Software Development for Low Cost, High Quality, Real-time 4D Ultrasound Imaging System on Personal Computers (PCs)

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1. Introduction

Ultrasound imaging is considered one of the most important imaging modalities used widely in the field of biomedical imaging; it has broad latitude of clinical and diagnostic applications. Real-time 4D ultrasound imaging is a medical technique used in obstetrical scans, which provide sonographers with rapidly animated three-dimensional images of the fetus. Sonographers around the world were always dreaming with these animated three dimensional images instead of ordinary B-mode two-dimensional scans. They were deliberating all the times in interactive fetus visualization. This interactive visualization will lead to better diagnosis and consequently to the welfare of the community.

2. Problem definition

Real-time ultrasound imaging modality is the system which can meet sonographers' dreams. However, until recently it was not possible to develop this type of ultrasound machines at all. This was down to the lack of adequate hardware and software platforms that make the developers capable of implementing interactive volume reconstruction. Despite hardware availability in that time, this hardware was not widespread in the market, as well as components' cost was too expensive. Consequently, ultrasound systems' overall cost was very expensive. Besides that, software development was a tedious matter in the past. This was a consequence of the limited functionality of the fixed-function pipeline on the available graphics cards in that time. Explicitly speaking, the real problem in an interactive 3D ultrasound lies in the massive data sets to be processed and rendered per second. All of these reasons made the developers waiting for affordable and flexible hardware that can make them capable of developing and manufacturing low cost and high performance 4D ultrasound machines that support interactive 3D volume visualization.

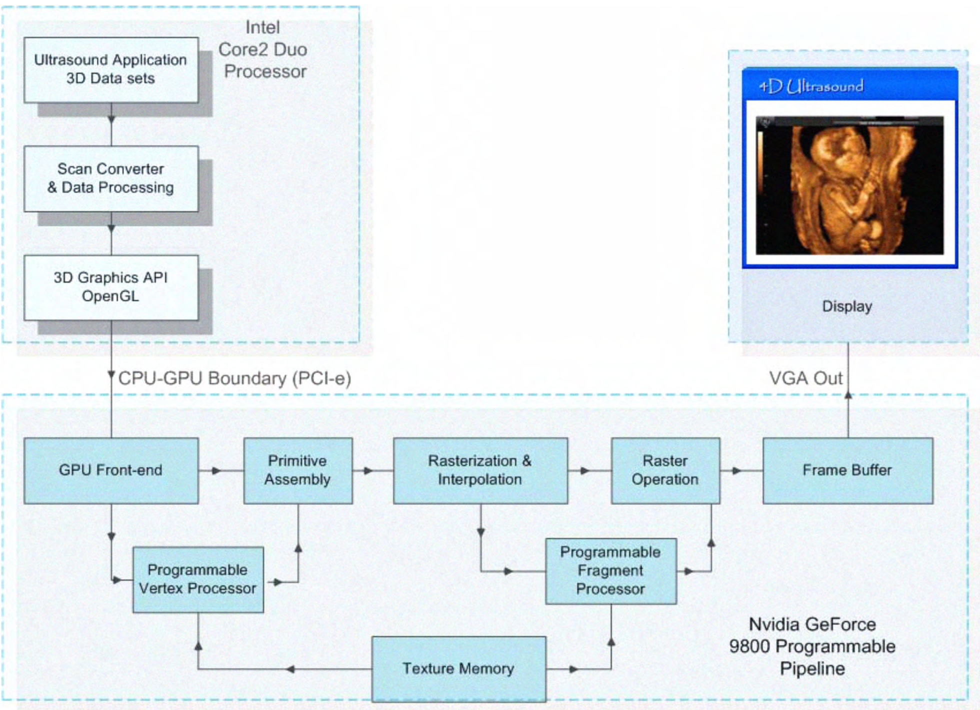
3. Technology

After the advent of the current state-of-the-art multi-core GPUs (Graphics processing units) in this era, graphics cards capabilities became more and more and even more flexible to be utilized in interactive visualization, they offer a level of programmability and performance that not only makes it possible to perform traditional workstation tasks on a cheap personal computer, but even enables the use of highly complicated rendering algorithms that previously could not be employed for real-time visualization at all. These modern GPUs are very brilliant and efficient at manipulating and displaying massive computer graphics datasets, as well as their highly parallel structure makes them more effective than general-purpose CPUs for a range of complex algorithms. These GPUs' pipeline is now programmable - yes they are programmable - not fixed-function any more. This programmability capability is the real power that has lead to great improvements in the field of medical interactive visualization. Thanks to great evolution of the consumer graphics hardware, we can exploit the nowadays available low cost and high performance hardware great functionality to write the adequate software that can yield the sonographers' dream; it is high quality interactive visualization that combines real-time performance with high resolution imaging.

4. Our work

Our target in this project is to develop applicable software dedicated for low cost, high quality, and high performance real-time 4D ultrasound machines. This software must have the flexibility to run on the current affordable consumers' graphics hardware available in the global market. As well as it must achieve what we are originally seeking for; the interactive visualization or real-time performance.

Regarding our choice for a hardware platform, we set on the nvidia GeForce 9800 GS graphics card which is considered a suitable graphics platform we can trust to implement our system on. This graphics card has the following features: 64 Stream Processors, 530 MHz core clock, 256 bit memory interface, 51.2 GB/s memory bandwidth, 17.0 billion texels/s texture fill rate. This GPU pipeline is programmable with both of its vertex and fragment processors. Shaders are codes written to program the unit (GPU) programmable rendering pipeline. We are going to use the Cg (C for graphics) shading language to write our vertex and fragment shaders. OpenGL will be used as the 3D graphics API (application programming interface) or graphics pipeline model and the interface between CPU and GPU. Both of the Cg and OpenGL codes will be encapsulated in the MS Visual C++ programming languages classes. And finally GUI design will be implemented using the QT library. The next figure depicts the pipeline we are going to follow.



Among the versatile volume rendering techniques, the need to a real optimized one that exploit the flexible programming model and 3D texturing affordable capabilities of modern GPUs is crucial such that it will finally affect the interactivity of the visualized volume. Although it is possible to implement other popular volume rendering algorithms on the GPU, such as ray casting or others, we are going to use the most one that offer a great level of interactivity without sacrificing the quality of rendering. It is texture-based volume rendering.

5. Conclusion

Interactive volume visualization was a dream that can't easily and cheaply be achieved in the past. This was due to the lack of the high performance graphics hardware that capable us of developing real-time 4D ultrasound machines. Current state-of-the-art low cost consumer graphics chips afford a level of programmability and performance that makes it possible to easily develop interactive volume visualization on them. Processing powers of the these chips has increased so much that today we can get real-time ultrasound equipment to acquire and display the 3D datasets with their multi-planar reformations and renderings in real time. In this project we are going to exploit the great programming capability of one of the available nvidia graphics cards chips to implement a texture-based volume rendering techniques on it, seeking for developing applicable software that achieve real-time and interactive ultrasound volume visualization.

Writing software is an easy job, but exploiting the ultimate hardware capabilities for developing bug-less (as possible) and suitable software for real-time performance is the real hard target we are trying to achieve in this project. Reaching this target in this project will give us the spark to put our efforts towards a final product; it is Real-time 4D ultrasound machine.