High Quality Real-Time Volume Rendering for Time Dependent Medical Data

Echtzeitverfahren zur Visualisierung zeitabhängiger medizinischer Volumendaten

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Purpose

Interactive visual analysis of a patients. anatomy by means of computer-generated 3D-imagery is crucial for many tasks in diagnosis and treatment planning. To support the radiologist with the possibility to inspect even small pathological structures in 3D, volume-visualization is becoming an increasingly important tool in a number of medi-cal procedures. Advances in imaging technology, on the other hand, are making available an unprecedented amount of data from intact organs. In particular, func-tional imaging devices can provide time-resolved sequences of physiological proc-esses at high resolution. Such scanning technology imposes significant requirements on the visualization system, and demands for new approaches amenable to real-time environments.

Methods

Texture-based volume rendering on PC graphics hardware, in general, has posi-tioned itself as a powerful tool for interactive visual analysis of reasonably sized data-sets. Slice-based approaches, which are solely used in practice, introduce distracting visual artifacts. Ray-casting, on the other hand, is known to produce superior image quality and allows for

the integration of various acceleration strategies, but it requires a substantial amount of computation. To combine the advantages of both texture-based approaches and ray-casting, we have developed a hardware-accelerated ray-caster that exploits the capabilities of recent graphics hardware. Additionally, it incor-porates effective acceleration strategies, i.e. early ray termination due to high opacity and empty-space skipping.
Nevertheless, to cope with the sheer amount of data produced by latest scanning technology, data-compression becomes mandatory in many clinical routines.
There-fore, we have developed a hierarchical compression scheme based on similarity measures. Although the process is lossy, it allows the user to flexibly trade between fidelity and compression ratio (up to 64:1). Our tool is capable of compressing arbi-trary input data, including multi-modal, vector-valued and time-resolved data, with a resolution of up to 16bit per data entry.
Our texture-based ray-caster has been extended towards the rendering of com-pressed data-sets. It directly renders the compressed bit-stream exploiting hardware-accelerated operations and texture memory bandwidth.

Results

The ray-casting approach avoids artifacts as they appear in slice-based approaches (see Figure 1). In combination with standard acceleration techniques, it considerably speeds up the rendering of typical medical data-sets including opaque boundary re-gions and empty areas (see Figure 2).
By incorporating our compression scheme into the ray-casting procedure, interactive renditions of Gigabyte data-sets at reasonable fidelity can be achieved (see Figure 3). Our approach enables the rendering of volumetric data-sets that would have not fit into texture memory. Streaming allows for simultaneous re-loading and rendering once the compressed stream is too large as to be processed as a whole.
On recent graphics cards, which are equipped with 256MB local memory, depending on user-selected fidelity data-sets of several Gigabytes can be directly rendered at interactive rates.

Conclusion

Our system exploits inexpensive commodity graphics hardware to generate images of the same visual quality as they are generated by software approaches, but at in-teractive rates. Moreover, the proposed compression scheme enables visual explora-tion of large-scale and even time-resolved data. Thus, it provides an effective means for the visual analysis of dynamic processes.

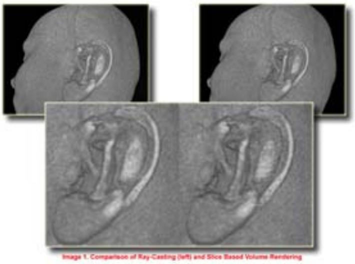

Image 1. Comparison of Ray-Casting (left) and Slice Based Volume Rendering

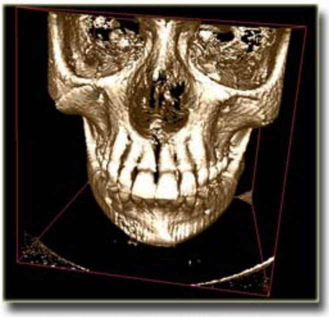

Image 2. Isosorface Rendering of a Human Scull
Empty Space Skipping and Early Ray Termination Result in a Speedup of 500%

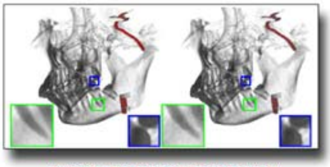

Image 3a. Rendering of the original (left) and 22:1 compressed (right) data set

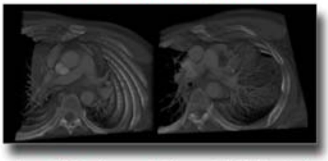

Image 3b. Two images of a time-resolved data set with 512^3 x 10 steps, 2.5 GB compressed to 60 MB rendered at 20 fps