Title:
Spatial Augmented Reality and Simulations to Improve Abdominal Aortic Aneurysm Diagnosis and Monitoring

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Introduction:
Virtual Reality (VR) is a technique that affords multi-sensorial stimuli totally immersive for the user who is projected onto a virtual world, completely separated from the reality. This type of technology usually does not represent a good method to improve a collaborative data analysis, especially when more users are involved. A better one is the Spatial Augmented Reality (SAR), where information is added to the real world and more users can avail it at the same time. In this work we investigated the possibility of developing an effective visualization methodology based on SAR of three-dimensional models derived from CT images, to better evaluate the condition of a patient suffering from AAA.

Main Idea:
The goal of this work is to generate a Spatial Augmented Reality (SAR) [4] environment, where the users (e.g., vascular surgeons and physicians) are able to extract useful information about the dimension of the vasculature and the blood flow, for a better diagnosis, efficient pre-operative planning and monitoring of the Abdominal Aortic Aneurysm (AAA) disease. Nowadays, there are many applications of Augmented Reality (AR) focused on image-guided surgery, implemented with the help of desktop. The acquired images of the patient are projected and used to plan or perform task. Another sector is represented by the rehabilitation and the treatment of phobias [1]. Among these existing applications, there are some other concerning the project NARVIS [3], where CT images are used for an AR system useful for spine surgery or the visualization system implemented by Aloisio G. and De Paolis L.T., where body structures are visualized on a screen by the use of markers placed through a patient's simulacrum. However, these systems can be provided exclusively through the use of tools or monitors worn by users.

In our work we recreate a vascular structure from Computer Tomography (CT) data in DICOM format [5] through the use of algorithms and tools implemented in Vascular Modeling ToolKit (VMTK) software. As first step, we compared four methodologies of geometry initialization, used as the starting point for the Level Sets method evolution, and we choose those able to describe the vascular disease excluding any foreign tissue (i.e., bones, internal organs, and muscles). Then, we evaluated problems connected to the relative parameters of reconstruction, their influence and their weight for the correct geometry representation, focusing the attention on segmentation level and the smoothing of the surface. In particular, we quantified the effect of the smoothing by the use of the Hausdorff distance. In this way we generated a standardized procedure able to guide users in the reconstruction of this type of vessels. We also recreated the body of the patient (the skin) using Slicer 3D software.

3D geometry of the vessel (Fig. 1.) can be used to carry out CFD analysis [2], to calculate parameters of the blood flow and evaluate the rupture risk indicator, like Oscillatory Shear Index (OSI).

This geometry and information are re-edited and used in 3DVIA Virtools software to create an interactive virtual environment where the user can visualize needed information. Finally, we created a Spatial Augmented Reality scenario (Fig. 2.), where numerical data and the pathology geometry are projected onto a dummy representing the patient who is able to generate a 3D visual effect. This work is a final process of a risk analysis procedure implemented by CDF analysis for diagnosis and pre-procedural studies. It can be intended also like the first step oriented to the generation of a simulation system for the EndoVascular Aneurysm Reapair (EVAR) procedure.

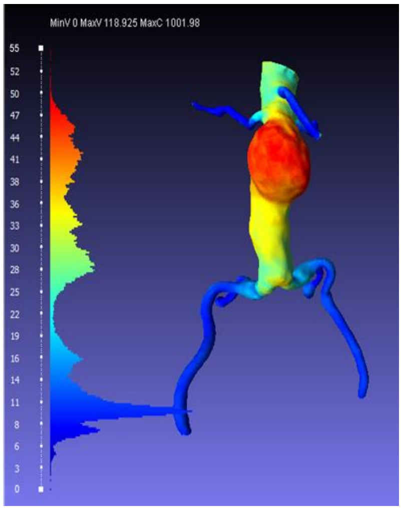

Fig. 1: Diameter data of the reconstructed vessel.

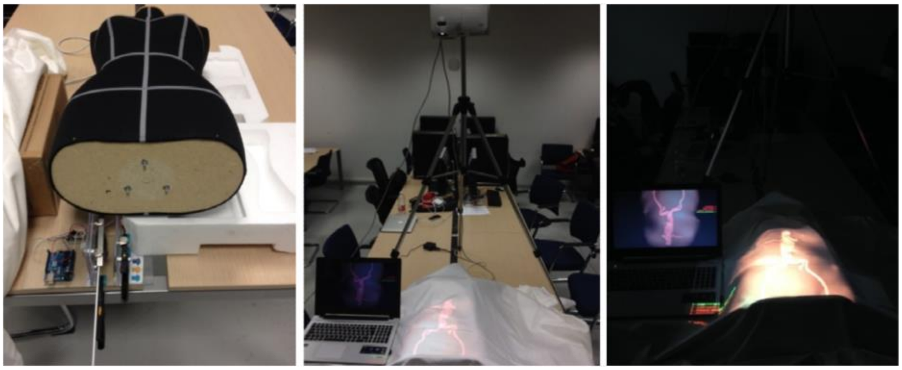

Fig. 2: Spatial augmented reality scenario.

<u>Conclusion:</u>

In this work we developed a SAR application able to generate an immersive environment for the users, without the need to wear any auxiliary system to analyze the information generated by the analysis taking the advantage of the system that generates information in 1:1 scale on a dummy of the patient. It was implemented the reconstruction technique, which results to be complete with all the features needed for the generation of aneurismal geometries usable both for computational analysis and virtual/augmented reality. It has been also paid attention on the reconstruction parameters, evaluating the goodness of different geometries.

The issue relating the implementation of the simulation control prototype has been investigated. The Arduino platform was proved particularly powerful for this type of applications. It was also

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implemented an augmented reality system for the simulation of a surgical repair of an AAA. From the geometrical reconstruction performed with the standardized process from the experimentation, it was possible to derive calculation grids for CFD simulations and therefore the calculation of the rupture risk based on hemodynamic indices which are the variation in the cardiac cycle of the WallShearStress .

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