A Graduate Level Course on Real-Time Medical Graphics

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1 Introduction

In this paper I am describing the outline of a graduate course on “Real-Time Medical Graphics” in a computer science curriculum. As interest for computer graphics using medical data has been increasing, we will see an increasing amount of similar courses. Therefore this paper takes a look at how such a course can be integrated with the current recommendations of computer graphics educators.

1.1 Motivations

Since the advent of programmable graphics cards, real-time volume rendering has given a boost to 3D volume graphics for medical applications. Real-time rendering, and therefore interactive analysis of medical data, is more suitable to the working pace (and therefore invoicing systems) of doctors than the previous non-interactive working style. Moreover, medical diagnoses will improve if thought processes and computer response time will harmonize.

For computer science students, interdisciplinary courses are a chance to broaden their knowledge into new disciplines, gain specific computing skills in a specific application area, and work with real-world (job like) constraints and co-workers.

Over the past few years, several Bachelor’s and Master’s theses have been developed at the University of Paderborn serving research or clinical interests at the Heart and Diabetes Centre of North Rhine Westphalia. Students were basing their knowledge on one undergraduate computer graphics course for the Bachelor thesis and one additional computer graphics course in case of a Master Thesis. Still, the basic knowledge each student needed to gather in order to qualify with their thesis was substantial. Therefore the need arouse to implement a course “Real-Time Medical Graphics” to provide students with core knowledge needed to perform well on today’s needs when working with medical volumetric data.

1.2 How this would fit into a Computing Curriculum

The course “Real-Time Medical Graphics” would ideally be a third computer graphics course, following a first undergraduate computer graphics course and a second undergraduate (or first graduate) advanced computer graphics course. While some schools offer a series of diverse courses on the topics of computer graphics and image processing, this paper is based on the (minimum) recommendations and requirements as outlined in the reports of the CGE (Computer Graphics Education) workshops (see references).

Previous CGE Workshops were held in Coimbre (1999), Bristol (2002), Hangzhou (2004) and Vienna (2006).

2 State of the Art in teaching medical graphics

Especially in the context of visualization, but also in the context of volume rendering, courses on medical graphics (e.g. visual medicine, volume rendering with medical data, etc.) are being taught at universities in the US and in Europe.

In this paper I have tried to develop core topics for such a course as it would fit in with the CGE workshop recommendations, thus using a curriculum outline that computer graphics educators are familiar with.

3 Course Outlines

Ideally, every computer science student will take at least one computer graphics course within their first three years of studying. In that case the content would be along the lines of the recommendations in CGE 2002 and 2004 – identified as “CG course I” here - and will allow him/her to “understand the processing implied by the graphics pipeline and polygon-based modeling with vertex attributes, including the following components:
* Transformations
* Modeling: primitives, surfaces, and scene graphs
* Viewing and projection
* Perception and colour models
* Lighting and shading
* Interaction, both event-driven and using selection
* Animation and time-dependent behaviour
* Texture mapping“.

A second undergraduate course or beginning graduate level course (called “CG course II” for our purposes) would include (according to slightly modified recommendations of CGE 2006)
* Any topics not covered in basic course (possibly animation and texture mapping)
* rendering: including visibility, rendering equation, ray tracing, anti-aliasing, possibly also environmental mapping, bump mapping, radiosity, volume rendering (incl. marching cubes algorithm)
* modeling: advance from lines to NURBS; include other modeling methods, such as constructive solid geometry, or other modeling issues, such as level of detail, or scene graphs

* computer-generated visualization (incl. presentation of multi-modal data)
* possibly include more animation issues
* GPU Programming: architecture of GPUs, rendering pipeline with GPU

There are many more issues to be covered in computer graphics. However, at this stage students are also ready for a third computer graphics course concentrating on medical graphics.

My recommended course outline for "Real-Time Medical Graphics" (course III) is as follows.

Mandatory topics

Medical data acquisition (and formats):
methods (e.g. MRT, CT); data values (e.g. dynamic ranges, Hounsfield scales); sampling; data formats (e.g. DICOM)

Preprocessing:
modify data for better visual identification (e.g. statistical analysis; point and neighbourhood processes); classification (e.g. 2d and 3d transfer functions); possibly segmentation, registration.

GPU Programming (may already be covered in course II): Rendering Pipeline with GPU; Vertex Processing; Fragment Processing; practical exercises are very important here;

GPU based volume rendering:
Ray casting; texture slicing methods; other methods specifically developed for the fragment processor (vertex processor).

Medical illustrations builds upon visualization knowledge in course II:
learn from "old" medical illustration techniques; detail and context (including smart hiding and uncovering); non-realistic lighting; other NPR techniques (e.g. strokes; points)

There might be different **optional topics** an educator decides on, such as work with time-dependent data; planning and training of operations; AR in medicine; animation in medicine (e.g. physically based tissue simulation)

An actual course with this mandatory outline ("Advanced Topics in Computer Graphics") was held at the University of Paderborn in the Fall/Winter semester 2006/2007 [AdvTop 2006].

Textbooks used for this course were [Gonzalez and Woods 2002] and [Engel et al. 2006]. I made extensive use of tutorials taught at IEEE Visualization, ACM Siggraph and Eurographics conferences (specifically "Illustrative Visualization", "Real-Time Volume Graphics" and "Visual Medicine") during the year of 2006. As an introduction to the OpenGL Shading language [Rost 2006] was used.

5 Summary

The need for courses on medical graphics, especially in real-time volume graphics, has increased. In order for students to develop skills sufficient to work on independent studies, or Bachelor's or Master's Theses, they will need 3 courses on computer graphics: course I teaches basic computer graphics according to the rendering pipeline; course II extends into advanced rendering and modeling algorithms and lays the foundation for computer-generated visualization; course III can then use these foundations to extend into medical graphics.

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References

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2004 Hangzhou:
http://www.siggraph.org/symposia/reports/Rep2004CGEworkshop.pdf
2006 Vienna:
http://education.siggraph.org/conferences/eurographics/2006/cge2006

Advanced Topics Course Website:
http://typo3.cs.uni-paderborn.de/fachgebiete/ag-domik/lehre/vorlesungen/ws0607-advanced-topics-in-computer-graphics.html

Textbooks for teaching course "Real-Time Medical Graphics"

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