

VASCULAR NETWORK SEMI-AUTOMATIC SEGMENTATION

Using Computed Tomography Angiography

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Keywords: Vascular Network Segmentation, Computed Tomography Segmentation, Portal Vein, Mesh Exporting.

Abstract: The article describes simple and straightforward method for vascular network segmentation of computed tomography examinations. Proposed method is shown step by step with illustrations on liver's portal vein segmentation. There is also described method of creating and exporting mesh and simple way of its visualization which is possible also from a web-browser. The method was developed to provide satisfactory results in a short time and is supposed to be used as geometry input for mathematical models.

1 INTRODUCTION

Medical diagnostic methods are quickly evolving branch of research. Properties of current medical instruments are improved year by year and larger amount of data is being stored. Important part of medical diagnostic methods is to correctly process imaging data which comes from different modalities. A lot of mathematical models have been developed to simulate functionality of different organs. Such models require inputs where some of them (like geometry) can be provided by processing computed tomography (CT) images. This article describes our experience with vascular tree segmentation process in order to gain geometry information for liver's model which is under development.

Geometry detection has been already solved but finding any suitable non-commercial software is not so easy. Therefore we are presenting here simple and straightforward method for geometry detection which can be implemented in a short time.

2 METHOD DESCRIPTION

We propose universal procedure for geometry information detection. This procedure is based on presumption that we know range of densities of the desired object. In order to liver's vascular network we want to find geometry of portal vein. We will describe whole process on a computed tomography dataset.

2.1 Input Examination

Input examination used in this article is CT angiography examination stored in DICOM format consisting of 1256 slices of 0.6 mm slice thickness. The examination covers bottom body part starting in a half of livers and ending before knees. Segmentation process of the liver's vascular network should be able to work also with non-complete data sources like this. At this point we cannot expect full network, but only the part which is covered by the examination.

2.2 Desired Outcome

We need to find surface model of vascular network. It means that we must find just surface of the network and describe it as coordinations of vertexes and list of connections between them forming triangles or rectangles lying on surface. The ideal surface should be formed by a mesh describing smooth tubes (cylinders) of diameters corresponding to detected vessels. But it is a task for a future work at the moment.

2.3 Preparation

Input examinations often contain more data than it is required and it makes process of vessels segmentation more time consuming. By selecting a sub-volume we significantly reduce time required for processing. Sub-volume selection can be described as finding upper left and lower right x , y , z coordinations of the sub-volume (see Figure 1).

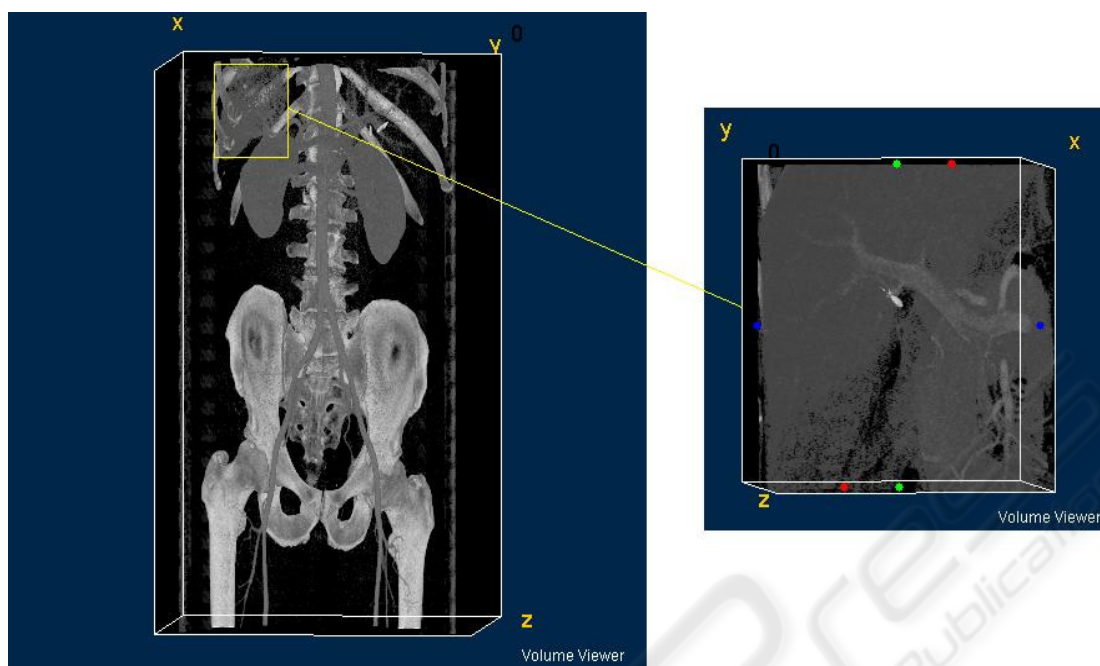


Figure 1: Sub-volume selection.

2.4 Segmentation

Segmentation is based on assumption that we know range of densities which desired object should have. In our case range of portal vein densities is 100-150 HU. Input examinations can contain noise which makes segmentation more difficult. We use averaging method of near neighborhood where dimensions of the considered neighborhood we are of the smallest object which we want to detect. In our case we want to find all vascular structures at least with diameter of 2 mm. We use neighborhood of spherical area with diameter 2 mm. We compute average density for each pixel of the sub-volume resulting in intermediate image where only two values are present (1 for average density of desired object, 0 elsewhere).

Portal vein comes from larger dimensions to smaller. Trunk of the vein is significant and can measure about several centimeters in diameter. As the vascular tree divides in branches the diameter is less and less. The smallest parts are out of instruments possibilities and are not visible in scans.

Figure 2 shows intermediate image. It requires further processing steps.

2.5 Grouping Method

Figure 2 shows that basic segmentation process produces too much points. Idea of further processing

is to divide all points into groups. Each group contains only points which border with each other. For this purpose we use seed filling algorithm. For each point of intermediate image with value of 1 we search his neighborhood in all 26 directions. If there is a point with value of 1 too it will be added to the same group as initial point (seed filling). The points which have been already assigned to a group will be skipped. We mark groups by numbers increasing by 1. When all groups are found we can count how many of the points each group have and easily we can remove groups where number of points does not exceed certain level. Threshold number is application depended. In our case we will finally leave just one group which will correspond to the portal vein which is the group with the highest number of the points. But in first tries it is better find a threshold value which will provide removing of those points which persisted by noise or by limited sensitivity of the instruments. Figure 3 shows our case using threshold of 50 000 points.

2.6 Final Adjustment

Result shown in Figure 3 contains desired portal vein but it contains also other connected parts which should be removed. We recommend to cut these parts already during creation of intermediate image. It is required to find bounding box of these parts in input examination.

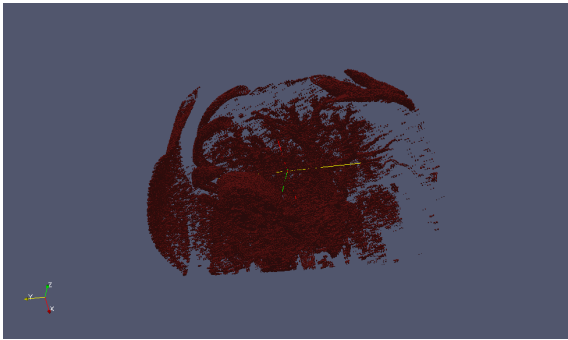


Figure 2: Intermediate image.

It is similar to finding sub-volume described in section 2.3. It means that for each part we must find upper left and lower right coordinations (x , y , z) forming a box which will not be present for further processing. Skipping these areas from intermediate image processing will influence grouping method (section 2.5). Correct bounding box of the object to be removed should break connections between object to be removed and desired object. It should not cut any part of the desired object (portal vein). This process will lead to division of groups where objects to be removed will have their own groups with less points thus it will be removed according to used threshold value. We used four bounding boxes to remove unwanted objects. The final result is shown in Figure 4.



Figure 3: Grouping method result.

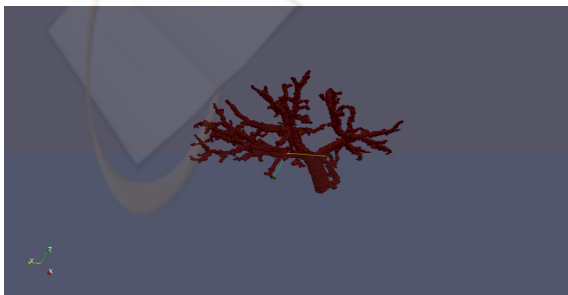


Figure 4: Portal vein network.

3 MESH GENERATION

Our method described in section 2 results in three-dimensional array where all places of vascular network are marked with value of 1. Mesh can be described as a list of vertex coordinations and description of faceset stored as indexes of the vertexes composing each face.

Mesh generation process is a process where only surfaces of the vascular network should be stored. We store mesh by processing all elements of the array. At those places where we detect transition from 1 to 0 we store it as a mesh face. In more details all elements with value of 1 undergo testing whether any of their neighbouring elements in 6 directions (left, right, up, down, forward, backward) contains value of 0 and if yes we store face information. As far as we use DICOM format examinations we know dimensions of each element of the 3D array so we use it for computing coordinations of vertexes. We store face in a rectangle form therefore a face will be stored as 4 new vertexes and one description of the face as 4 vertex indexes. Vertexes of adjacent faces can be shared so we prevent duplicities by testing whether required vertex has been already stored.

3.1 File Formats

Important part of vascular network segmentation is visualization. Visualization offers important feedback. Good visualization can help you with localization of parts to remove and tells where to remove it (see section 2.6). Visualization software exists but it differs in licence conditions and supported file formats. We use mesh exporting to Virtual Reality Modeling Language (VRML) file format because VRML files is easy to create and there can be also downloaded plugins into a web browser and you can display it directly in the web browser. For more information about VRML see [2].

4 FUTURE PLANS

Our goal is to improve this tool and make it usable from experimental database medical system [1]. The database stores examinations of different kinds including CT examinations. We hope that we will develop a system which will be able to segment imaging examinations starting with CT examinations according to needs of future mathematical models which will run above the experimental database

system. This will require to develop description system of mathematical model needs. All segmented vascular network structures will be stored in the database and will be available by web-based browsing system in form of VRML files.

5 CONCLUSIONS

We proposed simple straightforward method which is able to segment and export vascular network in a mesh form. This method is shown on example of liver's vascular network segmentation. We have described method which can be easily used for segmentation of other vascular networks. Description of each step with graphical figures can help others who are dealing with this problematic. Described method can be implemented in a short time and gives satisfactory results which can be used for further processing or base for mathematical modeling.

ACKNOWLEDGEMENTS

The work presented in this paper is supported by The Czech Science Foundation project 106/09/0770 dealing with brain perfusion modelling.

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