Success Story

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—Robert Sader, M.D., D.D.S., Ph.D.
Deputy Medical Director
Center of Advanced Cranio-Maxillo-Facial Surgery, Munich
Department for Reconstructive Surgery, Basel

Munich University of Technology: Superior Surgery through Visualization

The Challenge

- Improve planning for reconstructive surgery so that multiple operations can be combined into a single procedure
- Create an immersive environment for virtual surgery that combines multiple medical imaging data sets

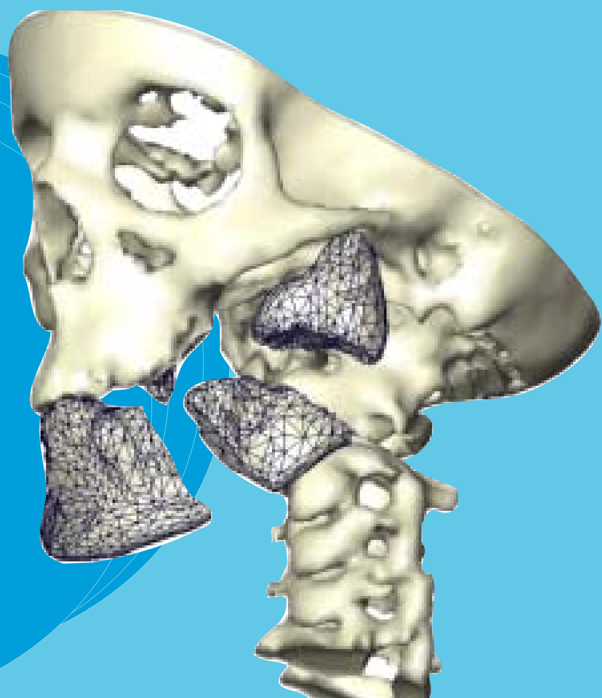
The SGI Solution

- Install a Silicon Graphics® Onyx2® visualization system driving projection and display systems
- Create an immersive surgical environment with virtual surgical tools
- Use combined medical imaging datasets of the patient to prepare a detailed surgical plan.

The Result

- Surgeons now perform reconstructive surgery armed with detailed, three-dimensional views of patients' physiologies.
- Surgeons can now achieve excellent results in a single operation rather than subject patients to up to six surgeries

In an examination room at the Munich University of Technology Hospital, a little girl is about to make a delightful discovery. Her parents have brought her to the hospital from her home in Belarus because she has mandibular hypoplasia—a severely underdeveloped jaw. More than her appearance was at stake; she was unable to chew her food properly, and the problem was getting worse. As the rest of her body continued to grow at a normal rate, her growing trachea was pressing against her tiny jaw, slowly cutting off her air supply. She was already breathing with difficulty, which made it hard for her to sleep. She would soon have required a tracheotomy. Today, however, she will see the results of her computer-assisted surgery. Powerful visualization software, running on an SGI® Onyx® family visualization supercomputer, has enabled her surgeon to enlarge her jaw, restore her ability to eat normally, eliminate the threat to her breathing, and give her the pretty face she was robbed of. She looks in the mirror and touches her face in wonder. She laughs with delight.



Creating a Virtual Surgery Facility

When the Center of Advanced Cranio-Maxillo-Facial Surgery was created by the Munich University of Technology in 2002 under the leadership of Professor Hans-Florian Zeilhofer, the emphasis was on techniques that could reduce the time required to plan and execute reconstructive surgery to the skull and jaw. One of the center's first technology acquisitions was a Silicon Graphics Onyx2 visualization system. Dr. Robert Sader, deputy medical director at the center, uses the technology to create three-dimensional simulations of the surgeries he is about to perform. The benefits to his patients are manifold: improved function, improved appearance, fewer operations, and less time spent in the hospital.

"If you do this kind of surgery in a conventional way, you must do it on an empirical basis," says Sader. "Because every case is different, you have to try a procedure, assess the results, and apply other procedures where necessary. All these patients used to require three, four, or five surgeries to get good results. Now we can use mathematical models to get the best possible result in a single operation. SGI Onyx technology has made it possible for us to do this."

Planning with Virtual Surgery

Sader's treatment of jaw malformations usually begins with CT scans. If associated soft-tissue problems are involved, Sader may also call for MRI or ultrasound scans of the patient. All this imaging data is merged into a single data set at the Center of Advanced European Studies and Research (caesar) in Bonn. Sader then prepares a three-dimensional simulation of

Example
Treatment planning of mandibular deficiency

4-year-old girl with hypoplastic mandible (left),
3D operation planning with a solid rapid prototyping model (center), and postoperative appearance (right) after callus distraction osteogenesis

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his surgical procedure using a virtual laboratory system written on top of Amira, a data visualization program initially written on the IRIX® platform by the Konrad-Zuse Center for Information Technology (ZIB) in Berlin.

The first step in Amira is segmentation of the patient's medical imaging data. Every voxel is classified as a specific tissue type: bone, muscle, fat, nerve tissue, or connective tissue. This is a semiautomated process controlled by the surgeon through Amira's three-dimensional interface. The result is a volume model (accurately representing the patient) that the surgeon can use to perform simulated surgery. The Amira simulation provides the full range of virtual surgical tools.

"Amira enables surgeons to simulate all basic operating-room techniques," says Christian Hege, head of the Department for Scientific Visualization at the Konrad-Zuse Center. "They can cut bone, or drill holes, or anything else they normally do." This is a faster and more flexible planning approach than the use of physical prototypes currently made from three-dimensional CT data. Surgeons can try a variety of techniques without touching the patient. Formerly, individual data-processing steps like artifact elimination, segmentation, three-dimensional modeling, and virtual reality simulation were performed separately by specialists who had not examined the patient—a costly, time-consuming process with questionable results. SGI® visualization supercomputing technology combines these steps into a single rapid process that the surgeon can easily handle.

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The treatment for mandibular hypoplasia involves cutting or breaking the bone in critical places so that natural regenerative processes can fill in the gaps and expand the jaw—a procedure called callus distraction osteogenesis. In all such cases, the patient's final appearance is of great importance because of its lifelong impact on social contacts. Amira gives surgeons a tool that simulates the patient's appearance after surgery. More advanced tools, now in development, will combine CT and MRI data to mimic the patient's expressions by activating virtual muscles.

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—Christian Hege, Head of the Scientific Visualization Department, Konrad-Zuse Center

The Heart of the Virtual Operation: SGI Technology
SGI visualization technology has accelerated and streamlined Sader's surgical routine. During his planning session, he sits and works in the normal position for surgery using a surgical simulation system. He uses Amira's virtual tools to simulate surgery on a three-dimensional model of the patient's anatomy, generated by a Silicon Graphics Onyx2 system.

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The Future: Remote Visualization
Sader and his chief, Professor Hans-Florian Zeilhofer, recently assumed posts at a new facility at the University of Basel. Sader has homes in both Munich and Basel, working in each city on alternate weeks. When working in Basel, Sader uses Visual Area Networking (VAN) to access the Onyx family system in Munich to perform research and clinical work.

Sader is also an assistant professor at the university, responsible for clinical research in scientific visualization, scientific networking, and telecollaboration, among other specialties. When in Munich, he does visualization research using a four-foot-by-six-foot rear projected immersive environment developed by the Konrad-Zuse Center in Berlin. By using a six-degrees-of-freedom stylus and the immersive virtual reality capabilities of Amira, he is able to visualize patient data from the inside out and devise surgical procedures that would be difficult to envision with standard keyboard and mouse interfaces.

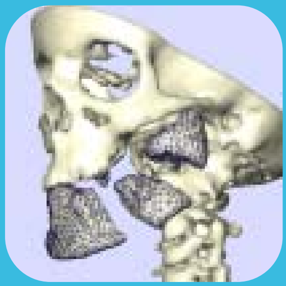
As part of his work, Sader also needs to visualize simulation results generated on an SGI Onyx 3800 visualization system located in the Konrad-Zuse Center in Berlin. The Konrad-Zuse Center is using SGI Visual Area Networking (VAN) solutions across the German Academic Research Network (DFN-Verein) to enable Sader and other researchers to view high-resolution 3D volume visualizations and other complex scientific results without traveling to Berlin or copying massive data sets to their home institutions. VAN solutions allow remote users to connect over standard networks to interactively visualize results and to collaborate with other professionals at widely separated locations.

Sader takes advantage of VAN solutions to interact at a distance with visualizations created at the Konrad-Zuse Center that combine multiple imaging modalities. VAN solutions allow the remote visualizations to be accessed on either low-cost desktop systems or in the Munich University of Technology's immersive environment where Sader views them to achieve greater insight.

Example
Treatment planning of mandibular deficiency

9-year-old boy with mandibular hypoplasia

Multimodal data set including bony and soft tissue information

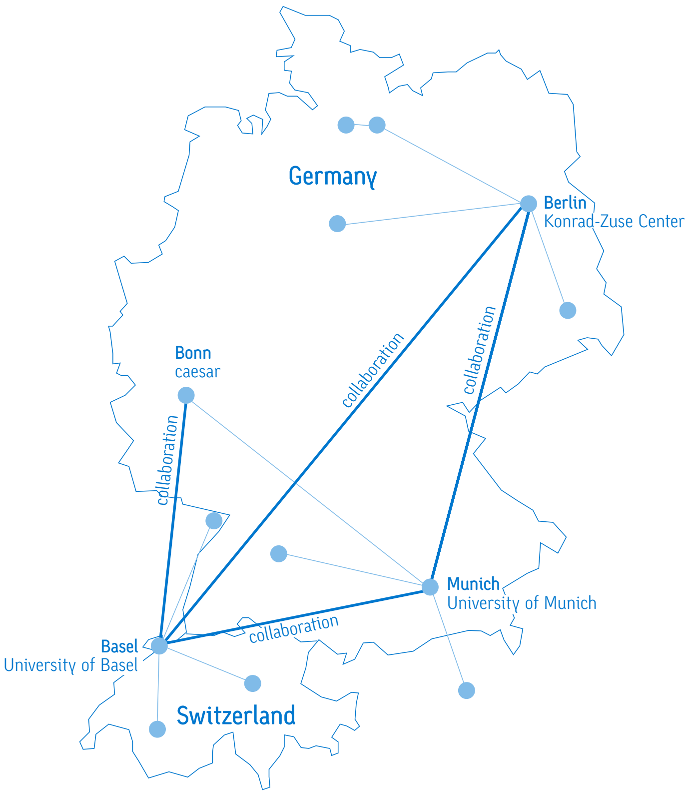


FE-Modelling of bone, operation simulation in a virtual environment

Postoperative soft-tissue prediction based on biomechanical modelling

Before Before After

Sader and Zeilhofer are already planning the installation of SGI Onyx family visualization technology in Basel. They will continue to work on the application of visualization and telecommunications technology to bring faster, more effective treatment to their patients.



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Corporate Office
1600 Amphitheatre Pkwy.
Mountain View, CA 94043
(650) 960-1980
www.sgi.com

North America 1(800) 800-7441
Latin America 1(650) 933-4637
Europe (44) 118.925.75.00
Japan (81) 3.5488.1811
Asia Pacific 65-6771-0290

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