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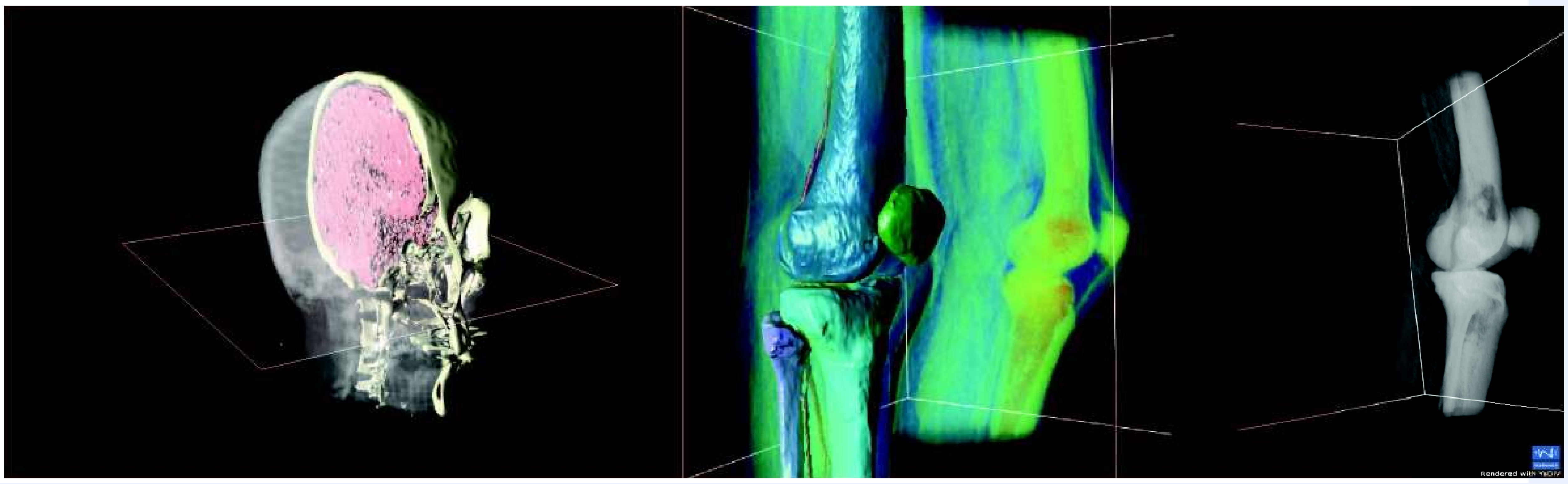
Virtual Reality System for 3D Shape Registration from Medical Data including a Haptic Interface and Fast, High Quality Visualization



With the evolution of medical scanning devices, especially Computer Tomography (CT) and Magnetic Resonance Tomography (MRT), 3D volume data is nowadays widely used in modern medicine. These modalities have become an integral part of the clinical practice. The resulting 3D images are used for diagnosis, therapy planning, interventional guidance, and follow-up.

Key Idea

We plan to develop a Virtual Reality (VR) system with a haptic interface to assemble fractured bone. A typical use case would be, for example, pre-surgical planning of an operation for a patient with a splintered fracture. Information on the shape of the bone fragments is obtained from CT images.
Enabling technologies will be:

- an interface to interactively perform a coarse alignment of the fragment models aided by collision detection;
- a high quality rendering for interactive visualization;
- automatic fine tuning of the fragment alignment, either based on their mechanical interfaces or based on a complete bone template.

The key idea is to develop a prototype for such a VR system, focusing on important haptic interaction features combined with a fast high quality rendering pipeline. The topic is also supported by Siemens with its R&D Center Siemens Corporate Research (SCR) in Princeton, NJ.
The proposed research aims to simplify the merging of Volume rendering and Surface rendering into a more unified rendering architecture. From a practical point of view, we also seek to reduce memory requirements, and structure the data to support progressive refinement for data streaming over networks. To gain clinical acceptance, new technologies need to empower the physician to achieve more with less effort, and they need to be presented with user-friendly interfaces. Compared to a simple mouse interface, haptics holds the promise of more intuitive interaction with the clinical data for surgery planning and fracture reduction, and we will explore its application in this domain by building a prototype system and collecting feedback from collaborating physicians.

Hardware

The prototype system planned to be developed will be implemented using hardware at the Welfenlab including:

- INCA 6D haptic input device;
- stereoscopic HD-Projection System;
- 3D workstation
- IBM BladeCenter H with currently 12 nodes, allowing complex simulations in real time;
- nVidia Tesla GPGPU cluster, allowing complex simulations in real time.

Details

The work will be focused on the interface between visualization and haptic interaction. Tools for prototyping and the necessary segmentation technology will be provided by Siemens Corporate Research.

Visualization Component
The prototype system will visualize the background scan data as well as the segmented bone fragments. Different visualization strategies will be analysed to guarantee visual quality as well as fast interactive reaction times for the real-time visualization during the haptic registration. In order to support the aforementioned goals an approach for voxel data of using multiple resolution levels forming a sparse octree with only non-empty blocks/cells storing strategy will be deeply reviewed. It can be expected this approach is compatible with Direct Volume Rendering (DVR) techniques used in Medical Imaging and is easy to integrate with DVR, enabling more efficient rendering algorithms of fused surface/volume rendering than previously used rendering techniques. Key criterion will be that the visualization is fast enough for the interactive registration/interaction. It has to be analyzed how the final implementation can make optimal use of a massive parallel cell architecture (IBM BladeCenter H) and General Purpose GPUs (nVidia Tesla) in the Welfenlab VR Research Lab.

Haptic Component
The haptic interface will support a convenient intuitive interaction. It will be possible to grasp a piece of bone and move it to a different location, including rotation (6 Degrees of Freedom, DOF). For this purpose, at least the contact mechanics between input device and bone segment will be simulated by some pseudo physical model assuring that geometrically correct positioning of objects will be easily possible. The next step will be to implement a fast collision detection (including some pseudo physical interaction) between the different segment pieces assisting the user controlled process of registration and to align different pieces of segments. This collision detection might also benefit from the sparse octree used for the visualization. Further research in this direction could be promising.

Evaluation
It is planned to evaluate the system with physicians of the Medizinische Hochschule Hannover (MHH). The physicians are collaborators of other research projects done jointly with members of the Welfenlab.

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