Advanced Medical Imaging Visualisation Tool using ITK

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Abstract. A visualisation tool for radiological data, including algorithms for image processing and advanced visualisation technology is presented. The solution uses public domain algorithms from ITK and VTK and in-house developed methods for accelerated rendering and includes a data management step, multiplanar reformatting and volume rendering steps, followed by a virtual endoscopic view.

1 Introduction

Most of the modern medical interventions (surgery, biopsy, catheterisation) rely on "blind" methods: during the procedure, the physician cannot observe directly the target, or the path toward it, or – in most cases – the structures (like vascularization) hidden behind the physical boundaries of anatomical organs. In many cases, even when one is able to use visualization means, these means have various limitations: they are either only two-dimensional, or too slow, or they offer only off-line rendering. The interactive visualization and the virtual reality technology are opening new prospects for the medical practice, by permitting realistic display of, and fast interactions with the images offered by various scanning modalities available in medical imaging. This allows generating perceptions similar with those from the real experience. When optimising, preparing, or even replacing the invasive exploration examinations, the modern imaging technologies prove to be of paramount significance for decreasing the risk level, of the morbidity, and for ensuring the full clinical comfort for the patient. Medical imaging technology advancement in recent years is stimulated both by development of modern scanning technology and increased research activity in the field of medical image processing [1,2]. During the last decade, the medical imaging has become a branch of virtual reality (VR) technologies. Modern applications offer complex functionalities, starting with the virtual entry and navigation through the patient body, to pre-operative simulations of interventions and implants, to intra-operative surgical guidance [1-4]. The virtual endoscopy offers the simulated visualization of various organs, visualization that tends to parallel that offered by endoscopic instruments.

2 Background

In classical medical practice, the pathological evaluation of cavities and anatomical tubular/hollow spaces (digestive system, the respiratory system, the ORL link system, blood vessels, uterus, etc.) is made by endoscopy, an invasive procedure, usually medium to severely

uncomfortable for patients, sometimes not recommended or impossible, with high risks, like perforation, infection, and hemorrhage. The medical imaging offers a modern alternative: the *virtual* endoscopy, i.e. the simulated non-invasive or minimally invasive clinical examination (in the case of radiologic modalities) of anatomical cavities, starting from classical radiology scans.

Virtual endoscopy uses two methods of visualization [2]: *surface rendering* and *direct volume rendering*, each with its advantages and technical drawbacks[7].

The surface rendering method requires a supplementary processing step, which is the *segmentation* - delimitation of a connected voxel set based on its pertaining to a distinct/uniform region/structure, followed by the transformation of the volumetric set of voxels to a polygonal grid ("tiling"), in other words the reconstruction of the surface that circumscribes the volume of interest. In the case of cavities one can reconstruct the inner surface, while in the case of anatomical "tubes" one can reconstruct both the inner and the outer surface. Usually, the segmentation can be performed semi-automatically. Current research works are trying to fully automatize this step; the robustness and the accuracy of a fully automatized segmentation process are problems still to be solved[1]. Direct volume rendering is realized using ray-casting, projections of observing rays through the whole volume. It results an image without information loss, with a "cloud" appearance, through whose transparency one can see the objects. Here there are also limitations: the visualization of small and complex shape objects becomes difficult in the case of "dense" sets. Presently, it seems that there is not sufficiently exploited the possibility to combine both rendering methods in order to optimize the visualization. In our present research, we have opted for a surface rendering. We applied a segmentation algorithm followed by a model building procedure, to obtain the 3D boundary surface of the segmented domain.

3 Segmentation algorithms

The segmentation algorithms are grouped in four main classes: Region growing, Watersheds, Level Sets and Hybrid. From the first class, the ITK library [7] implements the following algorithms: Connected Threshold, Otsu Segmentation, Confidence Connected, Neighborhood Connected. Watershed algorithms are edge based algorithms, using the pixel intensity delta detection. Level Set algorithms are based on the evolution of a surface described by a differential equation and under the effect of a force field depending on the pixel intensity and local curvature; related algorithms implemented in ITK are: Fast Marching, Shape Detection, Geodesic Active Contours, Threshold Level Sets algorithms.

We report here on the application of the Connected Threshold algorithm (implemented in ITK) associated with a preprocessing Curvature Flow filter used to reduce the initial image noise (smoothing). The algorithm's input is the processed image, a 3D seed point and the lower and upper threshold values for 3D pixel (voxels) color intensity. The set of voxels obtained through segmentation is then presented to a triangulation algorithm, using the Marching Cubes method [5], implemented in VTK.

4 Methods and results

The raw medical data, exported in *DICOM* standard format file sets by scanning devices (of various modalities, like CT, MRI) is imported by our software. The datasets are grouped based on various criteria, such as: patient, date, scanning modality, examination name. Several sets of data, from the same patient or from different patients, can be imported in the same session. Original data may be scanned in axial, coronal or sagittal direction, i.e., 2D reformatted slices

are aligned to one of the principal directions in the scan coordinate system. For each set of data, a representative thumbnail is created and displayed in a list window, allowing fast and intuitive selection by operator. Browsing through datasets and individual images is extremely simple and intuitive.

An example is shown in Figure 1, where multiple sets from two anonymous patients is presented. From each set of slices a so called medical volume can be formed using ITK predefined algorithms. The medical volume is then resliced (reformatted) through axial, coronal or sagittal sliding planes. This gives the freedom to browse all details of the anatomy. For the example shown in Figure 2, a CT scan abdominal procedure was performed. Here he present the application main window with all 4 views selected. Browsing the slices in one view is reflected also in the complementary views and in the three-planar view.

Selection of regions of interest is performed using segmentation algorithms mentioned above, which are tuned for each practical application.

Finally, a 3D model for surface rendering is built using Marching Cubes algorithm. Figure 3 displays the 3D view of the model after segmentation of bones and blood vessels. The 3D model is superposed over the three-planar reformatting view using transparency. Separation of aorta and bones is difficult, since they almost touch on some points and their voxel intensity intervals are superposed. In Figure 4 is shown the result of segmentation of the large blood vessels only, using a smaller voxel intensity interval between the lower and upper threshold values for the segmentation algorithm.

In Figure 5 we show an endoscopic view of the aorta, with surface rendering visualization, after segmentation and model extraction.

The results shown here were obtained on a HP mobile workstation (laptop computer) with dual CPU, with 1.8 GHz and 2 GB RAM.
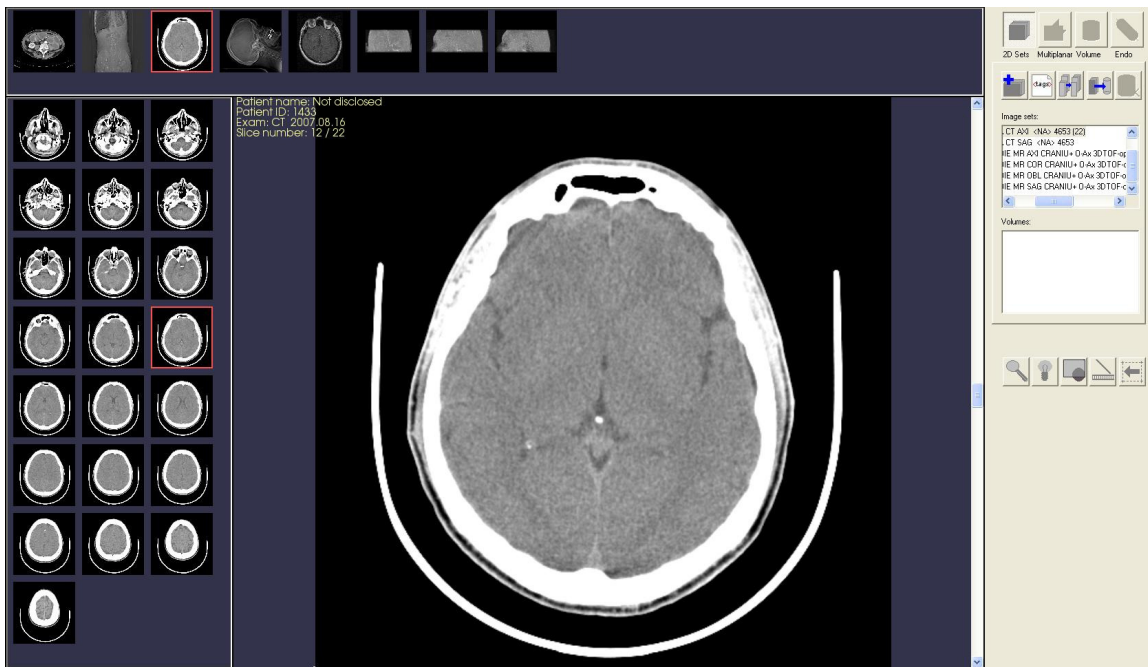

Figure 1: Management step of the medical imaging system developed; multiple patient, multiple sets and modalities (CT and MRI) included; selection shows a brain CT scan
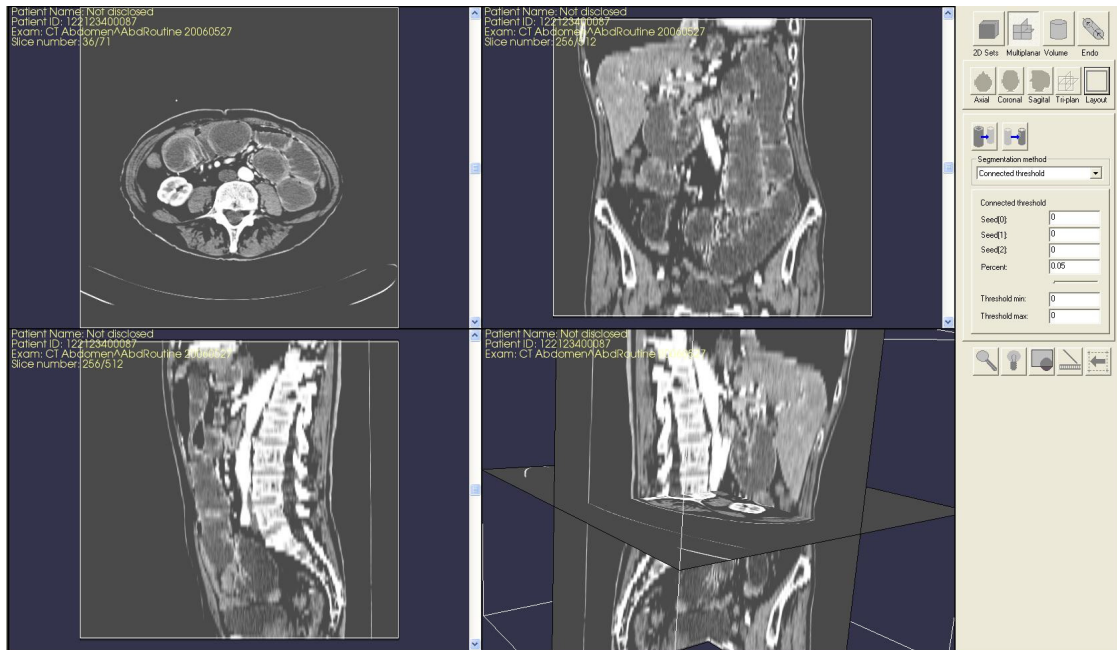
Figure 2: Multiplanar reformatting shows axial (upper left), coronal (upper right), sagittal (lower left) and 3-planar view of the medical volume created from a 2D set; CT abdominal procedure
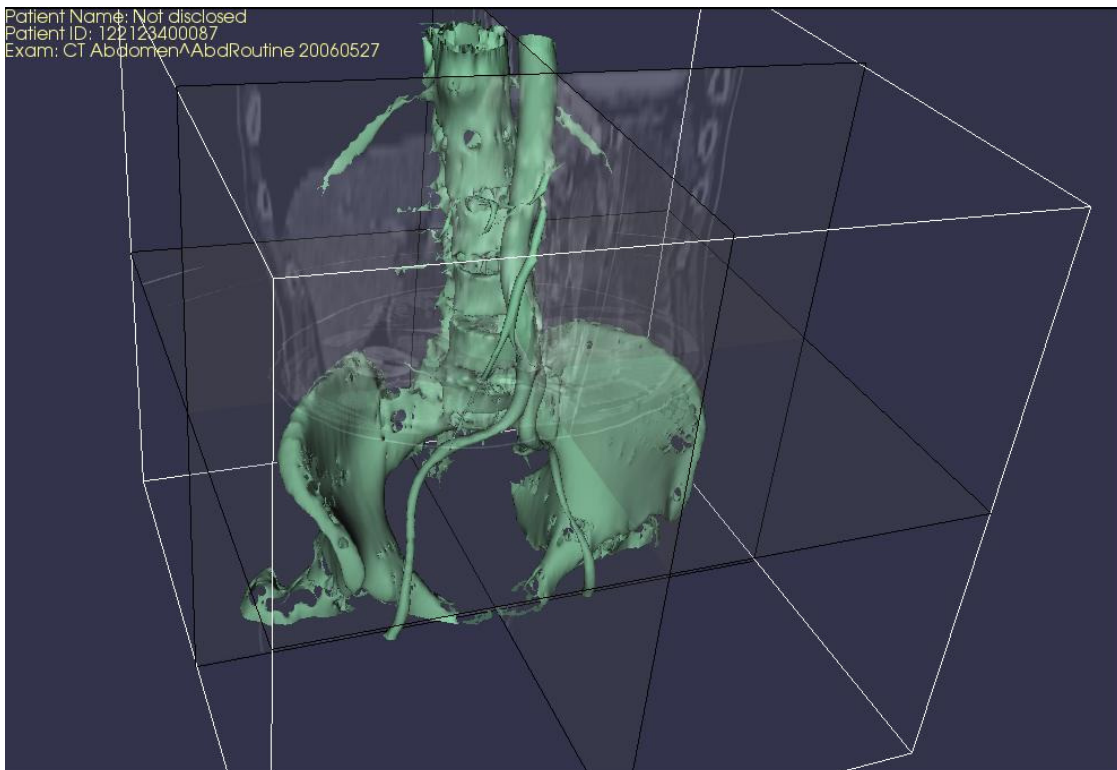

Figure 3: 3D view of the medical volume segmented from CT data of abdominal procedure: massive bones and main blood vessels
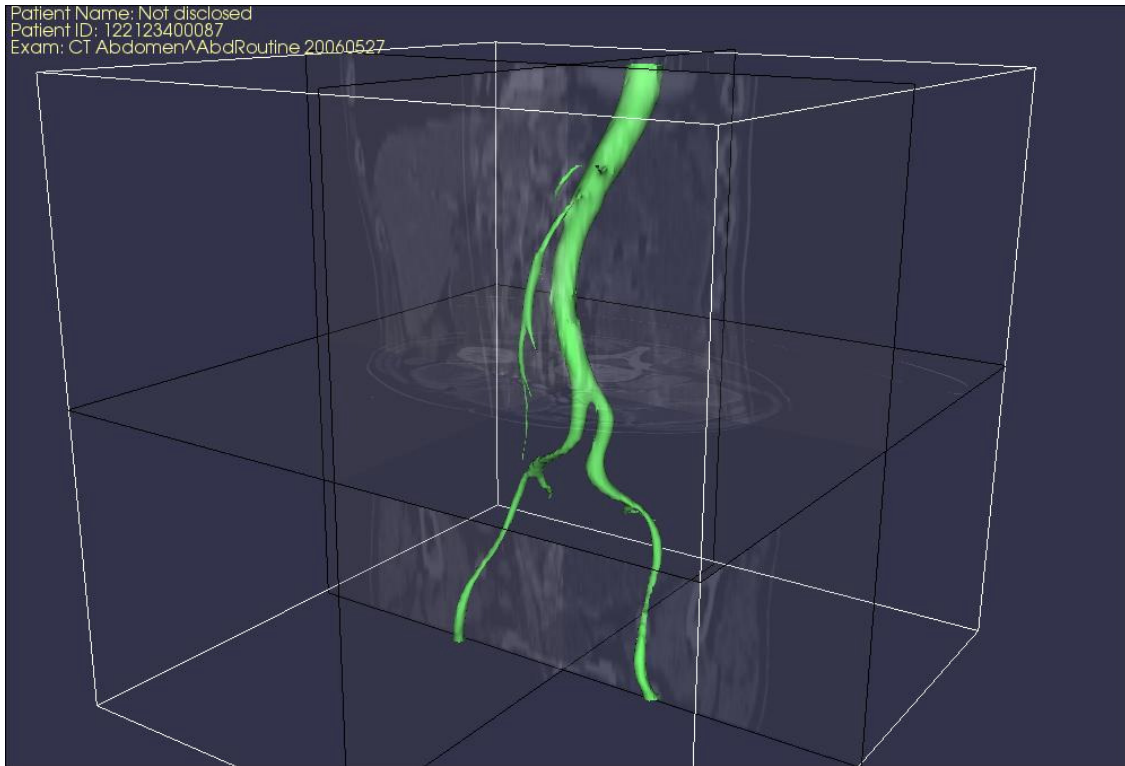
Figure 4: 3D view of the medical volume segmented from CT data of abdominal procedure: massive blood vessels only, with aorta and iliac arteries
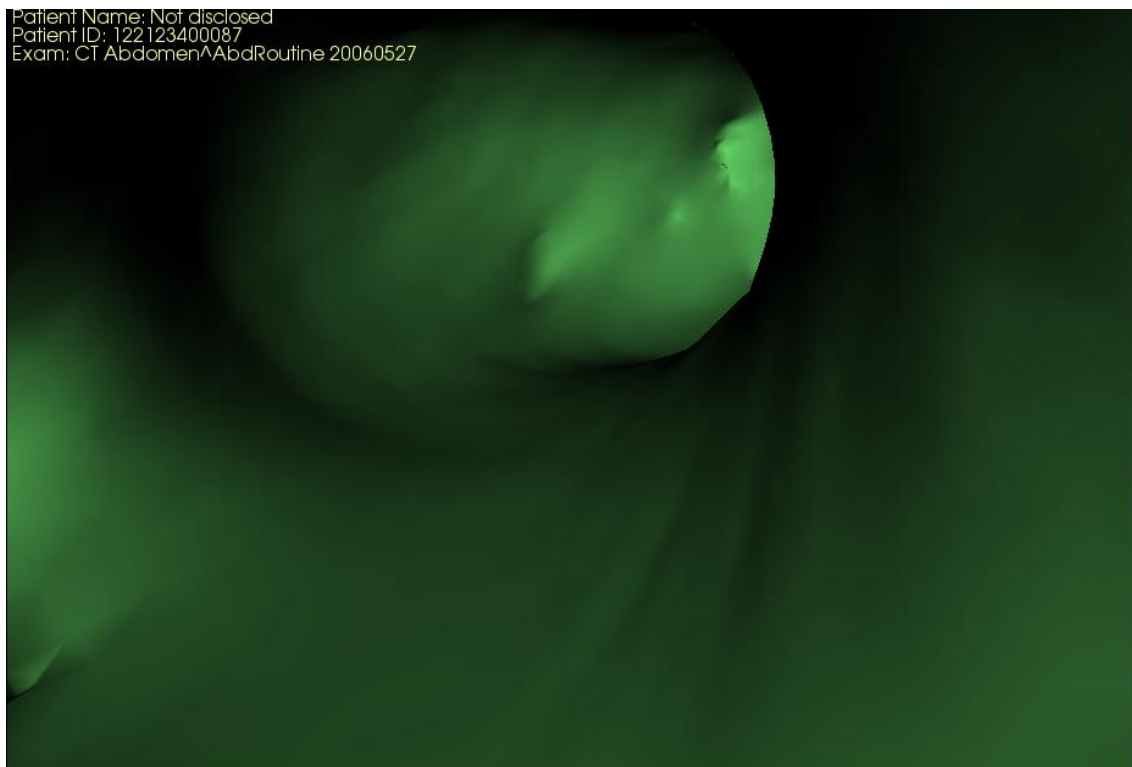

Figure 5: Endoscopic view of the segmented aorta.

5 Conclusion

The software system introduced here allows fast reconstructions of realistic images of selected organs and anatomic parts; the quality of reconstructions depends very much on the tuning of the selected segmentation algorithms. Necessary hardware resources can be as small as a simple laptop computer.

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