Improving Access to Image Rendering: Integration of Hospital-wide 3D Image Rendering with PACS and the Electronic Patient Record

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Introduction

With the introduction of spiral CT in the early 1990s, radiologists switched from classic film-based review of CT examinations to review on workstations. Viewing habits subsequently changed from an image- by image-based analysis to a more organ-based analysis, using a stack view of CT images. With the introduction of multislice CT (MSCT) in the late 1990s, CT scanners became capable of much higher spatial and temporal resolutions. Most departments have adapted their examination protocols to obtain thinner axial slices (typically 2 or 3 mm for body examinations) for the now standard stack view.

However, it does not make much sense to use the highest spatial resolutions (i.e. thinnest slices) that modern MSCT scanners are capable of delivering for routine diagnosis in the stack view mode: the number of images generated is simply too high when working at submillimeter isotropic resolutions. Full exploitation of these high-resolution volume data sets is possible with the help of tools combining 3D volume rendering (VR) and multiplanar 2D viewing (such as slabs or multiplanar reconstructions of varied thickness). To use these tools effectively, the workstation must be able to calculate and display 3D images from the volume data set in real time, otherwise the user will not easily obtain the desired results. Special examinations such as vessel analysis or cardiac imaging take advantage of specialized analytic tools (e.g. vessel tracking).

Specialized and expensive workstations for 3D viewing, including volume rendering, have been on the market for several years now, built by a variety of manufacturers. Most workstations on the market providing real-time volume rendering take advantage of TeraRecon's specialized volume-rendering boards, the "VolumePro" board series. These boards keep the complete volumetric data set comprising several thousands of slices in memory, and perform volume rendering in real time.

The inconvenience of these specialized workstations is that their computing power is available only at the workstation. Given their high cost, even large hospitals typically have only a limited number of VR workstations. Usually, radiologists render a few significant 3D views and store them within the PACS for access from the wards or during radiological-clinical conferences. Unfortunately, this fails to take advantage of the interactivity provided by volume rendering at the workstation.

While development of specialized workstations is ongoing and ergonomics of these workstations are still improving, the challenge today is to provide interactivity of VR to the clinical wards and conferences at reasonable costs. Combining a powerful server with streaming technology allows the delivery of high performance volume rendering to "thin clients", available on most wards. After a short description of this system, we discuss different ways to integrate the server with a PACS and the electronic patient record (EPR).

Methods

Streaming technology

The basic idea of streaming technology is very simple. Instead of performing complex and resource-intensive calculations at the user's front-end computer, calculations are performed by a back-end, high-performance computer, and results are delivered to the user as a continuous stream of images in real time. User commands input at the front-end (thin client) are sent to and executed at the back-end server, and the resulting images are sent back to the user. Intelligent use of this technology allows a relatively thin front-end client (typically a standard PC) to perform as a high-end 3D rendering server.

AquariusNET server system

The AquariusNET system consists of a server equipped with one or several VolumePro boards integrated into the network of the radiology department, and thin client software installed on PCs throughout the hospital. The client software is easily installed from the server once it is up and running. Workgroups (corresponding to different departments of the hospital) with individual access rights can be defined on the server. The software performs all typical 3D reconstructions, including Maximum Intensity Projections (MIP), Multiplanar Reformation (MPR) and Volume Rendering, and even image fusion from different sources such as PET and CT. The client software has a highly user-friendly interface, while 3D processing occurs within the server. Results of 3D processing (i.e. the 3D images) are streamed to the client and displayed in real time.

The server hardware is capable of reconstructing 3D volume-rendered images in real time from data sets containing up to 27,000 images. Such processing power allows the service of many clients simultaneously. Typically, performance is sufficient for the real-time processing of up to 10 or 15 data sets of high-resolution CT examinations (based on 2000 to 3000 images per examination).

Integration of the AquariusNET server system

Integration of the AquariusNET system into the department's and/or hospital's environment can be achieved at different levels, depending on whether a PACS exists within the department, or if there is an enterprise-wide PACS or even a PACS integrated into a hospital-wide electronic patient record. In the following paragraphs, we visit several different scenarios, going from the simplest to the most complex (Figure 2). We then will describe the integration of AquariusNET at Freiburg University Hospital.

Stand-alone use

In this scenario, all volume data sets are sent directly from the acquisition source to the AquariusNET server. Examinations are held by the system until the server's hard disks are full. The AquariusNET server can handle several terabytes of RAID hard disks, making it possible to hold several months' worth of data even in larger institutions. While not explicitly designed as a PACS, (which would require secure, long-term storage of all data), the AquariusNET system can be used as an image data distributor for the department and hospital. In addition, the system provides its own viewing software, including classical 2D viewing tools as well as 3D volume rendering.

In this context, it is important that the AquariusNET system offer an advanced access control system. Access to studies can be limited to certain users or user groups using password protection. For instance, image access for trauma surgeons can be limited to examinations that have been requested by the trauma department. The system can even allow secure access to the data over Virtual Private Networks, i.e. from non-secure networks outside the hospital, allowing consultation with outside specialists at larger centers.

Use of the server in parallel to a PACS

Typically, a PACS is already running and used for long-term storage when an AquariusNET system is installed. The AquariusNET system is then mainly intended to provide better 3D functionality than that of the PACS, and/or to extend 3D functionality to more computers. The AquariusNET system can run in parallel with an existing PACS. It is possible to integrate the viewer with the PACS interface, allowing the launch of AquariusNET from within the PACS.

Because of the increased availability and ease of 3D viewing afforded by running the AquariusNET system in parallel with the PACS, numerous slice images are often generated solely for the calculation of 3D images and are never viewed in slice format. Therefore, for all 3D-imaging studies, we calculate an additional thin-slice data set with a very smooth kernel. Although it is possible to store these additional images in the PACS, our experience is that 3D calculations are nearly always performed within the first days after an examination, so long-term storage of additional thin-slice images within the PACS may not be necessary.

Using AquariusNET as intermediate server

The AquariusNET system can also act as long-term storage. In this scenario, all "classic" sectional images are sent from the imaging source directly to the PACS, and only soft-kernel, thin-slice images are sent to the AquariusNET system for 3D image calculation. The resulting 3D images are then sent to the PACS for documentation and permanent storage. The thin-slice, soft-kernel data set is deleted once the storage of the server system reaches a high watermark by a "last-recently-used" or "first-in-first-out" mechanism. The total hard disk-space needed on the AquariusNET server has to be assessed in order to keep data produced by the department for the desired amount of time. In our department, we think a three-month storage capacity is sufficient.

Integration with the Electronic Patient Record

Image distribution respecting access rights and data protection is possible by utilizing user groups and password protection provided by the AquariusNET system. However, user groups and access rights must be entered into the AquariusNET server. In larger hospitals, a large database of users and access rights must be maintained. In institutions with an electronic patient record, such a database usually already exists and is either an integral part of the EPR or used by the EPR. In this case, for image data access from outside the radiology department, it is possible to start the AquariusNET client from within the EPR by calling the client with the DICOM study instance UID of the examination to be rendered. Access to patient data is thus controlled by the EPR, and there is no need to maintain a user database within the AquariusNET system.

Results

Installation at Freiburg University Hospital

As in most departments, we have experienced a continuous increase of the image data volume produced. Most of this increase is due to the introduction of modern, multislice CT scanners (Figure 1). The newest generation of scanners (Siemens Sensation 16 and 64) allows us to obtain isotropic imaging with submillimeter voxels. Our motivation for the introduction of the TeraRecon system was (1) to enhance the 3D solutions that had been implemented on some of our PACS workstations (TIANI, now AGFA) and (2) to make 3D processing available on every workstation in the radiology department and on selected workstations in other departments.

Our installation consists of both a TeraRecon AquariusNET server and an Aquarius Workstation. The workstation is located near one of our CT scanners, where most surgical and CT-angiographic studies are performed. This guarantees constant 3D-processing power at the point where it is needed most and sometimes immediately.

Thin-slice, soft-kernel data sets are routinely calculated for all CT-angiographic studies (Figure 3) and

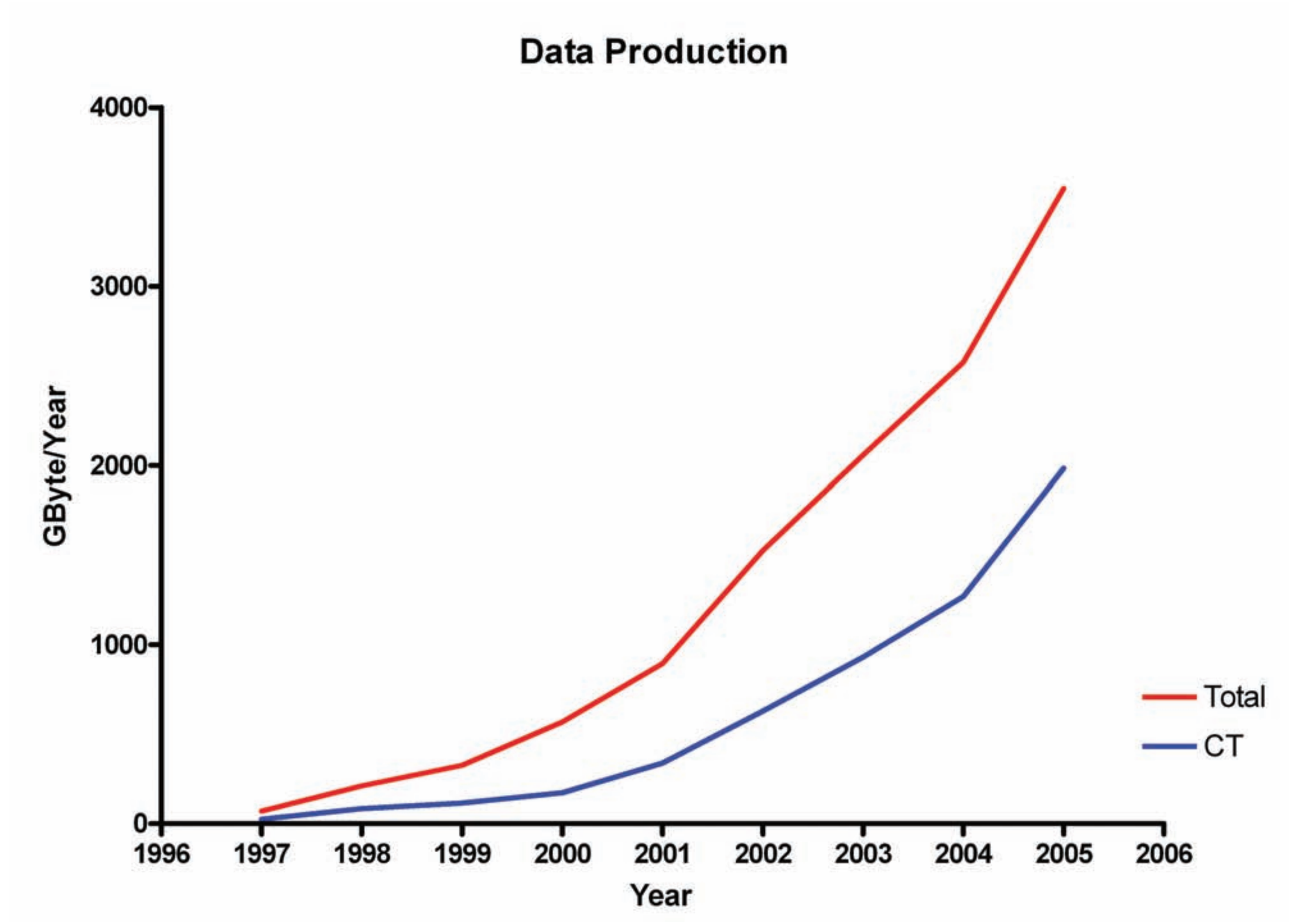

Figure 1: Data production at Freiburg University Hospital since the introduction of PACS. There is a continuous increase in data production. Most of this increase is due to the increasing number of images per study and the higher number of examinations obtained with modern multislice CT-scanners. The additional calculation of thin-slice, soft-kernel data sets needed for high-quality 3D processing will further enhance this trend. In most cases, these data sets are considered an intermediate step towards the calculation of 3D images. Using the AquariusNET server as a medium-term storage for these data sets might reduce the long-term storage needs if there is no legal requirement to have a long-term storage of all images that have been calculated (depending on local regulations).

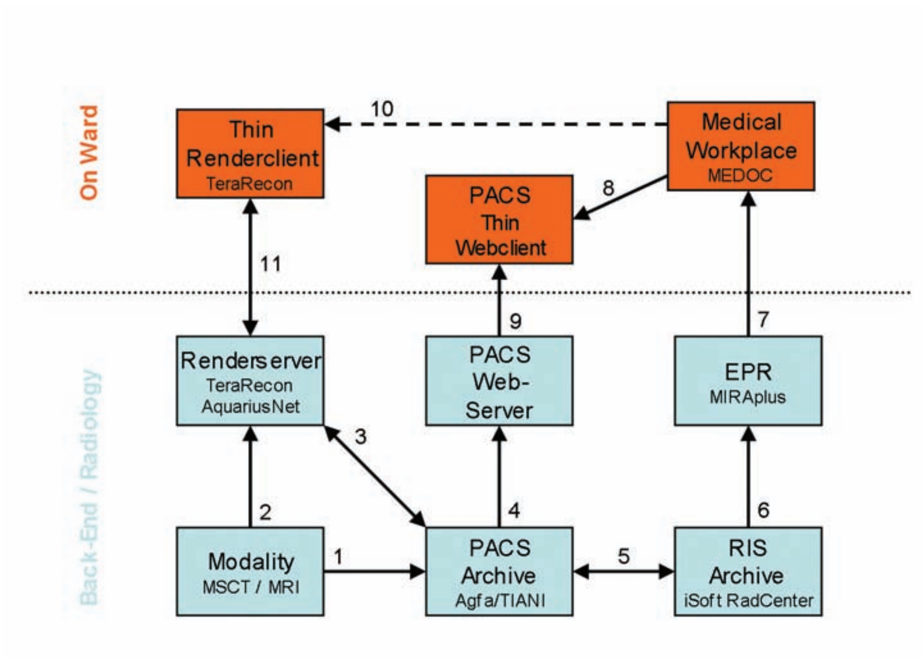

Figure 2: Integration of the TeraRecon AquariusNET server system with the PACS and EPR at Freiburg University Hospital. Modality sends axial images to the PACS archive (1). Thin-slice, soft-kernel images necessary for high-quality 3D imaging are either sent directly to the render server (2) or to the PACS (1). DICOM study instance UID is communicated between RIS and PACS (5), and transmitted to the Electronic Patient Record (EPR) (6). The EPR is accessed from the medical workplace (7), the user being authenticated with a password. The EPR contains a mechanism controlling access rights to all patient data. Once access is granted to the radiology report stored in the EPR, the user can call the PACS web client (7) which will retrieve the images corresponding to the study instance UID from the PACS web server (9) which accesses the PACS archive (4). In the future, we plan for a similar integration of the AquariusNET thin-client with the EPR. During the call of the thin-client from the EPR, the study instance UID will be transmitted (10) and allow access to the corresponding data set (11).

for all trauma patients (Figure 4), and at the radiologist's request for all other studies. At the time of writing, these data sets are still sent to the PACS archive, from where they can be retrieved to the workstation and the server within a few seconds. For the future, we have planned to extend the RAID capacity of our AquariusNET server to 4 TB, allowing us to store all thin-slice, soft-kernel data sets on the server for at least three months post-examination.

The AquariusNET server is not yet integrated with our EPR. While the call from the thin-client technically would be quite simple (the same calling procedure as with our PACS web viewer), we need to integrate the call somewhere in the interface of our EPR-client or the interface of the PACS web viewer. We do not want to replace the PACS web viewer with the AquariusNET client, but would like to be able to call either client, depending on the user's needs.

Conclusion

The AquariusNET system brings high-end 3D processing to the entire hospital. Costs are reasonable when compared to traditional 3D workstations. Access to 3D rendering is improved not only within the Department of Radiology, but also for other disciplines, such as orthopedics and trauma surgery, vascular surgery and neurosurgery. The capability to link AquariusNET with PACS and the Electronic Patient Record allows us to integrate AquariusNET seamlessly into the clinical workflow.

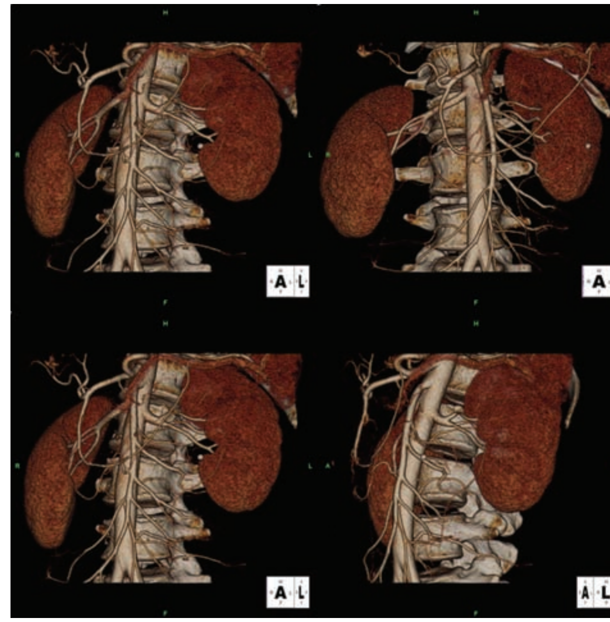

Figure 3: Example of volume rendering (VR) of a CT-angiography performed as routine work-up for donors before renal transplantation. In addition to the standard axial images, both thick slice MIP (25 mm thickness with an increment of 1 mm, not shown here) and 3D VR images are calculated to show exact anatomy of renal arteries. While radiologists rely mainly on thick-slice MIPs for interpretation, surgeons prefer the VR view since it allows them to have a quick overview of the anatomical situation.

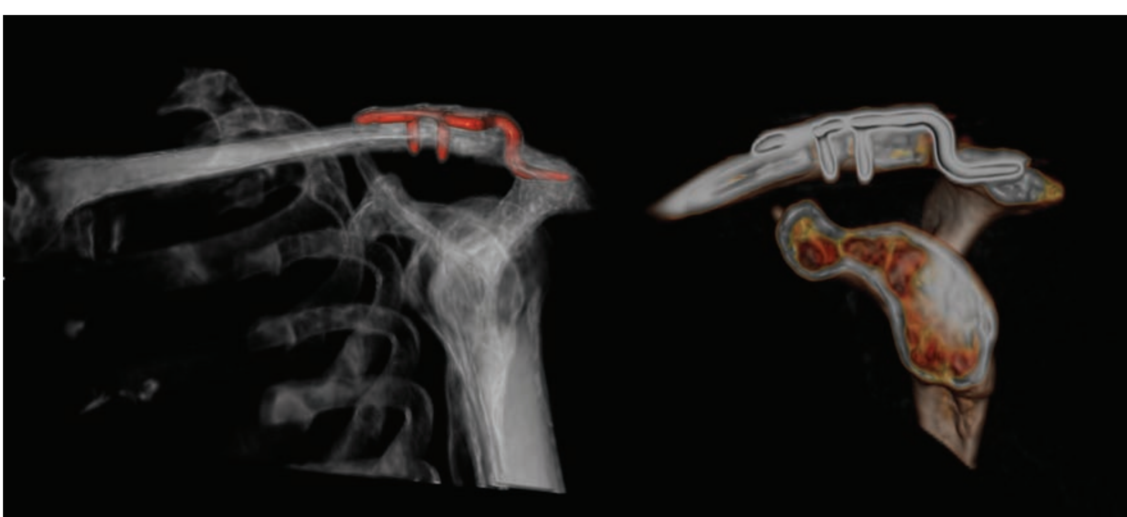

Figure 4: Visualization of a hook-plate using different volume-rendering techniques. In this case, axial images did not reveal whether the hook was located below the acromion or within it. VR-images clearly demonstrated that the hook was placed within the acromion. Left: VR image, with metallic structures in red and bone in gray. Right: paracoronal slab through a more conventional VR image, with metal in gray and bone in red/gray.