CASE STUDY
INSTITUTE OF MEDICAL PHYSICS (IMP)

»THE FUJITSU CELSIUS R670 SYSTEM SUPPORTS US IN OUR DAILY RESEARCH TASKS, FOR EXAMPLE WHEN IT COMES TO PROMPT PUBLICATION OF RESULTS, SO THAT WE AND OUR INDUSTRY PARTNERS CAN ALWAYS BE ONE STEP AHEAD OF THE COMPETITION.«

Prof. Dr. Marc Kachelrieß, Institute of Medical Physics

THE CUSTOMER

Institute of Medical Physics (IMP) at the Friedrich Alexander University in Erlangen.
www.imp.uni-erlangen.de

THE PROJECT

Supporting the further development of processes for optimizing the quality of images from computed tomography (CT) scanning through the use of high-performance workstations.

THE SOLUTION

CELSIUS R670 workstation from Fujitsu.

IMP ENHANCES THE 3D RECONSTRUCTION OF CT IMAGES

The Institute of Medical Physics (IMP) at the Friedrich Alexander University in Erlangen, Germany, specializes in developing processes and enhancing diagnostic imaging technology for the medical sector. IMP engages in research related to various medical imaging topics such as cardiac CT imaging, dose assessment and reduction, as well as image optimization and artifact reduction in x-ray-based computed tomography (CT) to name only a few.

For example, to improve image quality and reduce artifacts, IMP develops algorithms for the rendering of coronary vessels having cross sections that are only a few millimeters or less in size. Very complex mathematical processes are then used to reconstruct these cross-sectional CT images into 3D images. The objective is to use real-time computation for reconstructions having very high image quality and thus continue to improve diagnostic imaging techniques.

IMP works in close partnership with Fujitsu because, economically speaking, real-time image reconstruction, parallel to CT scanning, needs to be performed using lower-cost industry standard computer technology.

IMP IMPROVES 3D IMAGE QUALITY IN REAL TIME WITH THE CELSIUS R670

To develop and test highly sophisticated and iterative processes quickly and efficiently, the medical imaging team headed by Prof. Dr. Marc Kachelrieß relies on the CELSIUS R670 workstation from Fujitsu. The CELSIUS R670 used by IMP is based on the Intel® Nehalem processor architecture. The system also features NVIDIA® Tesla™ C1060 computing processor cards to achieve additional high performance.

»A FAST SYSTEM WITH A HUGE AMOUNT OF MAIN MEMORY ENABLES US TO ACHIEVE OPTIMAL RESULTS. AND THERE IS NO NEED FOR TRAINING OR ADJUSTMENT IF THE TEAM MEMBER IS ALREADY FAMILIAR WITH THE PLATFORM. SUCH A SYSTEM DELIVERS REAL VALUE TO THE INSTITUTE OF MEDICAL PHYSICS.«

Prof. Dr. Marc Kachelrieß, Institute of Medical Physics

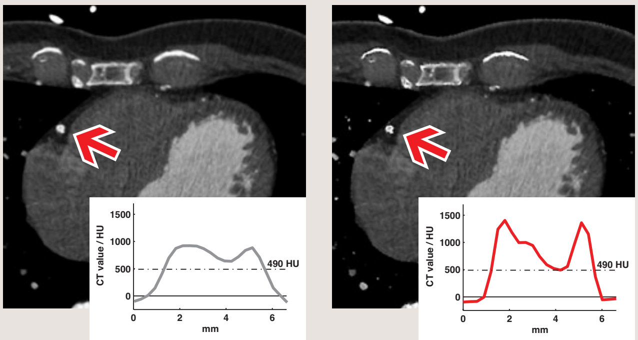
PROJECT DEFINITION

Examining patients with computed tomography (CT) is one of the most important diagnostic imaging techniques and has thus become a standard medical diagnostic procedure. The number of CT scans and the economic significance of this technique are steadily increasing, as are the demands for better image quality and dose efficiency. Remarkable progress has been made in CT technology in terms of hardware through improvements in x-ray technology and detectors, while innovative software developments have contributed to new computational methods for image rendering, also known as image reconstruction.

The medical imaging team at the Institute of Medical Physics (IMP) focuses on the development of algorithms for improving image quality and reducing artifacts in CT. Based on sophisticated computations, their goal is to achieve the best possible images at a defined patient dose or, as an alternative, to achieve a defined image quality at the lowest possible patient dose. During the early years of clinical CT mostly analytic processes were developed and implemented, whereas today the image quality can be improved even more, but often only on the basis of very complex methodologies. This usually requires the correct modeling of the physical quantifying process. However, algorithms having better physical modeling are frequently based on an iterative approach and unfortunately thus have the disadvantage of being much more complex in terms of computations than the algorithms currently used in clinical environments today.

When it comes to the improvements in image quality than can be expected, the algorithms are of special importance for the rendering of extremely small structures. For example, CT scanning to render images of the human heart is a great challenge. In cardiac CT imaging the coronary vessels that are examined have a cross section of only a few millimeters or less, meaning that they are so small that it is just barely possible to render them with CT technology. Many interesting structures can even be smaller than the width of a sampling x-ray beam. Therefore, special imaging algorithms can be quite helpful when examining very minute constrictions (stenoses) in blood vessels. Cases that cannot be conclusively diagnosed with CT often require that patients undergo invasive coronary angiography procedures that can involve some risk.

The development of a new iterative reconstruction algorithm requires, in addition to the derivation and implementation of the process, an extremely high number of reconstructions in order to determine the optimal parameters, to analyze typical patient data and thus to characterize the algorithm in order to test it in terms of stability and capability. When developing an algorithm, it is important and even decisive that this be done as quickly as possible so that the results are available in just a few seconds or minutes rather than within hours, days or weeks. Only then can the results flow directly into the further development and only then can the time needed for completion be held at an acceptable level.



COMPARISON OF IMAGE QUALITY

This image of a heart clearly shows the advantages of using new algorithms to achieve improved image quality. Example: Rendering of a stent (see red arrow) with a diameter of 2 mm. The image on the left represents the current image quality provided by the manufacturer today. The quality of the image on the right is much better thanks to the use of sophisticated filter and reconstruction techniques.

»WITH THE CELSIUS R670 WE HAVE OUR RESULTS MUCH FASTER, SO WE CAN EITHER RECONSTRUCT IN REAL TIME, OR WE CAN INVESTIGATE NEW AND ESPECIALLY COMPUTE-INTENSIVE ALGORITHMS.«

Prof. Dr. Marc Kachelrieß, Institute of Medical Physics

THE SOLUTION

To develop and test highly sophisticated and iterative processes quickly and efficiently, the medical imaging team headed by Prof. Dr. Marc Kachelrieß relies on the CELSIUS R670 workstation from Fujitsu. Thanks to the new platform computational results are available much faster. Prof. Dr. Marc Kachelrieß adds that the high-performance spiral CT reconstruction developed jointly by IMP and RayConStruct GmbH delivers a performance of 55 billion updates per second on the CELSIUS R670 (Steckmann, S.; Knaup, M.; Kachelrieß, M.: High performance cone-beam spiral back projection with voxel-specific weighting. In: Phys. Med. Biol. 54 (2009), S. 3691–3708). That is the equivalent of a reconstruction rate of more than 180 layers per second. With this combination of hardware and software it is possible to reconstruct in real time or to investigate new, especially compute-intensive algorithms.

IMP DRAMATICALLY IMPROVES PERFORMANCE WITH CELSIUS

IMP develops and tests new algorithms with the CELSIUS R670 workstation from Fujitsu. NVIDIA® Tesla™ C1060 computing processor cards were also tested to achieve additional high performance.

For the back projection 720 projections each having 512 x 512 pixels were projected into a volume of 512 x 512 x 512. The problem thus had a dimension (720 x 512 x 512 x 512)/(1024 x 1024 x 1024) = 90 Giga Updates (GU). The performance is measured in Giga Updates Per Second (GUPS). The zoom factor was set at 50%, i.e. all voxels in the volume can also be reconstructed.

The perspective, spiral and parallel geometries were examined. As expected, results showed that the GPU (Graphics Processor Unit) was better suited for the perspective geometry, whereas the CPU was better suited for the parallel geometry. Since the eight CPU cores deliver performance that is comparable to that delivered by the two Tesla cards for the spiral and parallel geometry, there is a great advantage in running the computations from the CPUs and GPUs in parallel. When it comes to the perspective geometry, however, running the CPUs along with the Tesla cards makes little difference in terms of added performance.

PERSPECTIVE GEOMETRY

PROCESSORS	SPEED (GUPS)	HARDWARE
CPU	9,7	8 CPU Cores
1 GPU	26,4	1 Tesla C1060 Card
2 GPU	47,9	2 Tesla C1060 Cards
CPU + 1 GPU	32,6	8 CPU Cores + 1 Tesla C1060 Card
CPU + 2 GPU	50,7	8 CPU Cores + 2 Tesla C1060 Cards

SPIRAL GEOMETRY, PARALLEL GEOMETRY

PROCESSORS	SPEED (GUPS)	HARDWARE
CPU	55,7	8 CPU Cores
1 GPU	31,7	1 Tesla C1060 Card
2 GPU	56,3	2 Tesla C1060 Cards
CPU + 1 GPU	76,4	8 CPU Cores + 1 Tesla C1060 Card
CPU + 2 GPU	92,1	8 CPU Cores + 2 Tesla C1060 Cards

GUPS: Giga-Updates/Second

BENEFITS FOR THE CUSTOMER

- **Faster:** IMP improves image quality by reconstructing CT data in real time
- **No need for training or adjustment:** IMP team members can focus on enhancing their experience in CPU-based algorithm development
- **Morecost effective:** IMP offers its industry partners a cost-effective solution for optimizing quality and productivity in computed tomography

HARDWARE, SOFTWARE, SERVICES

- CELSIUS R670
- Intel® Xeon® Multi-Core-Processor
- NVIDIA® Tesla™ C1060 Computing Processor Cards

CELSIUS IS THE IDEAL PLATFORM FOR COMPLEX COMPUTATIONS

The decision to migrate to a new platform was not difficult for IMP because the all programs used by IMP could be run on the new workstation – without any difficulty or need for adjustments. IMP team members can immediately start working with the system and enhance their experience to achieve higher levels of expertise in CPU-based algorithm development. Special architectures, for example graphic arithmetical and logic units, are not suited as general scientific working environments because they require time for employee training and adjustment, and due to the fact that not all algorithms can easily be converted to such architectures. That is why the CPU-based R670 platform is the ideal solution for efficient scientific research and for routine CT image reconstruction algorithms.

OPTIMAL SUPPORT EVERY DAY

Prof. Dr. Marc Kachelrieß, head of the medical imaging team, is very satisfied with the results IMP has achieved in partnership with Fujitsu:

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