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CALCULATION OF OBJECT CHARACTERISTICS OF ENDOSCOPIC IMAGES BY THE EXAMPLE OF APPENDIX

A. Nedzved, A. Belotserkovsky
United Institute of Informatics Problems, Minsk, Belarus

Here we propose a method to automate defining characteristics, which are useful for medicine and for endoscopic diagnostics in particular. A number of morphological and colorimetrical features of appendix is formalized in this paper. It allows to describe an object of interest qualitatively and quantitatively, and monitor its pathological changes in real time mode.

Introduction

Last years show that endovideosurgery reasonably takes its place in abdominal surgery [1]. However modern state of the art in the field of laparoscopy is not exclude misdiagnosis, which can give poor consequences [2]. Above all it concerns with verification of thin tissue structures, which are subjected to dissection (vessels, ducts and organ walls in close contact), and with object interpretation due to poor resolution and image distortion of video facilities [3].

It is very important not only to reproduce accurately an operational process but to automate its analysis by endoscopic images. It is possible to monitor a surgery operation in real-time mode but again the weak place is analysis of results. It is clear that the more numerical and statistical analysis to be, the better and optimal diagnostics will be performed.

The most difficult and responsible applications of computer engineering is medical diagnostics and intraoperative tasks, which is also related to the fact that a big amount of different data is used here. Next steps are important to extract information from endoscopic images: preprocessing, segmentation, feature analysis, representation of results. Section 2 is about of new segmentation algorithm which allows to obtain extracted endoscopic objects such as appendix.

For the purpose of accurate diagnostics of acute appendicitis at laparoscopic operations we have formalize a number of organ characteristic such as morphological (shape, size, volume) and colorimetrical (color, texture) features, which describe an object of interest qualitatively and quantitatively. Results of operational treatment of 84 patients make a fool-proof ground for our research. In sections 2 and 3 we discuss about results of it.

1. Segmentation of endoscopic images

Image segmentation is for extraction of regions which have same properties [3]. It is performed after preprocessing step. It is known that it is quite complicated task and depends on application. Here we propose a segmentation algorithm for processing of endoscopic images. We omit here description of first steps of image preprocessing, which is presented on general block-scheme on Fig.4, and will give segmentation by it self.

Image of appendix takes colors from a red-color range mainly. So, it is better to use opponent green component to enhance contrast of image. Main characteristics of appendix are its borders. That why we have chosen an edge extraction technique to segment such an images (fig. 1).

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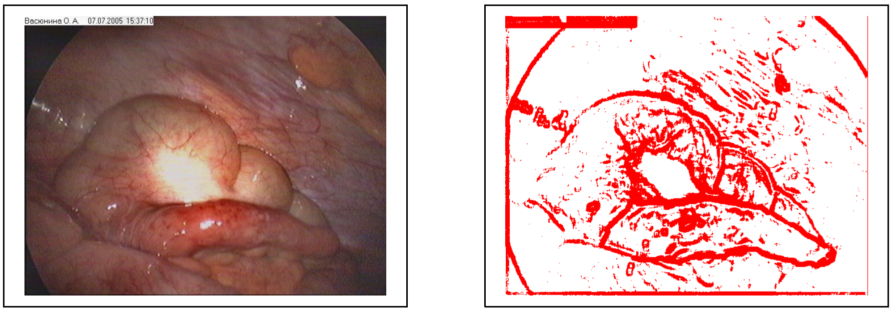
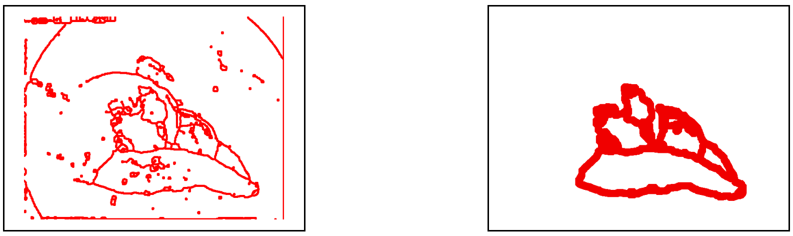


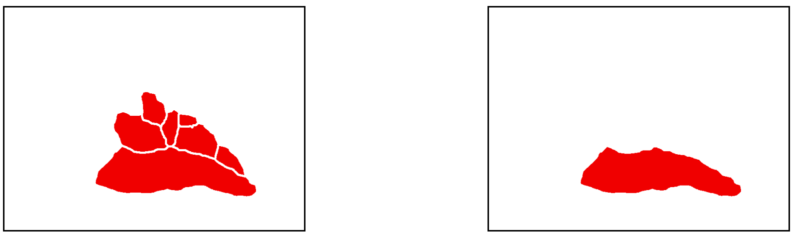
a) b)

Fig. 1 Edge extraction on image of appendix: a) initial image, b) result of extraction

However, it is only the first step of segmentation because extracted borders belong not only to object of interest, and it have a width (more than 1 pixel). Morphological thinning with deleting of tails is to be the next step of the algorithm (fig. 2a). All small open-ended contours are deleted then to remove geometrical noise, and dilatation is used to compensate errors on borders (fig. 2b). To reconstruct a width of object a thinning operation is performed followed with image inversion and deletion of objects which are close to edge. Resulting image consists of binary objects including appendix (fig.2c). Appendix is characterized by elongation factor. So, less elongated objects are finally to be deleted (fig.2d).



a) b)



c) d)

Fig.2 Steps of appendix extraction on binary image: a) borders thinning, b) noise removing, c) extraction of closed regions, d) resulting image of the object

Proposed algorithm of segmentation of appendix is an illustration of particular task and may be used taking into account features of illumination of endoscopic equipment.

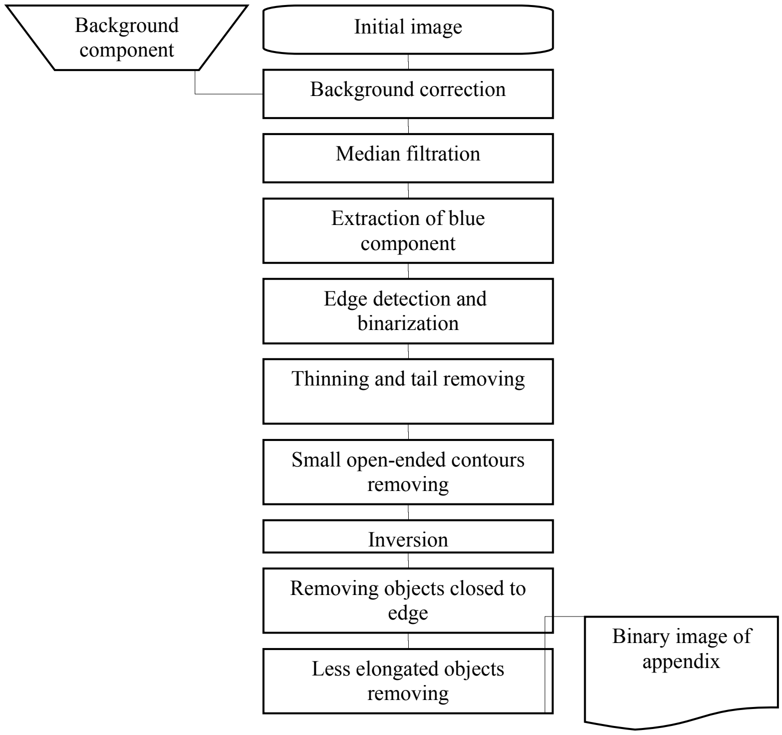


Fig. 3 Algorithm of extraction of appendix on color image

2. Analysis of characteristics at acute appendicitis

Following signs are usually chosen for diagnostics of acute appendicitis by endoscopic images:

1. Appendix is tense (rigid);
2. Vessels of serose of appendix are expanded;
3. Color of appendix is pink with glare effect;
4. Color of appendix is pink;
5. Appendix is covered with green coat fully or partly;
6. Liquid beside appendix is green;
7. Liquid beside appendix is red;
8. Bowels loops around appendix are hydropic and pale-pink;
9. Peritoneum of abdominal wall in right iliac region is ruby;
10. Omentum beside appendix is ruby;
11. Omentum beside appendix covered with green coats.

Next features are used to determine absence of inflammation:

a. Appendix is elastic (non-rigid);
b. Appendix is cyan;

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c. Appendix vessels are not enlarged along all surface;
d. Bowels loops around appendix are non-hydropic and pale-pink;
e. Peritoneum of abdominal wall in right iliac region is pale-pink;
f. Omentum beside appendix is yellow.

Since presented above features are reliable and are used in endoscopic diagnostics, we have formalized it by belongings to organs depending on different segmentation approaches.

	color	shape	texture
appendix	3,4,5,b	1,a,	
appendix neighborhoods	5,6,7,9,10,11,e,f	8,d	d
vessels		2,c	2,c

There are 5 global formalized features, which can be defined by topological, colorimetric and textural characteristics.

In the framework of experimental study 36 patients with acute appendicitis were observed and 32 patients without inflammation. Research was made through sequence of 159 digital laparoscopic images of acute appendicitis and 68 images of specimens with suspicion of acute appendicitis. Distribution of features which are specified for acute appendicitis, and features, which are not typical for inflammatory process, are presented in the table.

"*Appendix is tense (rigid)*" – feature, which is complicated for formalization. It is defined by physical method with the help of special endoscopic tools by dynamic changes of shape. Elastic appendix is bending, thus extracted region can be narrowed. Since that it is necessary to analyze ratio of areas before and after intrusion of surgical tool:

$$\text{elasticity} = \frac{\text{area2}}{\text{area1}} \cdot 100\%, \tag{1}$$

where *area1* – is area of extracted region of appendix before intrusion, and *area2* – is area of extracted region after intrusion.

Experimental study shows that elasticity usually is not more that 74%.

Features 3,4,5,b characterize color of appendix. Usually inflammation entails red or green color with glare effect and cyan in opposite case. It is very convenient to use a correlation of red, green and blue components as it shown below:

$$C = \frac{2 * B}{(R + G)}, \tag{2}$$

where R, G, B – mean values of red, green and blue components correspondingly.

We have achieved results which shows that C equal to 0,76 at acute appendicitis, while glare effect entails parameter in range from 0,98 to 1,1.

Features 5,6,7,9,10,11,e,f are also can be characterized by this parameter. In case of acute appendicitis it varies from 0,4 to 0,75, and from 0,6 to 0,92 for the rest. However, if there is no inflammation, dispersion of each color component is less than 18.

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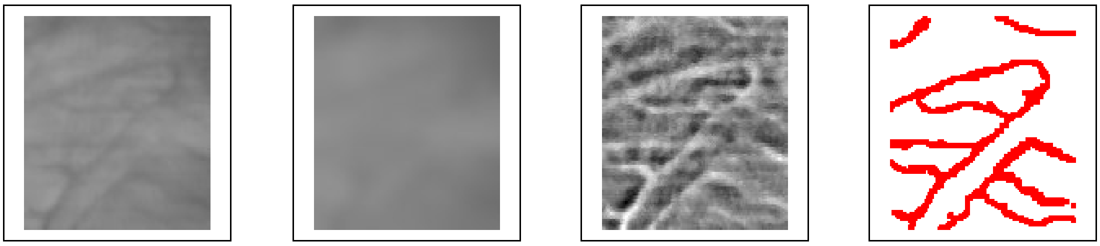
Features 8 and d are extremely difficult to formalize. It is need to perform a segmentation by edge extraction to automate this. Extracted regions should be analyzed with mean values and dispersion to find color similarity. There is no acute appendicitis in case of presence of several homogeneous regions. Since this feature is not very effective and it takes addition time for calculation, we recommend to use it with powerful hardware support only.

One of the most interesting and informative objects of endoscopic research is vessel (features 2,c). Vessels contain much of topological information, which may say about different topological processes. Nevertheless we do not show here all potentials of vessels analysis and are bounded with simplest characteristics.

To study vessels net it should be extracted on images. For this purpose we extract region which belong to appendix. Well known classical thresholding segmentation does not allow extract vessels net. It is so because of nonuniform distribution of brightness intensity though organ's body. Vessels have a small width and can be removed with low frequency filtration. (fig.4b). Difference of result of filtration and initial image allows to enhance contrast of vessels (fig.4c). After that procedure its binary pattern can be obtained by thresholding segmentation (fig.4d).



a) b) c) d)

Fig. 4 Extraction of vessels net: a) initial image, b) result of low frequency raster filtration, c) enhanced difference between filtration and initial image, d) result of thresholding segmentation of image (binary pattern of vessels)

Main feature of acute appendicitis is a width of vessels. However, it is impossible to find real dimensions on endoscopic image. Therefore, we use relative values to find a width. The most convenient way is to find a ratio of vessels and organ areas:

$$R = \frac{AreaV}{Area}, \qquad (2)$$

where $AreaV$ – area of vessels , $Area$ – area of organ.

The value of parameter is very high in case of acute appendicitis and varies in the rage of [0; 0,167] in other case.

A summary table of features for image analysis of appendix is presented below.

Feature	Acute appendicitis	No inflammation
elasticity	> 74%	≤ 74%
color correlation (C) for organ	< 0,76 or 0,98-1,1	0,76-0,97
color correlation (C) for or-	0,4 - 0,75	0,6 - 0,92

gan neighborhood		
maximal dispersion for color components	≥ 18	< 18
relative vessels area	$> 0,167$	0-0,167

Conclusion

It is known that applying of computer methods allows to automate defining characteristics, which are useful for medicine and for endoscopic diagnostics in particular. Proposed approach to such automation is very important since it allows to monitor pathological changes in real time mode.

Here we have shown a principal scheme of processing of endoscopic images of acute appendicitis. Main stages of such processing were examined. We have proposed 11 features and have defined 9 of them to use for diagnostics. The most important one is to study topological changes, although significant variability of organ's characteristics does not guarantee accuracy of diagnosis.

Conclusion

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