Volume Rendering in Medical Applications:

We've got pretty images, what's left to do?

Organizer:
Michael Meissner (Viatronix)

Panelists:
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Karel Zuiderveld (Vital Images),
Vikram Simha (Terarecon),
Rainer Wegenkittl (Tiani),
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Motivation and Key Issues

After more than a decade of research in the field of volume graphics, the most groundbreaking volume rendering algorithms and the necessary ingredients for meaningful image synthesis are fairly well known. By ingredients, we mean filters, gradient estimation, illumination, classification, compositing schemes, etc. Substantial effort has been used in accelerating these algorithms to accomplish interactive or even real-time performance, taking advantage of CPU based acceleration techniques [1,2] or hardware acceleration using texture mapping or special purpose hardware [3,4]. By combining these bits and pieces, we are able to perform image synthesis at reasonably interactive frame-rates. What is the implication of this for the research community as well as for the application areas? Where are the "unknowns" or needs that still require research and in which direction are medical applications heading?

The panel, assembling experts from well-known medical visualization companies and research institutions, attempts to address these items by answering some of the following questions:

- Doctors and physicians are trained to gather information from the original 2D image slices originating from medical scanners. Is 3D image synthesis appropriate/necessary for medical application, and are there any benefits at all?

- What are the valuable research contributions that are used in 3D medical visualization systems and which issues are still unsolved?

- What are the research challenges for visualization in the medical field, e.g., computer guided surgery, diagnostic screening, treatment planning, etc.

- Where in medical applications could "non photo-realism" [5] be applied, and what value could it add?

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- Is the image quality as well as the frame-rate already acceptable and of clinical value, e.g., for medical analysis or medical diagnosis, and what are the current limitations?

- What are the shortcomings that prevent volume rendering from becoming an integral part of daily hospital procedures?

- What are the novel features of the latest CPUs, commodity graphics hardware, or other accelerators that are valuable to medical applications?

- Are medical applications more restricted by image processing and being accepted by insurance companies than by visualization?

1. POSITION STATEMENTS

1.1 Bill Lorensen

Fifteen years ago, Pixar demonstrated interactive volume rendering on their image computer. Yet, today, even though processor speed has grown dramatically and algorithms have improved, volume rendering is not routinely used in most hospitals. Early technology adopters continue to develop new applications and there has been some penetration into second level hospitals, but the number of radiologists that have accepted the technology is well below 50%.
Several factors limit the acceptance of volume rendering in clinical practice.

- Researchers typically have little connection with the eventual users of their technology. Volume rendering, (actually any 3D visualization applications) is seldom integrated into the radiologist's workflow.
- For the most part, user interfaces are complicated and not tied to the mainstays (2D display, filming, archiving) of the radiologists.
- Many techniques have associated intellectual property constraints that limit broad acceptance and use.

- 3D has not been integrated into medical training.

Finally, new applications of 3D image analysis may decrease the need for sophisticated volume presentation. For example, screening for colon cancer or lung nodules requires fast, robust detection techniques that do not (and cannot because of the shear volume of procedures) benefit from visualization.

1.2 Karel Zuiderveld

"Pretty 3D images" are still not often encountered in modern radiology departments. Radiologists are expert at reading 2D slices and 3D renderings do not necessarily provide additional diagnostic information. Unless generation of 3D images is trivial and fast, use of 3D technology will be the exception, not the rule.

The main success factor for advanced imaging workstations is not the ability for creating pretty 3D images; instead, workstations need to provide additional clinical utility. This means (among others) seamless integration into the diagnostic workflow, ease of use, functionality for obtaining quantitative measurements (such as calcification of coronary arteries, tumor volume, vessel stenosis, and brain perfusion) and of course, fast visualization - both in 2D and 3D.

The current crop of clinical workstations only partially achieve these goals. For increased clinical utility, we need to address visualization topics like

- The ability to efficiently process very large datasets. 300-500 slice datasets are currently routine and in the near future we need to process datasets exceeding 3000 slices; this poses some interesting challenges.
- Standarized ways for storing and exchanging 3D processed images and rendering/processing parameters/results in a heterogenous environment. Vendors currently use proprietary techniques for storage of advanced rendering parameters; unless these get standarized (like DICOM standarized display of 2D images), the use of 3D technology might not become widespread.
- Providing new series of (large) CT and MR datsets to the research community for evaluation and validation of image processing and visualization algorithms. The ”UNC head MR” dataset is not representative for modern clinical datasets anymore and has outlived it usefulness.

1.3 Rainer Wegenkittl

Medical visualization is a highly manifold topic with many different facets including visualization for teaching purposes, diagnostics, pathology delineation, intra-operative navigation, operation planning, operation simulation and many others. All of these applications make different demands on the visualization techniques used. Producing "pretty" images may be sufficient for some of these applications, but I think that there is still much room left for specific, applied improvements. Especially speed and simplicity of user interaction are all time favorite research topics since the amount of data produced by medical scanners increases drastically with every new modality released. Examinations with up to 1GB of data per study will get more and more common in the daily clinical routine. For such an amount of data it is not only important to have fast volume rendering techniques, but also the displayed content should attract the radiologists attention automatically to pathological structures. Here non photo realistic volume rendering algorithms in combination with CAD (computer aided diagnosis) methods could be the perfect supplement to standard volume rendering techniques. If such methods yield in a fast, reliable and easy interpretable visualization, these techniques will automatically become an integral part of daily hospital procedures. This is particularly important for diagnostic screening, where speed plays a crucial role. In my opinion there are two major aspects for future research: first, to get "pretty" images in a fast and intuitive way and second, to achieve the transition from "pretty" images to meaningful images.

1.4 Michael Meissner

Generating “pretty images” for medical applications is still a challenging task not only because of the large amount of data one has to deal – no data compression please - but also because the diverse demands of different medical applications. Generally, a typical medical datasets can easily reach or exceed 1 GB but the workflow in the medical field permits only a few minutes for each case. In such a short period of time, the application needs to give the user immediate insight for an accurate analysis of the findings, since most of the time is spent on annotating the findings and writing a report. Thus, the main challenges lie in the fast and almost automatic generation of descriptive high quality images.

Rendering speed is - and will remain - a classic topic, especially in applications that require high quality, perspective projections and high flexibility in the classification, shading, and compositing stage. More descriptive images could be accomplished by applying non-photo realistic rendering techniques to the classical volume rendering process. This has the potential to emphasize boundaries of structures that could otherwise be missed by the user. The challenge is to avoid costly over-sampling and to (automatically) find good parameters for the non photo realistic effects (protocols), which can be as hard as finding a good transfer function (automatically finding good multi-dimensional transfer functions is hard, too!). Finally, the almost automatic generation of images is extremely challenging because it is more than just presets: It goes beyond classic (volume) rendering. Automatic detection of organs and pathological abnormalities, as well as volumetric registration, are very difficult problems. Once available though, they could allow to mostly replace the image guided analysis by some sort of automated analysis in the form of plain numbers, providing a few snapshots of the potential false-positives or false-negatives for human interaction. However, this is probably not part of the near future, and until then we can worry about “fast,” “descriptive,” and “automatic selection of good parameters.”

2. BIOGRAPHICAL SKETCHES

2.1 Bill Lorensen

He is a Graphics Engineer in the Electronic Systems Laboratory at GE Research in Schenectady, NY. He has over 35 years of experience in computer graphics and software engineering. Bill is currently working on algorithms for 3D medical graphics and scientific visualization. He is a co-developer of marching cubes and dividing cubes, two popular isosurface extraction algorithms. His other interests include computer animation, color graphics systems for data presentation, and object-oriented software tools. Bill is the author or co-author of over 60 technical articles on topics ranging from finite element pre/postprocessing, 3D medical imaging, computer animation and object-oriented design. He is a co-author of "Object-Oriented Modeling and Design" published by Prentice Hall, 1991. He is also co-author with Will Schroeder and Ken Martin of the book "The Visualization Toolkit: An Object-Oriented Approach to 3D Graphics" published by Prentice Hall in November 1997. He gives frequent tutorials at the annual SIGGRAPH and IEEE Visualization conferences. Bill holds twenty-eight US Patents on medical and visualization algorithms. In 1991, he was named a Coolidge Fellow, the highest scientific honor at GE Research. Prior to joining GE in 1978, he was a Mathematician at the US Army Benet Weapons Laboratory where he worked on computer graphics software for structural analysis. He has a BS in Mathematics and an MS in Computer Science from Rensselaer Polytechnic Institute.

2.2 Karel Zuiderveld

He is the Director of Advanced Technologies at Vital Images in Plymouth, MN. He has over 17 years of experience in software engineering, medical imaging and computer graphics; since 1989 his main area of research has been medical volume visualization. For more than 12 years, Karel occupied offices in the Radiology department of Utrecht University Hospital; he is therefore very familiar with practical issues associated with introducing new technology into a clinical environment. Karel is (co)author of over 30 technical articles on topics ranging from Picture Archiving and Communication Systems, 2D image registration, volume rendering and software architecture; he holds three US patents. Karel has a M.Sc. in Electrical Engineering (1986, Univ. Twente, The Netherlands) and obtained his Ph.D. in 1995 from the Medical Faculty of Utrecht University, The Netherlands.

2.3 Vikram Simha

He is Director of Software Applications at Terarecon. He has over 12 years of experience in the field of 3D Graphics, specifically in volume rendering. Vikram is currently Director of Software Applications at Terarecon, responsible for AquariusNet, a true 3DPACS/network based volume rendering system. From 1994 until 1998 he was chief architect at Vital Images designing the Vitrea volume rendering engine. In 1998 he joined Mitsubishi Electric Research Laboratories (MERL) where he was working on the VolumePro real-time volume rendering system before this division got bought out by Terarecon. Vikram is co-author of 10 patents related to the VolumePro technology. He received his Master in Mechanical Engineerig from UT-Austin in 1993.

2.4 Rainer Wegenkittl

He is leading the research and 3D visualization departement at Tiani Medgraph AG and is working in the field of volume rendering and medical applications for over 10 years. Furthermore he is key researcher of the medical visualization group at VRVis (Research Center for Virtual Reality and Visualization) and published numerous papers. Rainer received his PhD in Mathematics at the Technical University of Vienna and has been responsible as project leader for the development of two medical 3D workstations at TIANI Medgraph AG. Currently his research is focusing on specialized volume rendering algorithms for specific clinical investigations as well as on using volume rendering techniques in an Augmented Reality environment to supply surgeons in the operating room.

2.5 Michael Meissner

He is a senior researcher and project leader at Viatronix Inc., NY and has over 10 years of experience in software engineering and computer graphics. He is currently working on interactive graphics algorithms for volume rendering in medical applications and on high quality volume rendering algorithms. He received his Phd in computer science from the university of Tuebingen in 2001. In the past he has been working on hardware acceleration for volume rendering using general purpose hardware as well as building special purpose hardware for high quality perspective ray casting (VIZARD II). Earlier on, he worked for the Cube project at the state university of Stony Brook which served as a base for the now commercially available VolumePro system. He has published numerous papers at international conferences, contributed to book publications, and is committee member at the SIGGRAPH/EUROGRAPHICS Graphics Hardware conference.

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APPENDIX: Color Images

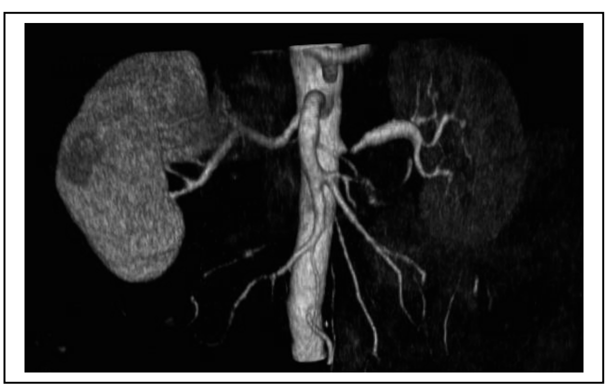

Figure 1 (from top to bottom and left to right): human hand showing bones and blood vessels (Tiani), renal stenosis (Vital Images), human skull and neck showing carotids (Tiani), aorta with stent and surrounding bones (Viatronix).