Real time video processing software for the analysis of endoscopic guided-biopsies

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Abstract. The severity in Barrett esophagus disease is, undoubtedly, the possibility of its malignization. To make an early diagnosis in order to avoid possible complications, it is absolutely necessary collect biopsies to make a histological analysis. This should be done under endoscopic control to avoid mucus areas that may co-exist within the columnar epithelial, which could lead to a false diagnosis. This paper presents a video processing software in real-time in order to delineate and enhance areas of interest to facilitate the work of the expert.

1. Introduction
Reflux oesophagitis takes place when the mechanisms existing in the gastro esophageal union fail. When enough time has passed, it can produce complications or turn into a chronic condition. One of the injuries that may appear is called Barrett esophagus, which is considered precancerous. Due to these reasons, the interest in this particular pathology has increased in the last couple of years. Barrett esophagus is caused by the reflux of gastric juices or intestinal content, which is rich in bilis, towards the esophagus [1]-[4]. This produces an epithelial damage, generally erosions or ulcers, whose ulterior curative process using basal pluripotentials cells, gives place to the different types of columnar epithelials that are seen in such alteration [5].
Barrett esophagus is defined as the presence of columnar mucosa with intestinal metaplasia in the esophagus. In practice, the best identifying method is through endoscopic diagnosis. The importance of this point is that the metaplasia of Barrett is a histological criterion rather than an endoscopic one, because it is possible to identify the intestinal metaplasia only with a directed biopsy; that is, looking for areas of dysplasia presenting greater likelihood for neoplasia. If the importance of Barrett esophagus lies on a high risk for malignant transformation, the treatments to induce its regression and the substitution of metaplastic mucosa by normal squamous epithelium may be the means to eliminate the risk of cancer. Because Barrett epithelium is a complication from chronic gastro-esophageal reflux, an efficient anti-reflux treatment could, theoretically at least, induce regression of the metaplasia. Such treatments include surgery and drugs to reduce gastric acidity. Therefore, in order to not only verify the occurrence of Barret esophagus, but also to diagnose its possible complications, it is absolutely essential obtain adequate biopsies that need to be performed under endoscopic control, so as to avoid areas of squamous mucosa that may coexist inside from the columnar epithelium, which –in turn- could lead to a false diagnosis. It is of fundamental importance
that the specialist performing the endoscopic study be given the means for distinguishing on the image the correct area to draw the biopsy samples, because the borders that envelop the illness are typically not well defined.

Various guided techniques to increase accurate of the diagnoses and making it less intrusive and fast are studied by specialists. Among them are the chromoscopy, which involves staining of the mucosa with dyes; the acetic acid, due to its mucolytic effect, provides better eyesight; and the narrow band imaging (NBI), recently developed by Olympus, which is based on modifying the bandwidth of the emitted light. All of these techniques have their advantages and their weak points. The chromoscopy and the use of acetic acid require additional time to succeed, by the other way NBI equipment have a high cost.

The objective of this work is to implement a filtering software in real time to enhance endoscopic images, in order to delimit, with less error, the area affected by the transformation of the mucosa, typical of Barrett's disease. This would enable the expert differentiating the different surfaces, reducing the possibility of false analysis and, consequently, false diagnoses.

2. Experimental bank
The prototype was mounted on an endoscopic imaging equipment formed of an Olympus CV-160 processor and an Olympus CLE-145 halogen light source.

The proposed system consists of a desktop PC and a video capture card Encore ENMVG-USB model, which supports an input signal type RCA-composite or S-Video in NTSC or PAL format and uses a 10-bit analog-to-digital converter, with a maximum resolution of 720x480 pixels for NTSC or 720x576 for PAL. The proposed and designed software is capable of acquiring video frames from the video capture card and to apply various filters in real time.

3. Software Design

3.1. Initial considerations
We consider the following issues in the development of the software application, according the professionals that perform the study:

- Real-time processing, ie, delay in the filtered images is indistinguishable.
- Good performance in any standard computer.
- Simple and intuitive graphical interface.
- Ability to store images for patient records and reports preparation, among others.
- Ability to store frequent use filter settings.
- The digital-analog conversion must not cause a significant loss in the quality of the video signal.
- Compatibility with different types of video signals.

according the developers:

- Easy to incorporate new processing algorithms.
- Supports multiple formats of image or video.

3.2. Software Development
We chose Visual C++ as programming language due to the following features:

- It is a very powerful object-oriented language, capable of generating simple and complex applications, such as operating systems or video games.
- It is widely used, it has a great support, so there are many online tutorials, books, open source codes, etc.
- Allows compiling and running C code.
It has a very powerful development environment, that allows object-oriented programming (OOP) in conjunction with the development system SDK of Windows (also called API). Because the Windows SDK is a complex set of functions, Visual C++ includes the class library MFC (Microsoft Foundation Classes) allowing create and manage an intuitive way typical components of Windows.

For handling the video signal and images, it was considered the open source libraries from Intel OpenCV as the best option. OpenCV is a high-level library that implements algorithms for calibration techniques, feature detection and tracking, shape analysis, motion analysis, 3D reconstruction, segmentation and object recognition. This library is capable of manipulate almost any video format or image transparently to the programmer. The best feature of this library, in addition to its quality and functionality, is its performance [6].

3.3. Graphical environment
Figure 1 shows the proposed graphical user interface, which can command all capture and processing actions.

The graphical interface allows to:

- Set filter parameters to a preset value.
- Adjust the filter parameters to the desired value.
- Adjust the scales of the original and processed video.
- Capture and store areas of interest through the screen.
- Store filter parameters.

![Graphical interface](image.png)

**Figure 1.** Graphical interface.
4. Implemented Filters

The filters implemented in the prototype were used successfully by the authors to delineate and enhance areas of interest to facilitate the work of the expert using the captured images from the video signal emitted by the endoscope [7][8].

4.1. Chromatic filter

A RGB color image is composed of three grayscale images of size $M \times N$, corresponding to the levels of red, green and blue. The chromatic filter consists in multiply by a constant, selected by the user according to a criterion, each color in order to enhance different attributes in the area under study [7][8].

4.2. Frequency Filter

In order to enhance important changes of gray level in the image we proposed to use a spectrum analysis. As abrupt changes are related to high frequencies while moderate changes are related to low frequencies, we modify the spectrum of the image, enhancing high frequencies and attenuating low frequencies, i.e. performing a high pass filtering. By this way, a new image is obtained, enhancing the variations that exceed a threshold and making darker the ones that do not exceed the threshold.

The spectrum of the image is obtained performing the Fourier transform in two dimensions. Since the RGB images are three dimensional, they are decomposed into three components, resulting in three grayscale images in two dimensions. Thus, the spectrum of each of these images have been calculated and processed, and finally recombined to a filtered RGB image [7-13]. The calculation of the Fourier transform is performed using the algorithms from the free library FFTW 3.2.2 [14].

4.3. Canny edge detector

The edges of an image are the boundaries separating regions with different brightness or color. J. Canny proposed an efficient method for detecting edges [15]. The algorithm takes as input a grayscale image and returns a binary image wherein the pixels whose value is nonzero represent the detected edge. The algorithm can be described by the following four steps [15]:

**Step 1 - Image smoothing:** The image is smoothed using a Gaussian filter whose band width is specified as parameter.

**Step 2 - Differentiation:** After smoothing, the image is derived in $x$ and $y$ directions. Then, we obtain the magnitude and phase of the gradient values through hypotenuse and arctangent functions.

**Step 3 - Non maximum suppression:** Once calculated the gradient at each point of the image, the edges can be located at the points of maximum gradient magnitude. This is accomplished through the suppression of the "non maximum", i.e. eliminating the points of the magnitude gradient that are not maximum.

**Step 4 - Edge thresholding:** Finally we describe the edges by applying what is called "hysteresis threshold". We operate on two thresholds, a lower and an upper one. They consist in eliminate those gradient values that are below the lower threshold, and keep those values that exceed the upper threshold. Those gradient values which are found between the two thresholds are kept only if they have a neighbor that exceeds the upper threshold.

4.4. Sobel filter

Sobel filter is an edge detection algorithm based on the calculation of the gradient of the intensity function of an image. The gradient of an image is obtained by calculating the partial derivatives $df/dx$ and $df/dy$ in each of the pixels of the image. There are many ways to implement digital derivative operators, however, Sobel operators stand out by its smoothing effect. This feature is important because, typically derivatives operators tend to increase the noise level.

The implementation of the Sobel operator is performed through the use of masks [16]. These are applied to the image using a spatial convolution, moving through the image pixel by pixel until a
complete output image is generated. We use two dimensional $3 \times 3$ masks, one for the horizontal and one for the vertical direction.

5. Results

5.1. Barrett’s images results
The images shown in this section reproduces the results obtained by using the developed software. Figure 2 (left) shows how the chromatic filter applied on the original image (right) clarifies the area under study, giving another perspective of tissue change.

Figure 3 shows several examples for frequency filtering. The images of figures (a) and (b) were obtained using preset settings. Figure (c) was obtained by increasing the passband gain, achieving an image with sharper relief, and figure (d) was obtained by increasing the attenuation of the rejection band, achieving an image where the parts with little relief are darker.

Figure 4 shows several examples of Canny filter for different values of lower and upper threshold. Also, chromatic filter has been applied to improve performance. It is noted that by decreasing the lower threshold value, the lesions and the less pronounced edges stick out, however, by increasing it, only the injuries are detected and the edges results more defined.

Figure 5 shows how the Sobel filter provides a completely different perspective to the rest of the filters, enhancing and amplifying the edges in the area under study.

![Figure 2. Original image combined with chromatic image](image-url)
Figure 3. Original images combined with images resulting from the frequency filter for different configurations. (a) Preset settings. (b) Preset settings. (c) Increasing the passband gain. (d) Increasing the attenuation of the rejection band.
Figure 4. Several images by applying the Canny filter for different configurations. (a) Canny filter on the original image. (b) Canny filter on the chromatic image when threshold value decreases. (c) Canny filter on the chromatic image when increasing the lower threshold.

Figure 5. Original image combined with resulting image from the Sobel filter.
5.2. Other pathologies results
Currently the number of patients who come to the clinic with symptoms of Barrett's esophagus do not represent the majority of cases. Due to the characteristics of the implemented filters, the software can be used for any kind of symptoms under study. Following, there are two images of different patients, with a brief remark made by the doctor who performed the study.

Case 1: In figure 6, we can see that filtering enhanced the mucosal pattern (pit pattern) and the grooves of the lesion confirming the presence of a benign adenoma.

Case 2: In figure 7, the original image shows a diffuse gastropathy. By applying the proposed filter, a sharper image with more pronounced relief was obtained, allowing the specialist perform a biopsy in the most representative tissue with greater precision.

Figure 6. Processed image that allowed the diagnosis of a benign lesion.

Figure 7. Enhanced image showing a diffuse gastropathy
6. Conclusions
Although digestive endoscopy has changed considerably in recent years, the images obtained by conventional endoscopic equipment face some technological difficulties. This is due in part to the fact that the white light that use these instruments does not allow identify areas of dysplasia. When identifying the affected area is not possible, the diagnosis lies in taking random biopsies. This adds complexity to the procedure and limits its performance, since sometimes the samples are not representative or are taken outside the lesioned area.
Select more precisely the pathological areas, it achieves a better diagnosis. The prototype developed has proved to be a simple and economic tool, allowing the delineation and enhancement of the areas of interest, the early detection of tissue changes and the errors reduction in the making biopsy. Its use does not require internal modification of the endoscopy equipment, simplifying the task of connecting and disconnecting the new image processing system.

7. Acknowledgements
The authors thank Dr. Gaston Jury and the CED (Centro de Estudios Digestivos de Mar del Plata) for their cooperation and the support provided for the development of the prototype.

8. References