LIVER TRACKING FOR INTRAOPERATIVE AUGMENTED REALITY NAVIGATION SYSTEM

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Abstract:

Liver cancer is one of the main causes of cancer related deaths in the world. To treat this deadly disease, open liver surgery is still the preferred method. Due to complexity of the liver structure, addition of augmented reality (AR) navigation would provide the surgeon with a necessary 3D anatomy of patient's liver. In this study we propose an AR navigation system where the main focus is on providing automatic 3D model registration during operative process. Difficulty in the process of registration, comes from the fact that liver is not a static organ due to deformation and movement of the soft tissue. We propose a method that finds liver movement by constantly tracking patient's organ during operation, using liver features detected by Shi-Tomasi Feature Detector. To be able to track only liver movement and deformation, it was important to first segment only the organ itself. Liver segmentation was performed using image segmentation method based on HSV color space.

Key words: augmented reality, liver segmentation, open liver surgery, tracking system

1. Introduction

Liver cancer changed from third-highest cancer mortality in 2018 to the second-highest in 2020 [1]. Liver metastases, as well as primary liver cancers (hepatocellular carcinoma and cholangiocellular carcinoma) are main contributors to these statistics. Even though there are different therapy approaches available, such as chemotherapy and radiotherapy, surgery is still considered as the best method for liver cancer treatment. Surgical methods have evolved over time and one of those advancement in surgical field is certainly laparoscopic surgery. However, laparoscopy is highly skilled procedure that requires expert surgeon and special equipment. These are the reasons why open liver surgery still remains the preferred method for liver cancer treatment. A proper surgical resection involves complete removal of tumors while preserving the surrounding healthy tissues, as well as blood vessels and biliary tree. Still, due to complexity of liver, proper surgical resection is quite a challenge, requiring high level of expertise and extensive preoperative planning. Traditionally, planning stage consisted of analyzation of patient's liver magnetic resonance imaging (MRI) or computed tomography (CT) scans. Recently, preoperative phase consists of combining aforementioned imaging data in a way that gives three-dimensional

(3D) visualization of liver anatomical structure. This 3D model can also be used during the operation as a way of intraoperative navigation. This addition of augmented reality (AR) navigation provides the surgeon with a necessary 3D anatomy of patient's liver. AR-assisted surgery is a surgical tool utilizing technology that superimposes a computer-generated enhanced image on a surgeon's view of the operative field, thus providing a composite view [2]. In this study, we propose an experimental method for AR incorporation during open liver surgery, with the main focus being on a registration of the 3D model during operative process.

2. Materials and methods

Main steps in using AR based intraoperative navigation system consists of:

1. Acquisition of preoperative imaging data (MRI, CT) of patient's liver
2. Imaging data preprocessing and 3D liver model creation
3. 3D model registration during operative process

The third and most difficult step of registration consists of correct direct matching between operative view and 3D model. This complication comes from the fact that 3D liver model is a static snapshot, while the liver itself is not due to constant deformation and movement of the soft tissue. The main causes of this deformation are heartbeat, breathing, tissue dissection and surgeon positioning, all of which alter the anatomy and position of the liver [3]. First approach, developing this navigation system, was based on interactive augmented reality, where 3D model is manually positioned, oriented and scaled in a way that properly aligns model and a real liver. Result of this navigation system is showed in a Figure 1.

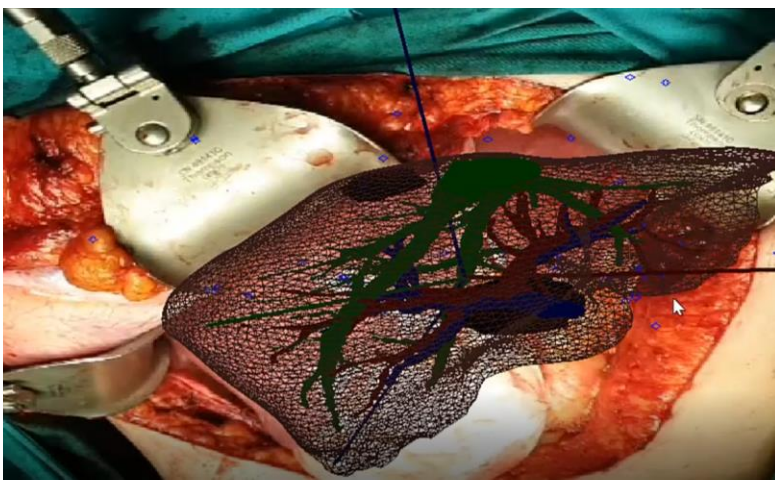
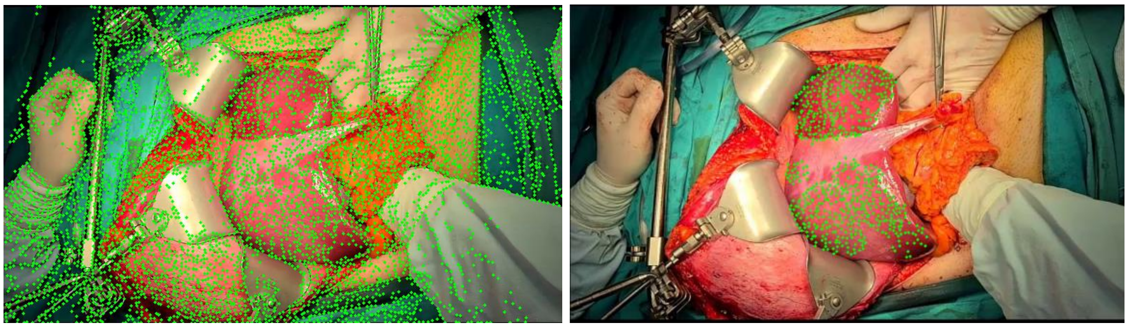


Fig. 1. AR navigation system based on interactive registration

This navigation system required the user to constantly track liver movement and manually adjust 3D model accordingly. This is a demanding task due to continual liver deformations, which ultimatly results in human made errors. Since surgery demands utmost precision, this margin of error is unacceptable. Because of this, experiments to change the current registration method are conducted with the goal of reaching an automatic registration method.
Most of the automatic registration methods use markers stuck on the patient during operation that are tracked in real-time, thus giving informations about liver position. However, this method requires additional steps during operation which increases its duration. Focus of our research is to develop automatic markerless registration method.

To track liver in real time without markers, Shi-Tomasi Feature Detector was used [4]. To implement Shi-Tomasi Feature Detector, we used common library in the field of computer vision, OpenCV. As seen in Figure 2a, feature detector did great job and discovered various features to track the liver, but due to the width of the camera field of view, surrounding area that is not a region of interest was also tracked. To prevent this behavior liver area needs to be segmented, before feature detector is applied.



a) b)

Fig. 2. Feature detector result: a) without liver segmentatnion; b) with liver segmentation

There are numerous ways to perform segmentation of the region of interest, but the most simple and robust way in our case was to perform image segmentation using HSV color space. Using trackbar system, the user selects minimum and maximum allowed values for each HSV component (Hue, Saturation, Value). All of the pixels, whose components are in a range between minimum and maximum allowed values, are considered region of interest. This trackbar system with the resulting segmentation is showed in the Figure 3.

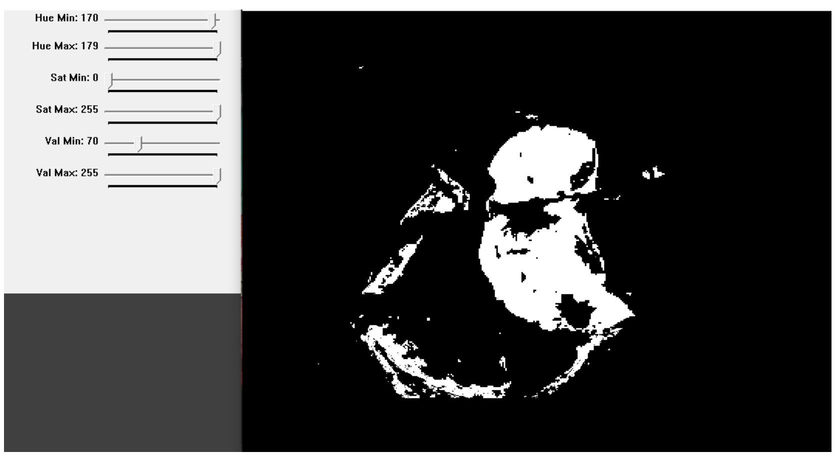


Fig. 3. Trackbar system with the resulting segmentation

Looking at a result of segmentation in Figure 3, it is clear that segmentation was not perfect due to the fact that some pixels outside of the region of interest have same color as liver itself. To try and reduce this noise in the image, operation of erosion was performed. Since this operation also affects region of interest, erosion was followed by dilation as a technique to recover some of the lost pixels in the region of interest. In order to control amount of applied erosion and dilation, system of trackbars was used. This system, with resulting segmentation, is showed in the Figure 4. Result of applied feature detector on to this segmented liver is shown in Figure 2b.

Fig. 4. Erosion and dilation control system with the resulting liver segmentation

3. Results

As seen in the Figure 2b, feature detector found adequate number of features to track so that navigation system can properly follow intraoperative liver movement and deformations. However, due to lightning and slight color variation in some areas of liver, it is clear that liver is not completely segmented, which results in detector not being able to find features in those areas of liver. F1 score between the whole liver and segmentation presented in Figure 4 is 91.38%.

4. Conclusion

In this paper we presented a liver tracking method that is, in further reserch, going to be used in an implementation of a markerless automatic model registration. In future project development, tracked features are going to be used as a way to bind 3D model with the patient's liver. Using this approach, our goal is to develop reliable, easy-to-use augmented reality intraoperative navigation system.

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