3D Model Generation of Patient Specific Liver with Pancreas and Portal Veins

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Abstract: *Recent day's Computer-aided design and image processing techniques are one of the most emerging useful tools for analysis of models in various medical, industrial and research areas. In medical field, the diagnosis of various diseases in vivo techniques including biochemical test, enzymatic tests are needed for continuous monitoring of patients. These diagnosis procedures are time consuming and inconvenient for patients. Therefore Computer assisted designing and image processing techniques are most promising non invasive tools for faster diagnosis and are useful for designing of biomedical implants. In this paper liver, pancreas and portal veins are segmented from patient's Liver computed tomography (CT) image by dedicated software. A Liver's CT images of 38 year old Indian male patients were collected and by using imaged based software MIMICS (Materialise's Interactive Medical Image Control System, Belgium) a steriolithography (STL) file of patient specific liver with pancreas is generated. These models can be used for designing of implants and analysis of portal vein's disorder like portal thrombosis, and portal aneurysm which are main cause of portal hypertension and also useful for surgeon for planning surgery. Moreover they can be helpful for understanding of portal vein hemodynamic. The motivation behind this paper is to improve existing methods and to apply new techniques to solve a number of typical segmentation problems in medical imaging. Even though the results are promising; more research is needed before reliable analysis of medical volume data can be performed. The contributions in this paper, however, are noticeable and represent a step forward in deriving complete automatic procedures for segmentation of medical volume data. The aim of this study was to create patient specific CAD models of normal- as well as diseased hepatic portal vein (HPV), liver and pancreas from the standard CT image of liver of an individual using dedicated image processing software.*

Key words: MIMICS, STL, DICOM, SEGMENTATION, 3D LIVEWIRE

1. Introduction

Modern quantitative computational analysis of two dimensional (2D) and three dimensional (3D) biomedical vasculatures images is currently most effective non-invasive method for diagnosis of disease in various medical areas. [1] The liver is the biggest digestive gland and plays a vital role in circulatory system containing three important vasculatures, including hepatic portal vein (HPV), hepatic vein (HV) and hepatic artery (HA). The HPV is the functional organ providing about 70%-80% of the liver blood. Therefore, the analysis of HPV is crucial for not only diagnosis of liver diseases but also important for planning of surgery.

Medical imaging has become common in the diagnosis and treatment of diseases. [2] While the image modalities are helpful, such equipment is expensive and resource demanding. Therefore, to reduce the workload of medical staff, automatic measurements and improved visualizations of the modality data is needed. One main challenge in order to perform automatic analysis on medical volume data is to separate the various tissues from each other. [3] Their boundaries may be diffuse and the medical volumes are typically distorted by noise. Furthermore, while the general anatomy is similar from person to person, previous interventions and genetic variations lead to variations in the size, shape, and location of organs. [4] To separate organ tissues well, advanced techniques based on pattern recognition are typically required. While humans are experts in pattern recognition, we have not been able to achieve results anywhere close to human recognition artificially. This is one of the reasons why there are presently few implemented applications for automatic measuring and 3D visualizations of medical volumes. [5] If automatic procedures do not achieve the level of accuracy of the results needed in medical science, it is likely that these methods can still prove helpful. Even if the distinction of tissues is poor, it can be used in a partially user guided system where the user defines the parameters needed to achieve a sound boundary between tissues semi-automatically. The various modalities are constantly improved and higher resolutions increase the possibilities to help patients. Increased resolutions, however, also challenge the hardware needed to make the necessary computations.[6] With respect to image processing, careful balancing must be made between the quality of the result, practical gain and processing time. The motivation behind this research is to improve existing methods and to apply new techniques to solve a number of typical segmentation problems in medical imaging. [7] A common factor in the segmentation techniques to be studied is that they use advanced techniques such as pattern recognition and models to guide the segmentation process. These methods are typically derived from various scientific fields such as mathematics, statistics, physics and biology, making the research highly interdisciplinary. [8]

2. Aim and Objective

The aim of this research is to create a patient specific STL model of liver with pancreas by converting the Digital imaging and communications in medicine (DICOM) file of a

patient to STL and separating the liver from the surrounding tissues. Further the objective is to standardize the protocol for conversion of a DICOM to STL file due to proven utility of accurate 3D models. However the protocol can be used for modelling various soft tissue organs. A 3D model not only can be useful in surgical practice (i.e. a better fitting, purposefully designed implant), but it can also help a surgical team in visually analysing the location, size and shape of the problem. In the event of a long operation, the model can also be used to plan and customise the surgery. This can be especially valuable when the surgery is performed on anatomical abnormalities. Such kind of segmentation technique offers both visualisation of anatomical details and the possibility of practicing directly on a specimen without involving a patient. 3D models can be a valuable tool for training nurses and doctors.

3. Methodology

The various steps involved in the conversion of DICOM file of patient to STL is as shown in figure 1.
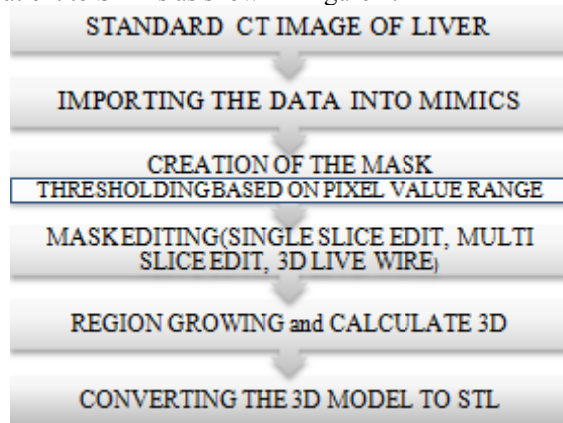

Figure 1: Flow diagram of conversion of DICOM to STL

The following tools of the MIMICS Software are used in 3D model generation of patient specific liver and its conversion to STL format: Opening the project, Thresholding, Region Growing, Edit Mask, Multi-Slice Edit, 3D Live Wire, Calculate 3D. The first step is to open the DICOM file directory, import it into MIMICS software and convert it into MIMICS project (.mcs file). Importing of DICOM File is done by selecting the new project wizard in the main toolbar. During importing, the DICOM header already has orientation information, but sometimes, the information is missing or the radiologist neglected to indicate the right orientation. From MIMICS Version 14 onwards, users need only to confirm the orientation perimeters. The next step is to generate a mask either by thresholding wizard or by region growing wizard. Thresholding wizard define an object by selecting a range of pixel grey values while region grow wizard only select the pixels that are connected.
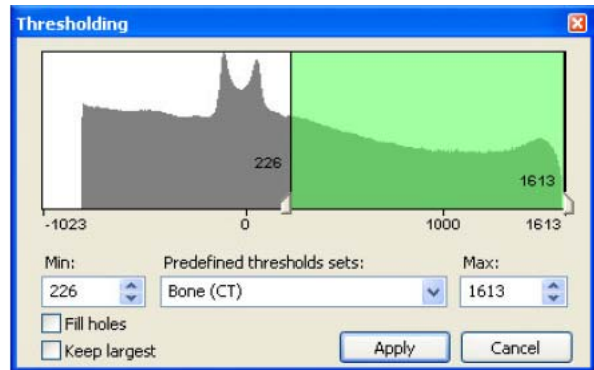

Figure 2: Creating mask by selecting a range of pixel grey values.

Segmentation is the important step in extracting 3D information from 2D images. MIMICS Software has several tools to segment regions of interest like edit mask, multi slice edit, 3D Livewire, etc. Edit mask wizards enables user to extract 3D information from 2D images in one slice only which is why user need to mark on each and every slice. However when slices are more user can mark on a slice, skip few slices, mark on another slice and the apply iteration wizard which will automatically mark on the slices that are skipped. Multi slice edit wizard enables user to mark on single slice and it will automatically mark on the other slices. Multi slice edit is less time consuming but less accurate as compared to edit mask wizard. For segmenting liver, MIMICS Software has a special tool- 3D Livewire in the segmentation menu in the main toolbar. In the 3D Livewire window make sure that target is always a new mask. In this tool user has to choose one of the three views- coronal, sagittal or axial and finally has to mark on the other two views. Basic idea behind it is to mark on the two views except the view user has chosen. Marking on one view will create horizontal lines on the selected view while marking on other view will create vertical lines on the selected view. Marking is done until we obtain our region of interest. Various techniques like edit mask, multi slice edit could be used to properly mark our region of interest. After proper marking of the region of interest click on the segment button in the 3D Live wire window as shown in figure 3 to extract the 3D information from 2D images.
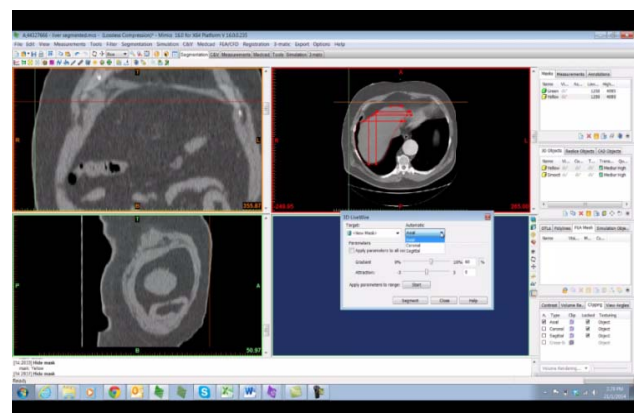

Figure 3: 3D Live wire tool for segmentation

Similar segmentation techniques are to be applied to create masks for patient specific liver, pancreas and portal veins. Once the masks are created user need to calculate 3D by selecting the Calculate 3D wizard in the segmentation menu

for generating the 3D model of the masks that the user has created. Calculate 3D tool is an iterative tool and take some time to calculate 3D of each mask. After 3D information of the mask is generated the same can be exported to STL format.

4. Results

The STL's generated after segmentation done on image based MIMICS Software are shown in figure 4, 5, 6 and 7 respectively. Figure 4 contains the STL of the liver, Figure 5 contains the pancreas, Figure 6 contains the veins coming out of the aorta and entering liver and Figure 7 is the combination of all 3 STL's generated.
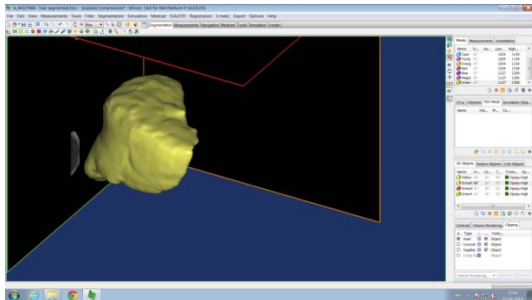

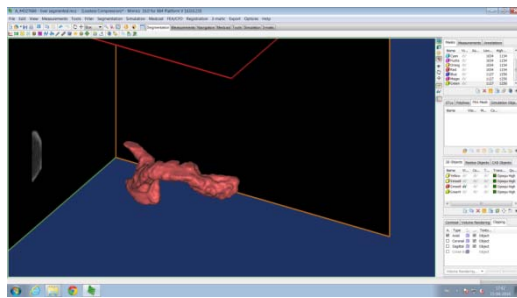**Figure 4**: 3D Representation of Liver

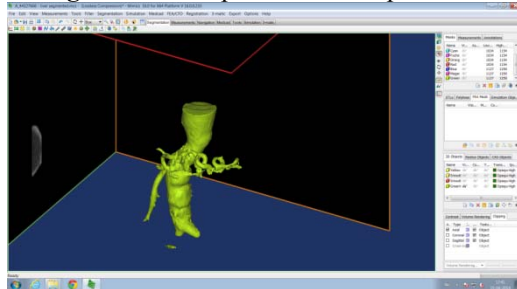**Figure 5**: 3D Representation of pancreas

Figure 6: 3D Representation of veins coming out from aorta
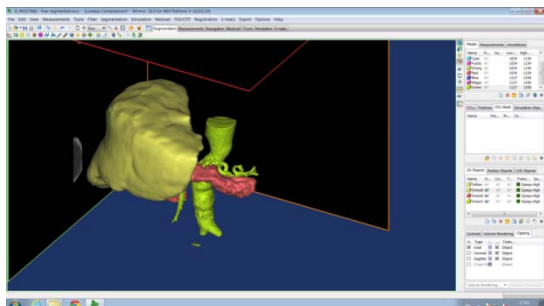

Figure 7: 3D Representation of combination of 3 STL's generated

5. Conclusion

This study describes technical parts of designing patient specific 3D models and conversion of DICOM to STL. A patient specific STL model of liver with pancreas and portal veins has been created by converting the DICOM file of a patient to STL file and separating liver from the surrounding tissue. The protocol has been standardising for the conversion of DICOM to STL file. However the protocol is developed for liver tissue but same protocol can be applied to segment any soft tissue organ. The 3D models generated can be used for teaching aids by 3D printing.

6. Future work

The designed 3D Models were created exactly with patient's mimicking conditions, and these can be used in the future for computational fluid dynamics (CFD) analysis of blood in portal vein normal and diseased condition. The STL generated can be imported into any of the computational fluid dynamics (CFD) analysis software. The STL file generated can be used to measure the diameter of the portal veins and compare the normal and diseased patient conditions.

7. Acknowledgement

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