uses a colour spectrum histogram after an intensity adjustment in HSI colour space to distinguish bleeding from non-bleeding zones. Furthermore, the block-based method [LC07] is a 2 step process that discriminates the presence/absence of bleeding zones dividing the images represented in HSV colour space in fixed sized blocks in saturation channel (first step), and a luminance and colour saturation pixel-based analysis (second step). Finally [GXY*08] presents the features extraction considering some measures such as histograms, dominant colour and co-occurrence of dominant colours. The classification method considers a balanced learning process of the SVM, since the examinations have a vast amount of data and the presence of diseases only occurs in a diminish number of examination data images.

The previously mentioned methods use colour images, which is a very important characteristic to explore for disease detection, particularly bleeding detection. The pill cam manufacturer [Giv09] provides a tool (Suspected Blood Indicator - SBI) to detect possible diseases over a recorded examination. Some authors reported studies using SBI and all conclude that sensitivity and specificity are poor to non-bleeding diseases and superior to active bleeding or associated diseases [BGK*08; GGV*07; LMR03]. In the previous case, the sensitivity values are typically between 58.3%-81.2%.

Our goal is to propose a rotation-based method that performs an efficient endoscopic video discrimination regarding the presence of bleeding regions. Since the most of the gastrointestinal images present red-based colour characteristics (in the case of bleeding frames the red colour is more accented and so our choice to use RGB colour space), the core idea is to perform a colour space rotation in endoscopic image, for not only to enhance the bleeding area perception, but also to project this information in a single channel, instead of the original three channels image.

However, analysing WCE images red channel by itself did not reveal accurate enough to effectively distinguish GI tract bleeding presence, since the bleeding information is spread along the three RGB colour channels. The use of colour space transformations have been applied to image processing related problems, to our knowledge, this is the first application in the bleeding diseases pathology area. With this approach, the diagnosis visualization time is intended to be reduced, since non-bleeding frames can be discarded by physicians, increasing the celerity of the diagnosis process.

The paper is organized as follows. Section 2 presents the proposed rotation premise that enhances the bleeding detection in GI tract images. Section 3 presents some experiments that validate the proposed methodology and discusses the results. Finally, Section 4 concludes the paper and discusses possible future developments.

2. The RGB Colour Space Algorithm

The endoscopic images used in this work are square sized and possess inside an area of a circular shape, which contains the informative data. This image sub-region (non-black zone) is named the region of interest (ROI), which is useful for processing performance increase. Since all the images have the same dimensions, this calculus is performed for the first image and extended to all set images. Typically, in a video sequence, images can possess significant variation of colour (dark/brown zones, pink zones – depending of image capture organ), different luminosity and focus (image capture too close or too far from tissue), may contain stool or bubbles, etc., which imply difficulty to symptoms detection. Some WCE exemplificative images are presented in Figure 1.

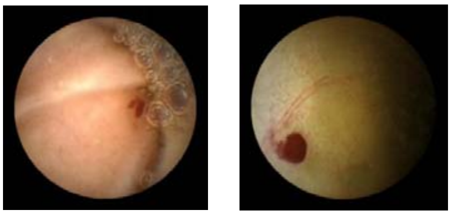


Figure 1: *WCE bleeding images examples.*

Consider an arbitrary image pixel x belonging to RGB space, i.e., $x = (x_r, x_g, x_b)$, where x_r, x_g and x_b are the red, green and blue components, respectively. A rotated pixel $x' = (x_r', x_g', x_b')$ is then defined:

$$x' = R_{rgb} \times x. \tag{1}$$

The RGB fundamental rotation matrix is defined as:

$$R_{rgb} = R_r \times R_g \times R_b, \tag{2}$$

and

$$R_r = \begin{bmatrix} 1 & 0 & 0 \\ 0 & \cos\alpha & \sin\alpha \\ 0 & -\sin\alpha & \cos\alpha \end{bmatrix} \tag{3}$$

$$R_g = \begin{bmatrix} \cos\beta & 0 & -\sin\beta \\ 0 & 1 & 0 \\ \sin\beta & 0 & \cos\beta \end{bmatrix} \tag{4}$$

$$R_b = \begin{bmatrix} \cos\gamma & \sin\gamma & 0 \\ -\sin\gamma & \cos\gamma & 0 \\ 0 & 0 & 1 \end{bmatrix}, \tag{5}$$

where α, β and γ are some rotation angles through red, green and blue axes, respectively.

Applying (2) to all image pixels results in:

$$I_{Rot} = R_{rgb} \times I_{Orig}, \tag{6}$$

where I_{Rot} is the resulting three channels RGB rotated image and I_{Orig} is the original image.

Next, the maximum and minimum pixel values from each channel of the RGB rotated image (I_{Rot}), I_{Rot}^{max} and I_{Rot}^{min}, respectively are obtained.

Afterwards, we normalized each channel of the earlier obtained rotated image I_{Rot}, then we combined all channels, resulting in the RGB rotated normalized image I_{Norm}, i.e.,

$$I_{Norm} = 255 \times \left(\frac{I_{Rot} - I_{Rot}^{min}}{I_{Rot}^{max} - I_{Rot}^{min}}\right) \tag{7}$$

Subsequently, a suitable binary segmentation to the red channel of the rotated normalized image I_{Norm} is applied, obtaining I_{Bin}. Since the videos can vary a lot between lumen zones, using only a threshold does not result in a good solution. A threshold based on the maximum of each images I_{Rot} red component was applied $I_{Rot}^{max,RED}$, as presented in (8):

$$thr = \begin{cases} x : I_{Rot}^{max,RED} \geq \varphi \\ y : I_{Rot}^{max,RED} < \varphi \end{cases}, \tag{8}$$

where x and y are the different intensity values (used as the boundary value) to segment each image, and φ is a constant value, obtained by experimental testing, as presented later.

A final step applied is to eliminate small zones of I_{Bin} that do not correspond to diseases (small zones in ROI frontier). The applied criterion was to remove zones with area inferior to 10 pixels. To obtain such zones, a search method for connected pixels was applied to I_{Bin}, using a 4-connected point neighbourhood.

For method evaluation performance, one additional step was applied, in which the number of white pixels inside I_{Bin} is calculated. This allows to classify the image as bleeding image (if the number is greater than a pre-defined value) or non-bleeding, (for the other cases).

Some considerations about the application of the method are presented in the following Section.

3. Experimental Results

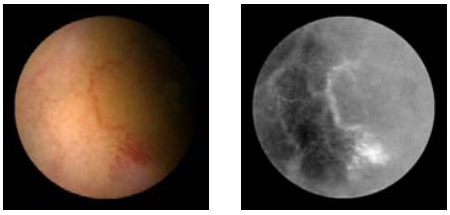
3.1 Setup

The images used in this study were obtained from 2 subjects and were manually classified by a gastroenterologist physician. Each frame is 8-bit colour depth and 576x576 pixels. The experiments were conducted in 5 random experimental sets, each with sequential 3000 images extracted from the afore mentioned videos. The colour space rotation analysis was realized on a PC (Intel Core 2 CPU T9300 at 2.5 GHz), using Matlab R2008a (The Mathworks, Inc., Natick, USA).

3.2 Experimental Considerations

In order to apply the suggested method, extensive empirical search was required. Therefore it became necessary to clarify some issues concerning the implementation.

The achieved angles for (2) were set to $\alpha = 0^o$, $\beta = 0^o$ and $\gamma = 300^o$. These values were selected with the purpose to magnifying the projection of bleeding characteristics in the red channel of R_{rgb}. It was our choice for this work to project it for the red channel. To perform such magnification for the green or blue channel individually, other different set of angles must be obtained. Figure 3 presents an exemplifying image following the previous considerations. Fig. 3(a) shows a random WCE image with bleeding presence and Fig. 3(b) represents the resulting image applying the proposed method until (7), i.e., I_{Norm}:



(a) (b)

Figure 3: *WCE images: (a) Original image with active bleeding; (b) Normalized image after RGB rotation.*

The maximum pixel value present in each I_{Rot} red channel image ($I_{Rot}^{max,RED}$) was used to select the intensity value to use as threshold of I_{Norm} , resulting in the binary segmentation. After some evaluation of the $I_{Rot}^{max,RED}$ variation through a set of random 300 images (150 with bleeding presence and 150 without bleeding presence), previously classified using the SBI [Giv09], an approximation value $\varphi = 9.8$ was obtained as boundary, as presented in following Fig. 4.

Taking into account the previous considerations, the following intensity values were obtained. To binary segment each image, one of these threshold intensity levels will be applied according to each images maximum pixel value on the red component:

$$thr = \begin{cases} 205 & : I_{Rot}^{max,RED} \geq 9.8 \\ 205 + 40: & I_{Rot}^{max,RED} < 9.8 \end{cases} \quad (9)$$

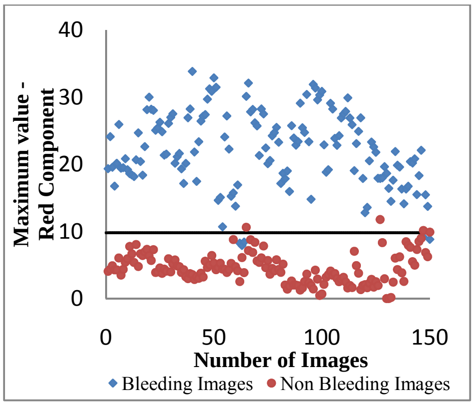
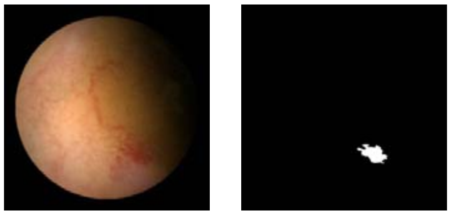


Figure 4: *Variation of maximum values through RGB rotated red component images*

Figure 5 presents an exemplificative bleeding image following the previous considerations. Fig. 5(a) Illustrates the same random WCE image presented in Fig. 3(a) and Fig. 5(b) represents the resulting image applying the final result of the proposed method.



(a) (b)

Figure 5: *WCE images: (a) Original image with bleeding presence; (b) Proposed method resulting image.*

3.3 Method Performance

To perform the evaluation of the proposed method, some broadly medical statistical indicators were applied, i.e., the sensitivity, subjectivity and accuracy as follows [GXY*08; LM09]:

$$Sensitivity = \frac{TP}{TP+FN}, \quad (10)$$

$$Subjectivity = \frac{TN}{TN+FP}, \quad (11)$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN}, \quad (12)$$

where TP, TN, FP and FN designate the number of positive examples correctly labelled, the number of negative examples correctly labelled, the number of negative examples labelled as positive, and the number of positive examples labelled as negative, respectively. Accuracy reflects the relation between sensitivity and subjectivity to each other. These indicators should show a high tendency.

Table 1: *Performance results of the proposed algorithm.*

	Sensitivity	Subjectivity	Accuracy
Set 1	75.00%	84.50%	84.47%
Set 2	91.16%	93.01%	92.88%
Set 3	100.0%	93.30%	93.41%
Set 4	100.0%	81.40%	81.40%
Set 5	86.67%	95.56%	95.52%
Average	90.57%	89.55%	89.54%

From Table 1, one can observe that the proposed method presents an encouraging performance for bleeding detection, as it presents high average sensitivity, subjectivity and consequently accuracy percentages. Comparing to other state-of-art bleeding detectors, our work over performed some [BGK*08; GXY*08; LMR03] that present sensitivity values around 80% and slightly under performed others [GGV*07; JKL*08; LC07] that present sensitivity values around 92 to 93%.

Moreover, the high sensitivity also reveals that the number of FN classified images, compared to TP, is low. This indicates that few bleeding images are classified as non-bleeding ones, taking into consideration that each image is analysed by itself without adjacent frames information considered.

4. Conclusions and Future Work

This paper proposed a simple colour space rotation to augment the perception of bleeding patterns in WCE images, by projecting the information in a single channel, instead of the original three channels. The system presented an overall average sensitivity and subjectivity around 90%, which proved to be promising to physicians diagnosis assistance, not only through the reduction of images to observe (and consequently the reduction of time spent to obtain the diagnosis), but also by the proposal of the location to inspect in bleeding classified images.

Future work may include working in several details, such as including non-static rotation angles to the method using some criteria to adjust to the best perspective rotation. Eventually, the threshold method in binary segmentation could also be improved to dynamically be adjusted to each image.

Another objective may be to improve the detection to include an improved approximation of shape of the bleeding in the final segmented image, and include information of adjacent images to classify images as bleeding/non-bleeding ones.

References

[ASV04] ALI A., SANTISI J. M., VARGO J., Video capsule endoscopy: A voyage beyond the end of the scope. *Cleveland Clinic Journal of Medicine* (2004), 71(5), 415–424.

[BMK05] BOURBAKIS N., MAKROGIANNIS S., KAVRAKI D., A neural network-based detection of bleeding in sequences of WCE images. *In Proceedings of the Fifth IEEE Symposium on Bioinformatics and Bioengineering (BIBE'05)*, 324-327

[BGK*08] BUSCAGLIA J., GIDAY S. A., KANTSEVOY S. V., CLARKE J. O., MAGNO P, YONG E., MULLIN G.E., Performance characteristics of the suspected blood indicator feature in capsule endoscopy according to indication for study. *Clin Gastroenterol Hepatol*, (2008) 6(3), 298-301

[CC06] COIMBRA M. T., CUNHA, J. P. S., MPEG-7 Visual Descriptors-Contributions for Automated Feature Extraction in Capsule Endoscopy. *IEEE Transactions on Circuits and Systems for Video Technology,* (2006), *16*(5), 628-637

[CCC08] CUNHA J. P. S., COIMBRA M., CAMPOS P.; Soares, J.M.;.. Automated Topographic Segmentation and Transit Time Estimation in Endoscopic Capsule Exams, *IEEE Transactions on Medical Imaging,* (2008), *27*(1), 19-27.

[GGV*07] GALTER S., GONZALEZ B., VILLANUEVA C., ORTIZ J., MONFORT D., ORDAS I., GALLEGO A., CASAS M., BALANZO J., Sensitivity and Specificity of the Suspected Blood Identification System in the Capsule Endoscopy. *Gastrointestinal Endoscopy,* (April 2007), 65(5), AB174.

[GXY*08] GIRITHARAN B., XIAOHUI Y., JIANGUO L., BUCKLES B., JUNGHWAN O., SHOU J. T., *Bleeding detection from capsule endoscopy videos*. in *Engineering in Medicine and Biology Society, 2008. (EMBS 2008).*

[Giv09] GIVENIMAGING, Given Imaging Inc., Retrieved 29-07-2009 from http://www.givenimaging.com/

[GA03] GOSTOUT, C., ADLER. D. G, State of the art, wireless capsule endoscopy. *Hospital Physician,* (2003), *39(5),* 14-22.

[JKL*08] JUNG, Y. S., KIM Y. H., LEE D. H., KIM J. H., Active Blood Detection in a High Resolution Capsule Endoscopy using Color Spectrum Transformation, *International Conference on BioMedical Engineering and Informatics (BMEI 2008)*, (2008), 1, 859-862.

[LC07] LAU P. Y., CORREIA P. L., Detection of bleeding patterns in WCE video using multiple features. *29th Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, (EMBS 2007), 2007.

[LMR03] LIANGPUNSAKUL S., MAYS L., REX D. K., Performance of Given suspected blood indicator. American Journal of Gastroenterology, (2003), 98(12), 2676-2678.