Doctoral thesis position

Title: Interactive Visualization of 3D Echography Images with Volume Rendering.

Hosting institutes:
- Research Institute Against Digestive Cancer (IRCAD) of Strasbourg
- University of Strasbourg, ICube lab, IGG team (Computer Graphics and Geometry)

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Location: Strasbourg, France

Keywords: Volume rendering, 3D ultrasound imaging, classification, transfer function, empty space skipping

Desired skills:
- Visualization
- Volume data processing
- Knowledge of GPU/shaders programming
- C++ programming

Context and motivations:

In the past few decades, surgery has produced significant advances in the fight against cancer. Today, computer science research offers surgery a new revolution with augmented surgery. Augmented surgery allows the surgeon to surpass standard human cognitive skills to significantly improve the quality of care, by enhancing vision, decision and gesture. An important imaging modality in surgery is ultrasound. This is painless, safe, real-time, non-invasive and compatible with standard surgical tools. In fact, unlike computed tomography (CT), it does not require the use of X-rays, and unlike magnetic resonance (MR), it can be performed with the presence of ferromagnetic objects. In addition, its cost is much lower than these modalities. However, the understanding of these images requires great expertise to mentally reconstruct the structures observed in 3D space, using the sequence of images acquired during an examination.

This is the reason why, for several years, researchers and manufacturers in the sector have been seeking to provide 3D ultrasound images. Nowadays, this can be achieved in two ways. The first one consists in reconstructing a volume from a sequence of 2D images, using a 2D ultrasound probe equipped with an electromagnetic or an optical sensor. This approach is commonly referred as "freehand 3D ultrasound". Real 3D or even 4D ultrasound probes also exist, but they are less common, and they provide lower resolutions and refresh rate.

Whatever the source, visualizing a 3D ultrasound image is a particularly difficult and unresolved research topic. Today, it is accepted that direct volume rendering is the most suitable method for viewing 3D images [1] (figure 1). Each voxel is associated with colour and opacity, allowing the operator to look through the volume. To operate globally on the image, a transfer function, conventionally 1D, combines ranges of intensity with pairs of colour and opacity.

However, the nature of ultrasound images is very noisy and has a low dynamic range. Unlike CT MR images, ultrasound shows changes in physical properties rather than the physical properties themselves. Consequently, conventional 1D transfer functions fail to segment these homogeneous structures.

Finally, conventional ultrasound probes offer a second mode, the Doppler mode. It is mainly used to distinguish arteries from vein. The fusion of 3D images in B and Doppler mode is technically difficult due to the increase in data size and the actual blend between the two images [5, 6].

In this thesis, we are interested in the visualization of 3D ultrasound volumes for computer assisted sonography, diagnostics, interventional radiology and percutaneous surgery and training simulators. We will focus on the liver and the kidney to distinguish target structures (organ, tumour), critical surrounding structures (blood vessels, lymph nodes, etc.) and needles in the volume.

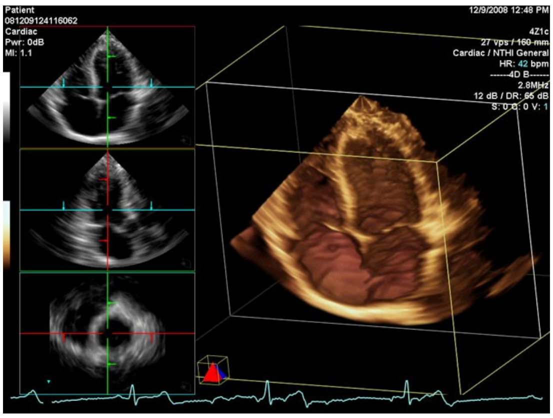

Figure 1: Volume rendering of a heart with Siemens Acuson SC2000

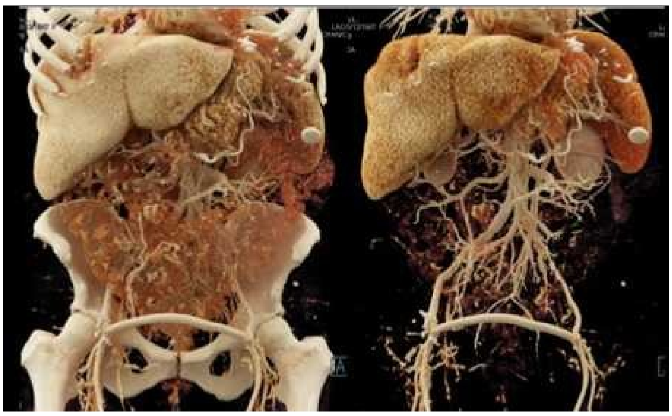

Figure 2: Physically realistic volume rendering from a CT-scan (Siemens Cinematic Rendering)

PhD Objectives:

In the above context, the objective of this thesis is to tackle the challenges of interactive visualization of 3D ultrasound images [1] by direct volume rendering, with a particular focus on the classification of the data, combined with a rendering performance concern. There are three main scientific and technological objectives.

As a first objective, the aim will be to propose a system to design efficient transfer functions [3] to define appropriate opacity levels [8] for the different target structures to be visualized in volumes acquired by ultrasound. For such volumes with low dynamic range, a significant amount of noise and variable intensities for the same tissue, it will be necessary to adopt approaches that consider additional information beyond the simple voxel intensity level [2] (classical 1D functions). In addition, we will focus on the visualization of multi-modal ultrasound image fusion (B-mode, doppler, elastography) and possibly with other types of acquisitions (CT-scan, MRI). It will be necessary to develop methods to combine data classification, either by a single transfer function that groups all modalities or with several independent transfer functions. Hence, it will also be necessary to think of a way to adapt the visualization to multi-modality in relation to the chosen type of classification.

As a second objective, we will focus on an approach oriented towards the efficiency of the rendering performance. It is possible to improve the performance of the direct volume rendering algorithm by using accelerating structures, like pyramidal representations [7]. Indeed, approaches that divide the volume space into appropriate sub-regions, not only allow to increase the size of data volumes, but also allow to efficiently apply empty spaces skipping [4] (due to their transparency associated with the transfer function), the latter contributing to accelerate rendering. The aim is to focus on the implementation of an accelerating data structure that updates itself dynamically in relation to the interactive management of the selected classification tool. Thus, propose the implementation of an efficient rendering adapted to the visualization of structures with empty regions, which are not necessary for diagnosis and which can reduce rendering costs.

Finally, the goal is to target the design of a complete interactive visualization tool. Thus, the development of methods based on recent advances in the literature in terms of data filtering, clipping, lighting and shading, and the management of uncertainty in the context of medical ultrasound image acquisition will be considered.

Work environment:

The PhD. student will be hosted in the Surgical Data Science team of IRCAD Strasbourg for three years, allowing him to benefit from existing software, infrastructure, agile management, support from experts in computer graphics and the possibility of testing the results in a clinical setting. Part of the research time during the thesis will also be spent in the Engineering, Computer Science and Imaging Laboratory (ICube) of the University of Strasbourg with researchers from the Computer Graphics and Geometry team.

The IRCAD Surgical Data Science team has been researching and developing augmented surgery software for 20 years that is intended to assist surgeons, interventional radiologists and gastroenterologists. The complexity and multiplicity of challenges associated with augmented surgery naturally require a team of suitable size. Consequently, in addition to its collaborations with the University of Strasbourg, the Surgical Data Science team is developing and forging international partnerships thanks to twin IRCAD institutes, and in particular IRCAD Africa, located in Kigali. The growth of the IRCAD Africa Surgical Data Science team has been carefully planned. The team now has 9 members, reaching 40 members within 5 years. To achieve this ambitious goal, IRCAD Africa is supporting the most deserving African computer scientists to receive funding enabling them to complete their doctoral training in Strasbourg. This is in collaboration with the best research teams of the University of Strasbourg. The best post-graduates will then have the opportunity to help lead, mentor and train new talents in IRCAD Africa in a virtuous cycle.

References:

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