Measurable Models of Abdominal Aortic Aneurysm on the Web

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Abstract In this paper we describe a method for 3D reconstruction and web distribution of vessel structures specifically designed to allow the remote measurement of parameters of surgical interest. Deformable models are used for segmentation, while VRML and ECMA scripting are used to obtain 3D models that are not only viewable from any VRML97 enabled browser, but that also allow users to interact with the model, navigate along the vessel lumen and perform guided measurements of distances and angles.

1. Introduction

Since the introduction of VRML97 it has been possible to generate three dimensional models of organs from CT or MR data using standard image processing software, and convert them to a format that could be visualized on any web browser. The application of this technique has been mostly limited to proof of concepts, see, for instance, the nice demos of surgical simulation proposed in [1], but not to tasks immediately useful to clinical applications.

Here, we show an example of a 3D web based application directly motivated by a specific clinical need: the measurement of the geometrical characteristics of Abdominal Aortic Aneurysms. Recent advances in the endovascular treatment of this kind of pathology require, in fact, a precise knowledge of the 3D structure of the specific patient abdominal aortic aneurysm in order to evaluate risk factors, decide if the intervention is necessary, select the prostheses to be used, plan the surgical procedure [2].

The system proposed in this paper builds enhanced patient specific VRML97 models of AAA, which contain also specialized guided measurement tools. These models enable surgeons to perform 3D measurements needed in endovascular AAA intervention planning directly from their web browsers. The structure of the system is naturally suited for the operation of an Internet based image processing service that receives in input DICOM data obtained from hospitals acquisition modalities and returns WWW browsable models.

2. Segmentation techniques

In order to support the relevant measurements on vascular geometries, we needed a segmentation algorithm able to extract both the complete surface mesh with no holes for the vessels internal surface and a series of 1D lines representing the vessels centerline. We organized these data in a dedicated data structure called *arterial tree*. We adopted two different metods to build arterial trees: a 2d contour based method and a 3D segmentation based on Simplex Meshes. The first consists of generating single tubes from series of contours located in the 3D space and then joining them with basic operations. Contours are extracted from 2D slices (with arbitrary orientation) using customized region growing or balloon snakes [3] algorithms, and can be modified and controlled through a specialized user interface. Tubes segments are then generated from contour series and their centerlines are also built from contours centers of mass. The operations introduced to join the contours are three: simple joint, anastomosis and bifurcation. The first connects two tubes at their extrema, the second joins two intersecting tubes, the third joins three different tubes in a bifurcation structure.

The same procedure of the balloon evolution, can be performed directly in 3D starting from a small sphere first put inside the data set and then grown driven by an internal pressure, regularizing forces and voxel based forces. We found a good 3D geometrical structure to be used as a basis to implement the balloon in the Simplex Meshes introduced by Delingette el al. [4]. Simplex Meshes are very simple surface meshes where each node is connected exactly to three neighbours. This makes very easy to write the code for the dynamics and the algorithms obtained are simple and fast. The only problem of this method is that the geometry obtained is composed by non−planar polygons. We overcame the latter by saving for rendering a dual triangulation of the surface, obtained from nodes placed at the center of each simplex face connected with the other nodes corresponding to the neighbouring faces of the simplex mesh. We control the size of the faces by splitting them if they overshoot either an area or an elongation threshold and by merging them if under another threshold. The Simplex balloon method we implemented do not provide an Arterial Tree as output, but only the external surface of the vessel. We reconstruct in this case the centerline directly from the dataset, after binarization. This step can be done by voxel coding technique by Zhou [5]. The simplex reconstruction is more regular than the 2d contour based method near the bifurcations and it is usually better with irregular vessels. However, in case of plaques or local structures it is convenient to correct locally the reconstruction with 2d contour information.

Fig.1 Virtual endoscopy with measurement of radii on the browser

3. VRML97 generation

VRML97 files are generated, including surfaces, centerline and also an user interface that can be used to start guided navigation inside the vessel's branches, and to select the measurement mode preferred. Different ''nodes'' of VRML97 have been used to represent the geometry of the vessel surface and the vessel centerline; to make easier the measurement of angles and distances the centerline is also duplicated in another part of the scene. The Viewpoint node is used to define a set of privileged points of view (at the end of each vessel branch and an external global view). The simple VRML user interface allows the control of pre–defined animations. Our conversion script automatically creates a guided navigation along each branch of the tree along the vessel centerline. The VRML97 language specification includes a particular node called Script that allows the introduction of code inside the file using ECMAScript or Java. The output of the node can be used to change the value of variables in the other VRML nodes instantiated. Using ECMA scripting we implemented a method to measure parameters, with three main options. The first consists of printing the 3D coordinates and the distance from the centerline for an arbitrary point on the surface, selected with the mouse (Fig.1). The second consists of measuring the distance traveled by a point moving along the centerline between two user selected reference points (Fig. 2 A). This is an extremely useful measure, since usual measurements of vessel length done with 2D imaging or endoscopy are often wrong due to the effect of vessel curvature [2]. The last one is the measurements of angles defined selecting three points on the centerline (Fig. 2 B). With these tools the end user can perform many useful computations on realistic models that can be distributed worldwide a few hours after the image acquisition and just by using standard web browser.

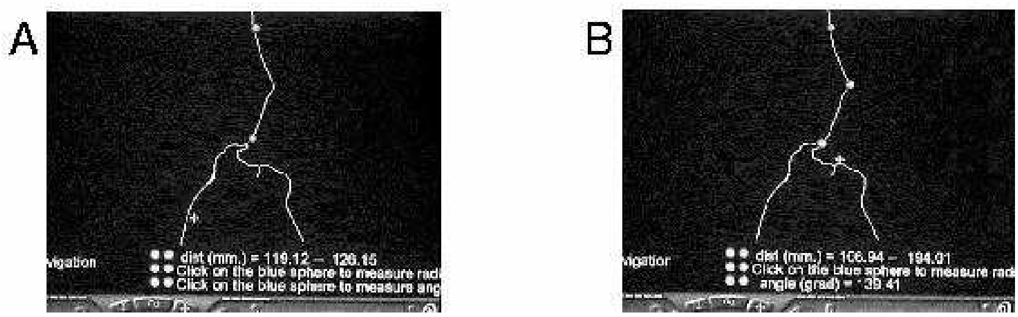

Fig.2 Measurement of distances and angles on the reconstructed centerline

4. Results

With our software tools, 3D models can be created and distributed within a few hours from the image acquisition. The scripting code allows quick measurements of the parameters used by the surgeon; the accuracy of these measurements is currently under test on controlled data sets

5. Conclusions

In this paper we have shown how it is possible to harness VRML technology to provide surgeons with a new tool directly applicable to clinical practice.

References

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