DETECTING CONTOURS OF PATHOLOGICAL FORMS IN COLONOSCOPY IMAGES USING A HYBRID METHOD

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Abstract

As colonoscopy is needed for screening colorectal polyps, and the first step of classification these polyps is recognizing them, it is worth to research, whether the colonoscopy databases could be improved by image processing and contour detection. In the following considerations a reflection filtering and background subtraction with large-sized mean filter is used as image preprocessing tools, and hybrid method for segmentation of pathological forms, based on template matching and active contour model as contour fitting for segmentation of the image is made.

1. INTRODUCTION

As in the past couple of decades colorectal cancer advanced to one of the leading cause of death, it would be very useful if population wide screening could be carried out. As types of colorectal cancers [1] all develop from polyps inside the bowel, and these warts can be seen by colonoscope at very early stage, colonoscopy is probably the best and least intrusive method for detecting colorectal polyps. The alternatives, capsular endoscopy [2] and virtual colonoscopy are either much harder to process or have higher risk. Colonoscopy nowadays has several image enhancing tools, such as chromoendoscopy or narrow band imaging [3]. If the polyps are found, the medical experts can determine whether biopsy or removing of the polyp is necessary based on their shape [4,5], colour and Kudo's pit pattern classification scheme [6-8]. In the past years several groups started to develop tools for the medical staff in order to help drawing their attention to those domains of the endoscopy picture, where some pathological forms, such as polyps are likely [9]. Some of them made their databases available [9-12], too. These databases consist of pictures, which are taken by colonoscopies also there are masks, corresponding to the pictures and showing the areas of the polyps.

There are number of polyp segmentation methods, which have been reported in the literature [13]. Canny operator and the Radon transform are used to detect polyp boundaries [14]. Using structural entropy a fuzzy decision method for finding polyps is developed [15]. An adaptive deformable model is used to present segmented polyps [16]. Geodesic active contours with a modified speed function on the colon surface are evolved to detect polyp neck regions [17]. By using level-set method and active contour model without edges the polyp mass region is extracted [18, 19].

In the following considerations first the image preprocessing stage is presented in Section 2, then a brief survey about the proposed hybrid method, based on template matching and active contour model is given, and as a last step, in Section 4, some results of segmentation are presented.

2. CALCULATION OF THE REFLECTION DOMAINS AND THE BACKGROUND FOR SUBTRACTION

For the present study images of database built at ETIS Larib [10] are used, as these images have high resolution and low noise. As it can be seen in Fig. 1, the image is mainly of pinkish colour, its histograms have large empty domains between the important information of the image, i.e., the middle

region and the absolutely light (reflections) and absolutely dark (frame) ends in all three colour channels. The first step of pre-processing is to remove the black frame of the picture in a rectangle, the corners remain black. This can be seen in Fig.1. The cropped image is studied in the followings.

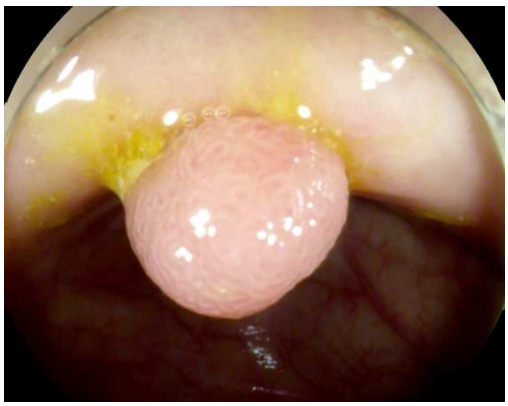

Figure 1. The original colonoscopy image number 66 of ETIS Larib [10]

Next, using the histogram, an automatic threshold is set both in the dark and in the light end of the histogram at the point it starts to increase after the first peak. At these new thresholds the histograms of R,G and B channels are cut, and the 3 histograms are renormalized to the 0- 255 domain. These histograms are presented in Fig. 2.

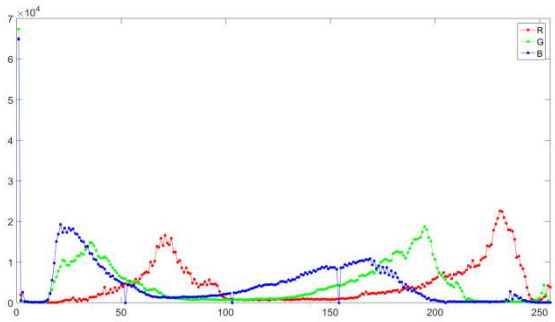

Figure 2. Histograms of the image

Those points, which used to have darker shades than the minimum of the new histogram, are collected to a mask for the black points, and the ones that used to have lighter shade then the maximum of the new histogram are collected in the white mask. The masks are treated together, when average is calculated, i.e., all the masked points are excluded from the averages. Both masks are extended in such a manner, that if points differ more than a threshold from their neighbours' average, then they are given to the masks. If the brightness value of a point is higher than the masked average of the environment, then the point will belong to the white mask, if lower, to the black mask.

As a next step, the white mask is used for creating the matrix, which has to be subtracted from the histogram-stretched image so, that the obtained image would be reflection-free. This mask image is presented in Fig. 3. The resulting image, which was obtained after mean filtering around the masks, is presented in Figure 4.

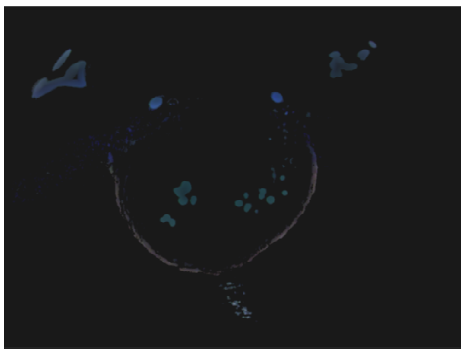

Figure 3. The white mask

Figure 4. Reflection-free image

As a last step, the images are filtered with a very large mean filter (not masked) in order to receive the background and this background is subtracted from the reflection-free image. The background is shown in Fig. 5, while the final result is given in Fig. 6.

Figure 5. Background of the image

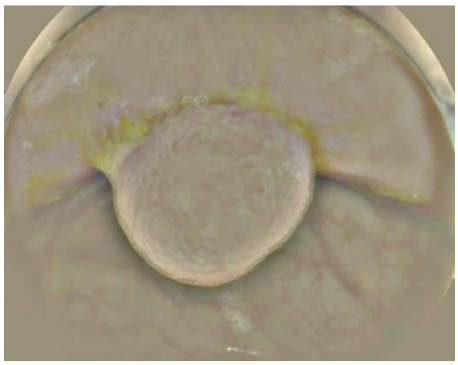

Figure 6. The background subtracted version of the image

3. CONTOUR DETECTION OF THE POLYPS BY HYBRID METHOD

The colorectal polyp segmentation is made by the implementation of the Chan and Vese active contour model [20]. In this case, the stopping term does not depend on the gradient of the image, as in the classical active contour models, but is instead related to a particular segmentation of the image. This method of segmentation is based on active contour without edges. We propose to use the given mask from database, which corresponds to the image and showing the area of the polyp. This mask is a template for the shape form of the initial contour, from which the contour segmentation begins. It is presented in Fig. 7.

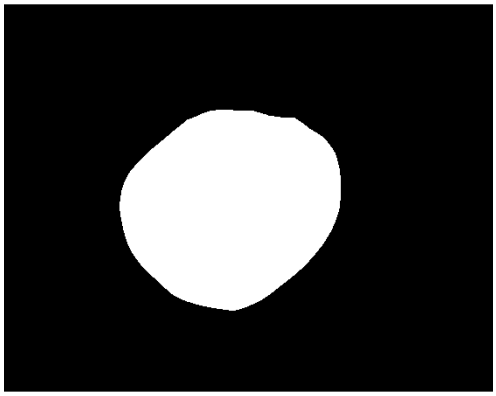

Figure 7. Mask from database showing the area of the polyp

4. RESULTS AND VALIDATION

The formulated stages of processing are realized by computer simulation in MATLAB 7.14 environment by using IMAGE PROCESSING Toolbox. For the experiments 200 images with size 1216x962 pixels in tif format of database built at ETIS Larib are used. The grayscale colorectal image with segmented polyp in yellow colour is shown in Fig. 8. The segmentation is performed by 200 iterations.

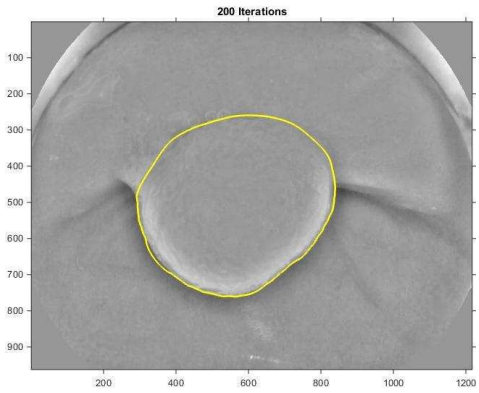

Figure 8. Grayscale colorectal image with segmented polyp

For validation of the segmentation results, we compute the undirected partial Hausdorff distance between the boundary of the segmentation with the hybrid method and the boundary of the manually-segmented ground truth. The obtained results are compared to the results from segmentation without pre-processing stage. The averaging results for the partial Hausdorff distance between automatic segmentation and the manually-segmented ground truth are given in Table 1. The grayscale colorectal image with segmented polyp in yellow colour without using pre-processing stage is presented in Fig. 9.

Table 1. Partial Hausdorff Distance

Method	K [%]
Manually-segmentation without pre-processing stage	72.9
Automatic segmentation by hybrid method without pre-processing stage	76.5
Manually-segmentation with pre-processing stage	92.3
Automatic segmentation by hybrid method with pre-processing stage	95.7

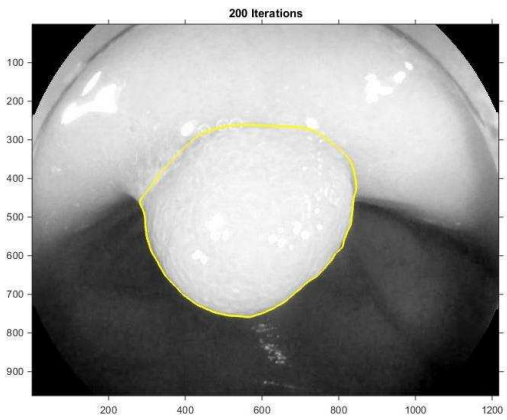

Figure 9. Grayscale colorectal image with segmented polyp without pre-processing stage

These results have indicated that the segmentation is better in the case of the proposed approach

compared to manually segmentation. On the other hand, the application of the pre-processing stage with a reflection filtering and background subtraction increases the accuracy of defining the contour of the polyp and allows visual observation of the structure and appearance of its surface.

5. CONCLUSION

In this paper, an effective approach for automatic colorectal polyps segmentation is proposed. The pre-processing stage is applied for calculation of the reflection domains and for background substraction. Then the reflection-free image was processed by mean filter in order to receive the background and this background is subtracted from the reflection-free image. The contour of the polyp was detected using hybrid method. It is based on template matching and active contour model without edges.

The proposed approach can be applied for screening of early colorectal carcinoma, especially by sigle colorectal polyps. It can be used also in monitoring the disease progression.

References

[1] *K. Soreide, B.S. Nedrebo, A. Reite et al., "Endoscopy Morphology, Morphometry and Molecular Markers: Predicting Cancer Risk in Colorectal Adenoma", Expert Rev. Mol. Diagn, Volume 9, Taylor&Francis, London, 2009, pp. 125-137.*

[2] *J. J. W. Tischendorf, H. E. Wasmuth, A. Koch, H. Hecker, C. Trautwein, and R. Winograd, "Value of magnifying chromoendoscopy and narrow band imaging (NBI) in classifying colorectal polyps: a prospective controlled study", Endoscopy, Volume 39, Thieme, Stuttgart-New York, 2007, pp. 1092-1096.*

[3] *I. Rácz, M. Jánoki, and H. Saleh, "Colon Cancer Detection by 'Rendezvous Colonoscopy': Successful Removal of Stuck Colon Capsule by Conventional Colonoscopy", Case Rep. Gastroenterol., Volume 4, Karger, Basel, 2010, pp. 19–24.*

[4] *J. R. Jass, "Classification of colorectal cancer based on correlation of clinical, morphological and molecular features", Histopathology, Volume 50, Wiley, Hoboken, 2006, pp. 113–130.*

[5] *I. Rácz, A. Horváth, M. Szalai, et al., "Digital Image Processing Software for Predicting the Histology of Small Colorectal Polyps by Using Narrow-Band Imaging Magnifying Colonoscopy", Gastrointestinal Endoscopy, Volume 81, Elsevier, New York, 2015, p. 259.*

[6] *S. Kudo, S. Hirota, T. Nakajima, et al., "Colorectal tumours and pit pattern". J Clin Pathol, Volume 47, BMJ Journals, London,1994, pp.880-885.*

[7] *S. Kudo, S. Tamura, T. Nakajima, et al. "Diagnosis of colorectal tumorous lesions by magnifying endoscopy". Gastrointest Endosc, Volume 44, Elsevier, New York, 1996, pp. 8-14.*

[8] *S. Kudo, C.A. Rubio, C.R., Teixeira, et al. "Pit pattern in colorectal neoplasia: endoscopic magnifying view". Endoscopy, Volume 33, Thieme, Stuttgart-New York, 2001, pp. 367-373.*

[9] *Jorge Bernal, et al., "Comparative Validation of Polyp Detection Methods in Video Colonoscopy: Results from the MICCAI 2015 Endoscopic Vision Challenge". IEEE Transactions on Medical Imaging, Volume 36, IEEE, Piscataway, 2017, pp. 1231–1249.*

[10] *J.S. Silva, A. Histace, O. Romain, et al., "Towards embedded detection of polyps in WCE images for early diagnosis of colorectal cancer", Int J Comput Assisted Radiology and Surgery, Volume 9, Springer, Berlin, 2014, pp. 283-293.*

[11] *J. Bernal, F. J. Sanchez, F. Vilarino. "Towards Automatic Polyp Detection with a Polyp Appearance Model", Pattern Recognition, Volume 45, Elsevier, New York, 2012, pp. 3166–3182.*

[12] *J. Bernal, F. J. Sanchez, G. Fernández-Esparrach, et al., "WM-DOVA maps for accurate polyp highlighting in colonoscopy: Validation vs. saliency maps from physicians", Computerized Medical Imaging and Graphics, Volume 43, Elsevier, New York, 2015, pp. 99-111.*

[13] *V. B. Surya Prasath, "Polyp Detection and Segmentation from Video Capsule Endoscopy: A Review", Journal of Imaging, vol.3, issue 1, pp.1-15, 2017.*

[14] *A.K Jerebko, S.Teerlink, M. Franaszek, R.M. Summers, "Polyp segmentation method for CT Colonography computer-aided detection", SPIE Medical Imaging, 5031, pp.359–369, 2003.*

[15] *S. Nagy, F.Lilic. L.Koszy, "Entropy based fuzzy classification and detection aid for colorectal polyps", IEEE AFRICON 2017, Cape Town, South Africa pp.78-83, 2017.*

[16] *J. Yao, R.M Summers, "Adaptive deformable model for colonic polyp segmentation and measurement on CT Colonography", Medical physics 34, pp. 1655–1664, 2007.*

[17] *S. Tan, S., Yao, J., Ward, R.M., Summers, "Linear measurement of polyps in CT Colonography using level sets on 3D surfaces", In: Engineering in Medicine and Biology Society, Annual International Conference of the IEEE, pp. 3617–3620, 2009.*

[18] *J.J.Näppi, H.Frimmel, A.H. Dachman, H.Yoshida, "Computerized detection of colorectal masses in CT Colonography based on fuzzy merging and wall-thickening analysis", Medical physics 31, pp. 860–872, 2004.*

[19] *V.Georgieva, P.Petrov," An Approach for Colorectal Polyp Segmentation", 12th International Conference on Communications, Electromagnetics and Medical Applications (CEMA'17), Sofia, Bulgaria, pp. 1-5, 2017.*

[20] *T. Chan, L.Vese, "Active Contours Without Edges", IEEE Transactions on Image Processing, vol.10, № 2, pp.266-276, 2001.*