Tentative Results in Focus-Based Medical Volume Visualization

Timo Ropinski, Frank Steinicke, and Klaus Hinrichs

Institut für Informatik, Westfälische Wilhelms-Universität Münster, Germany
ropinski@math.uni-muenster.de, fsteini@math.uni-muenster.de,
khh@uni-muenster.de

Abstract. We describe our current work on volume visualization techniques developed with the aim to enhance interactive exploration of medical datasets. Volumetric lenses can be applied to a volume dataset to interactively focus regions of interest within these datasets. During rendering the parts of a volume dataset intersecting the lens, which is defined by a convex 3D shape, are rendered using a different visual appearance. The lenses proposed allow to apply non-photorealistic rendering techniques interactively to aid comprehension for medical diagnosis.

1 Introduction

Visualization of medical volume datasets provides an essential diagnosis tool for medical applications. With the availability of powerful graphics hardware it became even more and more important over the last years. Today, medical volume rendering techniques ease health professionals' work during medical diagnosis. Due to the rapid development of high precision medical imaging techniques, e.g., CT, MRI and PET, the spatial resolution and with it the amount and complexity of data increases. Therefore medical diagnoses become more and more challenging. Since in most medical applications the region of interest, e.g., tumors or arterial structures, is small in comparison to the overall dataset, mechanisms are needed which support health professionals to focus on these regions. Furthermore, certain features and properties of anatomical tissues are essential for the diagnosis and need to be preserved, e.g., size and shape of pathologies as well as their spatial position and vicinity to other anatomical structures. Therefore, it is important that visualization techniques consider these demands and aid comprehension by visualizing contextual structures and object relations.

We exploit an algorithm that allows to determine regions of interest within a dataset interactively, to which a different visual appearance is applied [3]. The region of interest, sometimes referred to as lens, is given by an arbitrary convex shape and a visual appearance associated with it. To be applicable to volume data we have extended the algorithm. Thus, volume data intersecting the lens can be emphasized using arbitrary rendering techniques, e.g., edge-enhancement, isosurface rendering etc.

A. Butz et al. (Eds.): SG 2005, LNCS 3638, pp. 218–221, 2005.

2 Interactive Focussing Using Focus and Context Visualization

Medical visualization can be improved by using NPR techniques [2]. The lens described in this section has been developed with the goal to provide the user insights into datasets by still preserving spatial cues, and to support the user to determine the spatial relationship to the rest of the dataset during exploration. In Figure 1 (right) a lens is applied to a CT scan of a human skull, i.e., the skull is rendered using isosurface shading outside the region of interest while special rendering techniques are applied within the region of interest, whereas shaded isosurface rendering with no lens applied is shown in Figure 1 (left). Shaded isosurface rendering is a good mechanism to provide the user with cues about the overall structure of objects and their spatial relationships. It does not contain as much information as for example direct volume rendering (DVR) where several voxels contribute to one pixel, but it provides a better overview of the surface structure. However, due to the fact that only one voxel contributes to each pixel's color, isosurface rendering does not allow to achieve insights into a dataset. Therefore, the lens is applied to allow the user to analyze the inside structure of the dataset by still maintaining the contextual information of the isosurface rendering outside the region of interest. In the sample rendering of the skull inside the lens the inner structure of the teeth is rendered using isosurface shading combined with a different transfer function. To draw the user's attention to these structures their silhouette is highlighted with a boundary. Furthermore rendering the front faces of the teeth translucently we ensure that the user can perceive the spatial relationship of the inner structure. Although several tech-

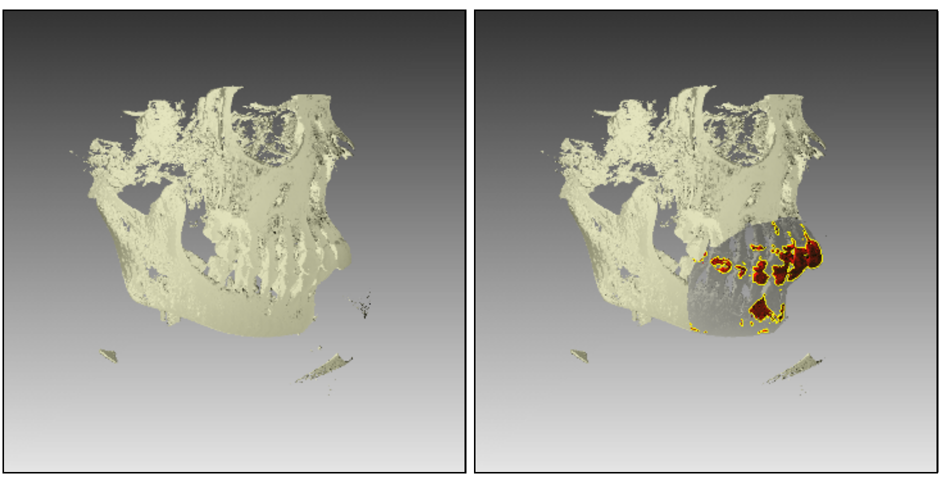

Fig. 1. CT scan of a human skull. Isosurface shading (left); spherical lens applied giving an occlusion free view to the highlighted inner structures. To provide a better focussing on the region of interest the voxels lying behind the lens have not been rendered (right).

niques are combined within the lens, there is no significant loss of performance using the describe approach compared to other more simple lens styles. This is ensured by processing the section of the ray intersecting the lens only once during the main rendering pass. Thus the three different visual appearances, i.e., translucent rendering, highlighting and isosurface shading, can be combined in a single rendering pass in a front to back order by using the following blending equations for determining the color resp. alpha value:

$$C_{dst} = C_{dst} + (1 - \alpha_{dst})\alpha_{src}C_{src} \tag{1}$$

$$\alpha_{dst} = \alpha_{dst} + (1 - \alpha_{dst})\alpha_{src} \tag{2}$$

C_{dst} denotes the RGB components of the destination color, while C_{src} denotes the RGB components of the source color and α_{dst} resp. α_{src} denotes the alpha value of the destination resp. source pixel. Only for the edge detection based highlighting a preprocessing pass is needed. In this pass parts of the volume lying inside the region of interest are rendered as non-shaded isosurfaces; in Figure 1 (right) an appropriate isovalue which can be used to extract the inner structure as object of interest has been determined interactively. The result of this preprocessing pass is stored in a framebuffer-sized texture which is accessed during the main rendering pass, in which the edge detection required for highlighting objects of interest is performed as initial step. Therefore the previously created texture is accessed four times at the neighboring texels corresponding to the current pixel position. The fetched color values c_{east}, c_{north}, c_{west} and c_{south} are used to determine whether the current fragment belongs to an edge in image space:

$$fragcolor = |(c_{east} - c_{west}) + (c_{north} - c_{south})| \tag{3}$$

If $fragcolor$ contains the maximum intensity in all three channels, i.e., it is white, the current fragment belongs to an edge in image space. In this case the current fragment color is set to the desired color used for highlighting objects of interest. By considering the different color channels R, G, B and A separately the described edge detection mechanism can be easily extended to support highlighting of different objects without needing extra rendering passes.

After the edge detection has been performed, in those cases where the current fragment does not belong to an edge the volume dataset is processed. Therefore, a ray is cast through the parts of the volume which intersect the lens. To achieve the visual appearance shown in Figure 1 (right) an isosurface rendering mode is used to determine the front faces rendered translucently. In cases where the ray intersects the volume, instead of terminating the ray after the isovalue has been encountered on the ray the ray is further processed until an object of interest, i.e., the inner structure, or the farthest back face of the volume dataset is hit. In both cases an appropriate shading is applied, which ensures that the back face is rendered translucently and the object of interest with the corresponding transfer function. Since the ray is further processed after a voxel contributing to the visualization is encountered, the number of samples processed per ray is not larger than when applying DVR inside the lens.

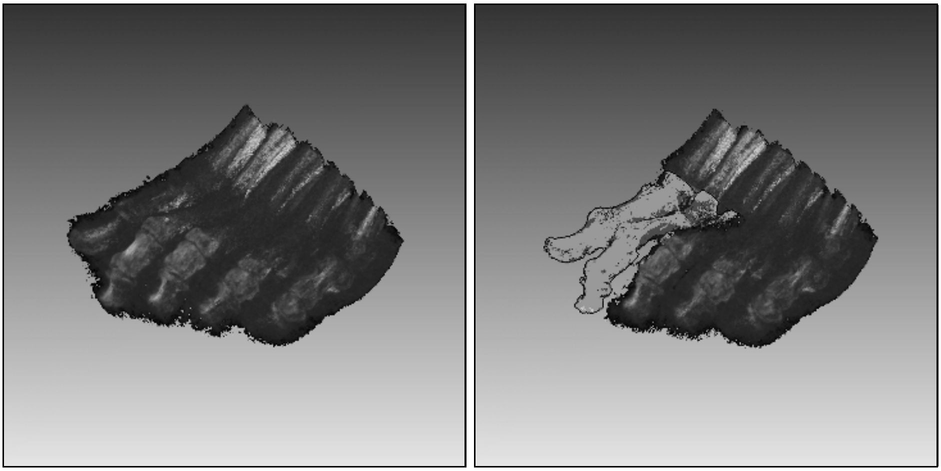

Fig. 2. A rotational b-plane x-ray scan of a human foot. DVR (left); cuboid toon-shading lens applied to reveal the bone structure.

Another medical example application of the lens metaphor is illustrated in Figure 2, which shows a lens applied to an x-ray scan of a foot. The foot is rendered using DVR outside the region of interest to provide an overview of the interior structure. Inside the voxels' gradients are exploited and toon-shading [1] is applied to the extracted isosurfaces of the bones. The toon-shading approach enhances depth perception, which results in improved comprehension. Furthermore to let the bones become more apparent a black outline is rendered using the edge detection technique described above.

The two presented visualization techniques are application of our current work on focus-based medical volume visualization. Based on this work we are developing visualization techniques specialized to support interactive exploration of PET datasets.

References

1. Amy Gooch, Bruce Gooch, Peter Shirley, and Elaine Cohen. A Non-Photorealistic Lighting Model for Automatic Technical Illustration. *Computer Graphics*, 32(Annual Conference Series):447–452, 1998.
2. Aidong Lu, Christopher J. Morris, David Ebert, Penny Rheingans, and Charles Hansen. Non-Photorealistic Volume Rendering using Stippling Techniques. In *VIS '02: Proceedings of the conference on Visualization '02*. IEEE Computer Society, 2002.
3. Timo Ropinski and Klaus Hinrichs. Real-Time Rendering of 3D Magic Lenses having arbitrary convex Shapes. In *Journal of the International Winter School of Computer Graphics (WSCG04)*, pages 379–386. UNION Agency - Science Press, 2004.