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EXTRACTION CHARACTERISTICS OF ENDOSCOPY IMAGES

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Estimation of 3D surface of a scene from a set of two or more images of that scene taken from the same point of view with different camera focal setting parameters is known as depth from focus\defocus problem. In this paper a system for 3D object reconstruction from endoscopy video is proposed which uses the same focal setting parameters for camera with different points of view of scene. In addition for preventing the undesired vessels dissection during operation, 3D video is augmented with extracted and recognized vessels. The vessels extraction is done with a novel real-time grey image thinning algorithm

Introduction

Interactive systems that allow users to control and manipulate real-world objects within a remote real environment are known as teleoperator or telerobotic systems [1]. Such systems are often used in medical applications to confirm diagnosis and make telepresence surgery. The most known telerobotic surgery systems are da Vinci telerobotic surgical system [2] and ZEUS ™ [3]. Such systems are controlled by surgeons remotely by viewing virtual surgical site with stereoscopic system and controlling stereoscopic camera and robot surgical armaments. However such “stereoscopic” telepresence can be significantly extended and improved with augmented reality based on 3D reconstructed surface and extracted vessels. Such augmented 3D scene allow to:

- prevent undesired vessels dissection
- view the organ and disease from different points without camera movement;
- plan the strategy of surgery more precisely;
- teach the surgeons on the basis of obtained video and 3D reconstructed scene.

In this paper we focus on endoscopy surgery and methods for 3D surface reconstruction and vessels extraction. Vessels extraction and recognition algorithm is based on a novel grey thinning algorithm which is described in details further. 3D surface reconstruction from endoscopy video sequence is based on depth from the focus\defocus approach [4, 5]. The image formation process can be described with optical geometry and the resulting image will appear focused and sharp only in a small 3D slice of the scene [5]. This fact is used in our approach to produce 3D surface reconstruction which consists from the following stages: image pre-processing, sharpness estimation for image features, estimation of features depth depending of sharpness, 3D slices generation with corresponding image features and depth, 3D reconstruction based on obtained slices.

1. Object reconstruction from depth of field region

Endoscopy video is usually formed with a fiber-optic endoscope allowing physician to view patient’s esophagus, stomach and part of duodenum. For image forming a complex optical system is used. However, it can be approximated with aperture camera model. The camera is always on the run and obtained image contrast depends on optical, acquisition and refining systems. Spatial geometrical and illumination distortions have a strong influence upon image quality also. Thus a pre-processing stage for image enhancement and distortion compensation is used for each video frame first of all and described in more details below.

According to the laws of geometric optics, the object point is represented on image by point, only if it is located at focal length from the lens (see point P 1 at fig. 1). Any other object points which belong to non focal plane will be represented with circles of confusion (see point P 2 at fig. 1). The larger diameter of the circle of confusion the unsharper image we get. As a result an endoscopy image I can be treated as image which consists from sharp I_s and blur image I_b components. The diameter of the circle of confusion depends on the distance to corresponding object point which can be estimated from the camera model.

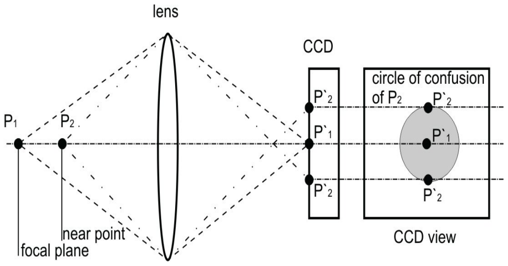


Fig. 1. Focus and defocus formation

The model of the camera can be approximated with the following well know equation:

$$1/f=1/g+1/b,$$

where g – distance to object, b – distance to CCD and f- a focus distance. The distance to sharp near and far points can be written as follows:

$$g = \frac{f^2 \cdot g}{\left(f^2 \mp k \cdot z \cdot (g - f)\right)},$$

where g – distance to object, f – a focus distance, k – aperture number, z – circle of confusion diameter. The main idea of the depth extraction is to extract sharp image component I_s for the each frame from video sequence. In addition, we make an assumption that at each moment we exactly know the camera position and its movement step Δs . The analysis and depth estimation is applied for sharp image component I_s . The image I is transformed into slices according to depth. Each video frame during camera movement provides additional slices for volumetric representation which is used to reconstruct 3D endoscopy scene.

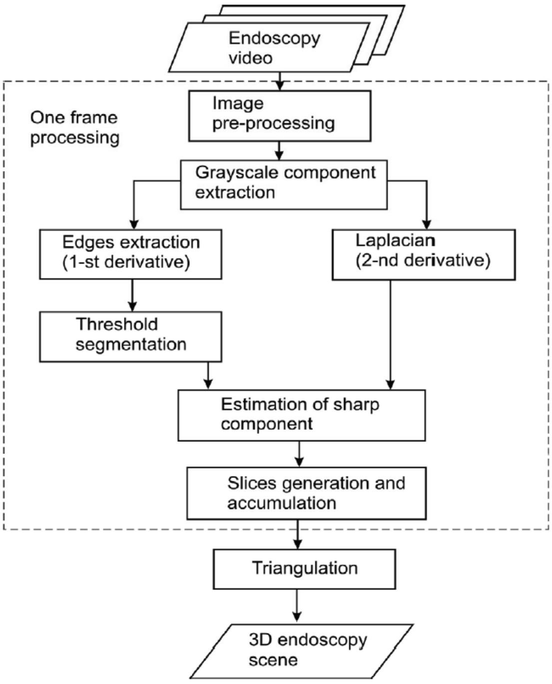
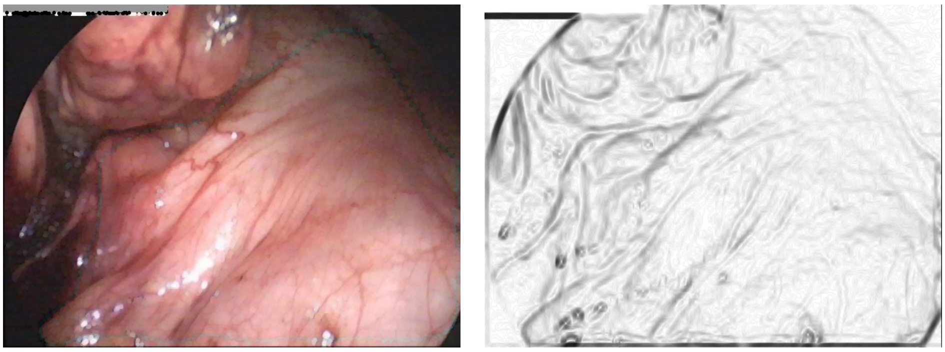


Fig. 2. Pipeline of the depth extraction

In general the pipeline of the proposed approach is represented at Fig. 2 which consists from the following main stages which are applied for the each video frame:

- pre-processing;
- sharp component extraction;
- slices generation;
- 3D reconstruction.

Sharp image I_s is represented with combination of two image features: contrast and edges. Such components are obtained with first and second derivatives processed with variation filter with kernel size 9x9 (See. Fig. 3b). The result of sharp image extraction is a set of high-contrast curves (fig. 3c) which are obtained for each video frame. As we know the camera parameters we can estimate the distance (depth) to high-contrast curves and obtain 3D points cloud which is used for 3D reconstruction. An example of depth generation by proposed approach is shown at fig. 3, d.



a) b)

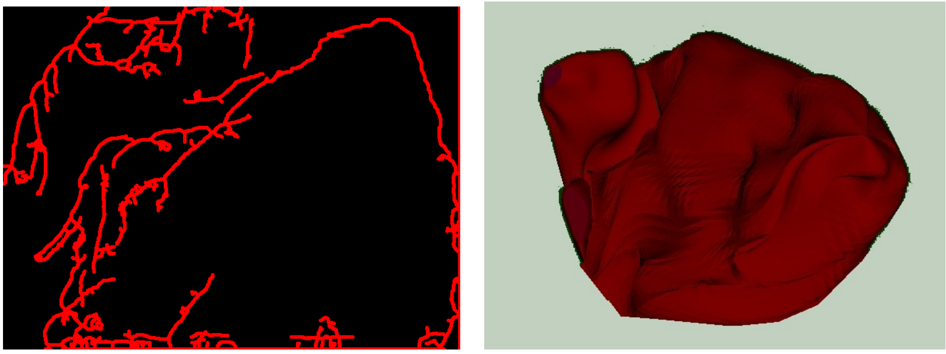


Fig. 3. Original image (a) and result of variation filtering of sharp component (b); high-contrast curves (c) and extracted depth from endoscopy video (d)

When we create 3D model it is possible to calculate geometrical sizes any fragment of tissue or organs. Calibration of geometrical sizes are produced form recalculation projective transformation and focus distance by calculation that was described below.

2. Endoscopy measurement

Calculation of object characteristics for endoscopy image is very complex problem. We can calculate geometrical characteristics form 3D model after depth reconstruction. This is long time calculation methods. For more fast description endoscopy objects characteristics of colorimetry and relative features. We can propose some relative features for fast calculation.

“Elasticity” – 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 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:

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

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%.

Usually inflammation entails red or green color with glare effect and cyan in opposite case. It is very convenient to use a correla-tion of red, green and blue components as it shown below:

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

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

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

One of the most interesting and informative objects of endoscopic research is vessel. 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.

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:

$$R = \frac{AreaV}{Area},$$

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.

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.

The automation analysis of endoscopy images is very complex task. This is connected with regularly changes image and difficulties of geometrical calibration. The object reconstruction from depth of field region allows to compensate this problems. These methods make possible a calculation of some geometrical characteristics. In addition relative features describe important properties of disease. The most important one is to study topological changes, although significant variability of organ's characteristics does not guarantee accuracy of diagnosis.

Proposed approach to such automation is very important since it allows to monitor pathological changes in real time and static mode.

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