AN APPROACH FOR COLORECTAL POLYP SEGMENTATION

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Abstract

In this paper, we present an effective approach for colorectal polyp segmentation by processing of endoscopy images.

In regard to quality limitations of colonoscopy images, a preprocessing stage is proposed. It consists of noise reduction with modified homomorphic filter based on wavelet packet decomposition of the transformed image, additionally correction of illumination and contrast enhancement based on CLAHE. The segmentation of colorectal polyps is based on active contour without edges.

Some experimental results are presented, obtained by computer simulation in the MATLAB environment. Implementation results demonstrate the effectiveness of the proposed approach for application in screening diagnostics.

1. INTRODUCTION

Colorectal carcinomas are the most common malignancies in industrialized countries, and can be classified as early or advanced according to the depth of invasion. Early colon carcinoma may occur in an adenomatous polyp and may be difficult to distinguish from a nonmalignant adenomatous polyp by colonoscopy. It is usually revealed by screening colonoscopy and may be curatively treated.

Important risk factors for the polyp malignancy include large size and high numbers of colonic polyps [1]. Based on endoscopic appearances, the advanced colorectal carcinoma can be divided into 4 groups, which are presented on Fig. 1. Type 1 lesion is characterized with protuberant tumor with fold convergence. Type 2 lesions show an irregular ulceration and clear marginal swelling. The lesion of Type 3 shows an irregular ulceration and unclear marginal swelling. The lesion of Type 4 is characterized with irregularly edematous mucosa with luminal stenosis due to diffuse infiltration.

Polyp segmentation is a challenging task. First, the intensity difference between a polyp and colon lumen (air) is apparent, the image intensity is quite similar between the polyp and its surrounding tissue. The low image contrast in a polyp's region makes automated polyp segmentation difficult. Therefore, polyps vary in shape, size, and location. The single shape or densitometry template is not sufficient to characterize all polyps

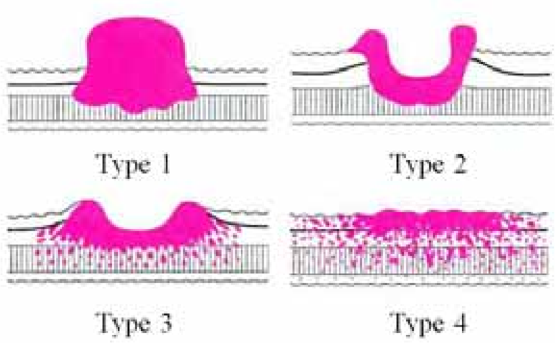

Figure 1. Macroscopic types of advanced colorectal carcinoma [1]

There are number of polyp segmentation methods, which have been reported in the literature [2]. Canny operator and the Radon transform are used to detect polyp boundaries [3]. Using structural entropy a fuzzy decision method for finding polyps is developed [4]. An adaptive deformable model is used to present segmented polyps [5]. Geodesic active contours with a modified speed function on the colon surface are evolved to detect polyp neck regions [6]. By using level-set method the polyp mass region is extracted [7]. Lu et al. propose a classification scheme to segment polyps [8]. Histograms are used to determine the threshold that would separate polyps from their surrounding tissue [9]. The prior knowledge of polyp shape is used in model-based approach for segmentation [10]. So the accurate measurement of polyp size was obtained because the pose of a polyp is well-defined.

We propose to segment the colorectal polyps via active contour model without edges. In regard to quality limitations of colonoscopy images, a pre-processing stage is proposed.

The paper is arranged as follows: In Section 2 is presented the main algorithm of processing; in Section 3 are given some experimental results, obtainned by computer simulation and their interpretation; in Section 4 - the Conclusion.

2. MAIN ALGORITHM OF PROCESSING

The flowchart of the main algorithm for colonoscopy image processing is given in Fig. 2.

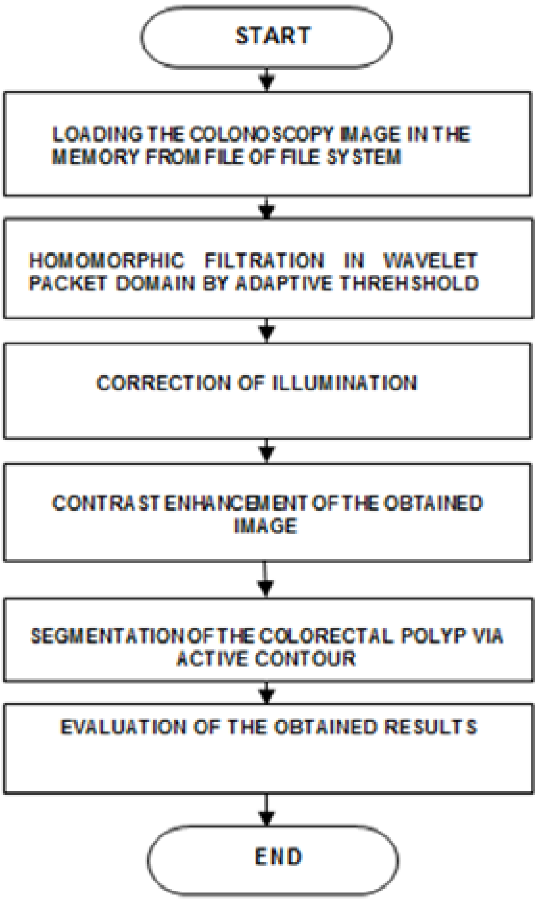

Figure 2. Flowchart of the maim algorithm

The pre-processing stage includes noise reduction with modified homomorphic filter based on wavelet packet decomposition of the transformed image and adaptive threshold of the wavelet coefficients [11]. The modified homomorphic filter uses the illumination-reflectance model in its operation. This model presents the image *f(x,y)* by two primary components. The first component is the amount of source illumination incident on the scene being viewed *i*(*x*,*y*). The second component is the reflectance component of the objects on the scene *r*(*x*,*y*). The intensity of *i*(*x*,*y*) changes slower than *r*(*x*,*y*). Therefore, *i*(*x*,*y*) is considered to have lower frequency components than *r*(*x*,*y*). Using this fact, homomorphic filtering technique aims to reduce the significance of *i*(*x*,*y*) by reducing the low frequency components of the image. This is made by executing the filtration in the frequency domain. However, before the transformation takes place, a logarithm function has been used to change the multiplication operation of *r*(*x*, *y*) with *i*(*x*, *y*) into an addition operation.

The modified homomorphic filtering schema is shown on Fig.2, where WPT is 2D Discrete Wavelet Packet Transformation, H(u,v) presents a filter function, IWPT is 2D Inverse Discrete Wavelet Packet Transformation.

Figure 3. Structure of modified homomorphic filter based on WPT

Because the noise of wavelet transformation usually concentrates on the state of high resolution, the method is useful for successfully reduction of noise in colonoscopy images. The filtration is obtained on the basis of the best shrinkage wavelet packet decomposition and the spatial adapted threshold [11]. The wavelet thresholding procedure removes noise by thresholding only the wavelet coefficients of the detail sub-bands and keeps the low resolution coefficients.

Then additionally, correction of illumination based on background subtraction by morphological processing and contrast enhancement based on CLAHE is applied. The background of the obtained images is estimated by mathematical morphology opening or closing. Then it is subtracted from the original image. The total sequence of operations corresponds to a top hat of the image. We use a disc structuring element greater than the size of the light objects (characters), which are typical for the corresponding colorectal images. The procedures noise reduction and CLAHE are applied to an image, processed in YUV system for more effectiveness.

The colorectal polyp segmentation is made by the implementation of the Chan and Vese active contour model [12]. It is a special case of the Mumford–Shah problem. We consider *f* to be the given grayscale image on a domain Ω to be segmented. Mumford and Shah approximate the image *f* by a piecewise-smooth function *u* as the solution of the minimization problem. Compared to the piecewise constant Mumford - Shah model, the key differences with the Chan - Vese model are an additional term penalizing the enclosed area and a further simplification that *u* is allowed to have only two values, given in (1)

$$u(x) = \begin{cases} c_1 \ where \ x \ is \, inside \ C \\ c_2 \ where \ x \ is \ outside \ C \end{cases} \qquad (1)$$

where *C* is the boundary of a closed set and c_1, c_2 are the values of *u* respectively inside and outside of *C* [13].

By the method of Chan and Vese is proposed to find among all *u* of this form the one that best approximates *f*, which is given in (2).

$$\begin{aligned} u(x) = arg \min_{c_1, c_2, C} \ & \mu Lenght(C) + \\ & + \nu Area(inside(C)) + \\ & + \lambda_1 \int_{inside(C)} \left| f(x) - c_1 \right|^2 dx + \\ & + \lambda_2 \int_{outside(C)} \left| f(x) - c_2 \right|^2 dx \end{aligned} \qquad (2)$$

Using the first term we can control the regularity by penalizing the length. The area of *C* and its size can be controlled by second term. The third and fourth terms penalize discrepancy between the piecewise constant model *u* and the input image *f.* By finding a local minimizer of this problem, a segmentation is obtained as the best two-phase piecewise constant approximation *u* of the image *f* [13]. In this case the minimization requires over all set boundaries *C* by using the level set technique introduced by Osher and Sethian [14]. We use a level set function *φ* for a circle of radius *r*. Instead of manipulating *C* explicitly, it is represented as the zero-crossing of a level set function *φ,* given in (3)

$$C = \{ x \in \Omega : \varphi(x) = 0 \} \qquad (3)$$

The parameters which can be selected for segmentation are following:

- ✓ *mask* – Initial contour as circle, which the evolution of the segmentation begins;
- ✓ *n – Maximum number of iterations* to perform in evolution of the segmentation;
- ✓ *R –Radius of the location in pixels;*
- ✓ *Alpha* – 'Smooth Factor' – Degree of smoothness or regularity of the boundaries of the segmented regions.

The procedure of segmentation begins after choosing all input information. Then the final result from segmentation is visualized – colorectal image with segmented polyp.

3. EXPERIMENTAL RESULTS

The formulated stages of processing are realized by computer simulation in MATLAB 7.14 environment by using IMAGE PROCESSING and WAVELET TOOLBOXES [15]. In analysis are used 30 images with colorectal polyps. It is used database of the colonoscopy images with size 574 x 500 [16], also database from Medical Academy Sofia of colonoscopy images with size 574 x 500 in bmp file format. Some results from simulation, which illustrate the working of proposed algorithm, are presented in the next figures below.

In Fig. 4 is shown the original image with colorectal polyp.

Figure 4. Original colorectal image

Fig. 5 illustrates the pre-processed image.

The graphical presentation of background surface is given in Fig. 6.

The segmented polyp and the grayscale colorectal image with segmented polyp are given on Fig. 7 and Fig. 8 respectively. The segmentation is performing by *n=100* iteration.

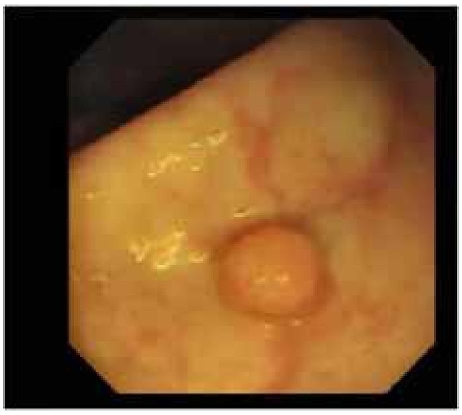

Figure 5. Pre-processed colorectal image

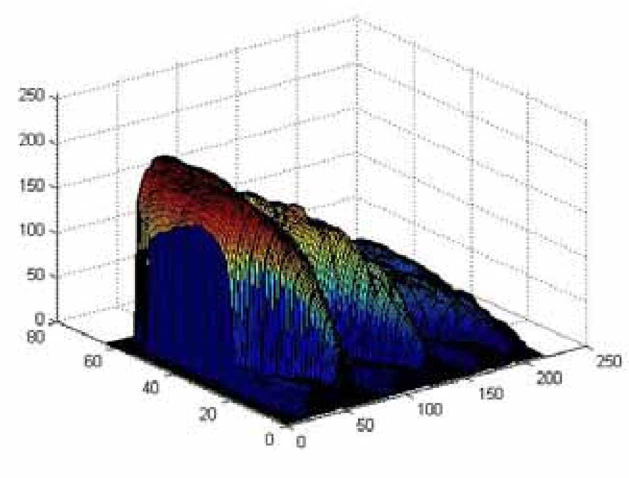

Figure 6. Graphical presentation of background surface

For validation of the segmentation results, we compute the undirected partial Hausdorff distance [17] between the boundary of the computed segmentation and the boundary of the manually-segmented ground truth.

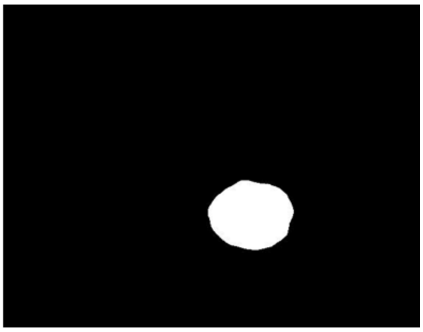

Figure 7. The segmented polyp after 100 iterations

The obtained averaging results for the partial Hausdorff distance between automatic segmentation and the manually-segmented ground truth are given in Table 1.

Figure 8. The grayscale colorectal image with segmented polyp

The obtained averaging results for the partial Hausdorff distance between automatic segmentation and the manually-segmented ground truth are given in Table 1.

Table1. Partial Hausdorff Distance

Method	K [%]
Manually-Segmentation	90.5
Active Contour Segmentation	96

The results shown in Table 1 indicate that virtually all the boundary points lie within some pixels of the manual segmentation, but the segmentation is better in the case of the proposed approach. Higher values of *Alpha* can produce smoother region boundaries but can also smooth out finer details. Lower values produce more irregularities (less smoothing) in the region boundaries but allow finer details to be captured.

4. CONCLUSION

In this paper is presented an effective approach for semi-automatic colorectal polyps segmentation. For enhancement of the colonoscopy images a pre-processing stage is proposed. It consists of noise reduction with modified homomorphic filter based on wavelet packet decomposition. Additionally correction of illumination and contrast enhancement based on CLAHE is made. The method of segmentation is based on active contour without edges. The implemented study and obtained results have shown a high validation of the segmentation. The proposed approach can be applied for screening of early colorectal carcinoma, especially by sigle colorectal polyps.

Our future work will be concentrated in hybrid methods for segmentation and classification of the polyps in regard to obtain more precise diagnoses. It can be used also in monitoring the disease progression.

5. ACKNOWLEDGMENTS

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