Proceedings of SPIE—The International Society for Optical Engineering

Volume 914

(Part B)

Medical Imaging II: Image Data Management and Display

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Chairs/Editors

Sponsored by
SPIE—The International Society for Optical Engineering
Cooperating Organizations
American Association of Physicists in Medicine
American College of Radiology
Center for Devices and Radiological Health, FDA

31 January-5 February 1988
Newport Beach, California

Published by
SPIE—The International Society for Optical Engineering
P.O. Box 10, Bellingham, Washington 98227-0010 USA
Telephone 206/676-3290 (Pacific Time) • Telex 46-7053

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Display of Multiple 3D-Objects Using the Generalized Voxel-Model

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1. INTRODUCTION

3D-display of medical objects derived from cross-sectional images has demonstrated its clinical usefulness in various applications such as surgery planning and recently also in diagnostic radiology. Instead of viewing sequences of images the region of interest can be looked at in its 3D-shape or at least as a cross-sectional image within the anatomical surroundings (fig. 1,2). This new way of viewing is certainly more natural and understandable than the conventional one. If we imagine that the invention of X-rays, CT or MR had not been made yet, would we not aim at an imaging modality which would deliver images as known from anatomy? So having the new 3D-imaging facilities the physicians might act in the future more like anatomists (with radiological eyes). A 3D-image, however, if generated from a single parameter (such as a Hounsfield value in CT) does not nearly have the information content of the anatomical reality. In addition, the capability of performing a dissection at the computer screen requires, that the program behind the screen is able to perform the corresponding anatomic segmentation. This means that the data structure on which the ´anatomist program´ is working must contain more detailed information on the organs to be displayed.

Figure 1. Combined presentation of a surface and cross-sectional information of a head in MRI. (Material: 128 slices, 256x256).

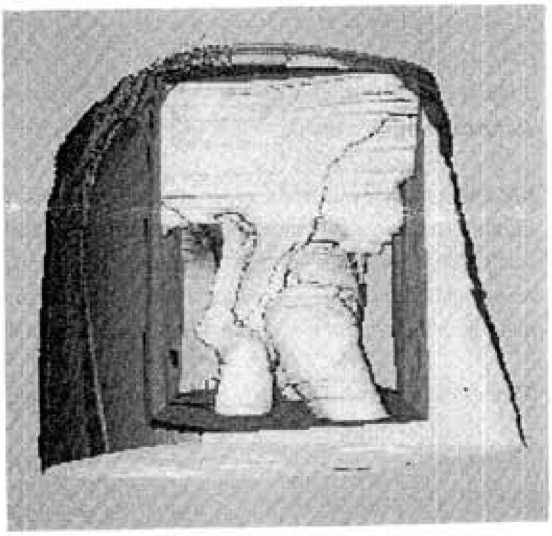

Figure 2. Combined presentation of surface and cross-sectional information of a fractured pelvis in CT. (Material: 77 slices, 256x256)

2. APPLICATION OF THE GENERALIZED VOXEL-MODEL

In classical 3D-display the underlying data structures are a-priori defined contours or binary images defining a surface. In previous papers we have presented display techniques based on a voxel-model in which every voxel contained the CT or MR-value.[1-4] When traversing the volume of data by a ray casting algorithm, surfaces can be detected on the fly, when the data are such that only a small neighbourhood needs to be considered. For the detection of the skin surface in MR only a threshold value can be used for surface definition (see fig. 3). For the detection of objects with less specific features a segmentation involving

Correspondingly we have extended the command structure of the program VOXEL-MAN, which produces the views from the data volume. In a first test we have added two kinds of information to the model: (1) organ labels derived from a semi-automatic 3D-segmentation of the data volume, (2) multiple parameters, such as T_1 and T_2 weighted MR data, or subtraction images from flow uncompensated and compensated MR data.

2.1 3D-Segmentation

In order to obtain smooth surfaces the segmentation of the objects to be displayed a real 3D-segmentation is necessary. For the examples in MR imaging we chose the Marr-Hildreth operator, because its 3D-version can be implemented as a sequence of three one-dimensional convolutions, which make the computing time affordable.[5] If I(x,y,z) is the original data volume and G(x,y,z) is a Gaussian, the operator produces a filtered volume

$$K(x,y,z) \;=\; I(x,y,z) * \nabla^2 G(x,y,z)$$

where ∇^2 is the Laplace operator, and

$$G(x,y,z) \;=\; \frac{1}{\sqrt{(2\pi)^3}\cdot\sigma^3}\cdot e^{-\frac{x^2+y^2+z^2}{2\sigma^2}}$$

This operator is not separable, but it can be shown that an approximation by a difference of two Gaussians has this property. The zero crossings of the resulting volume K(x,y,z) are considered as contours.

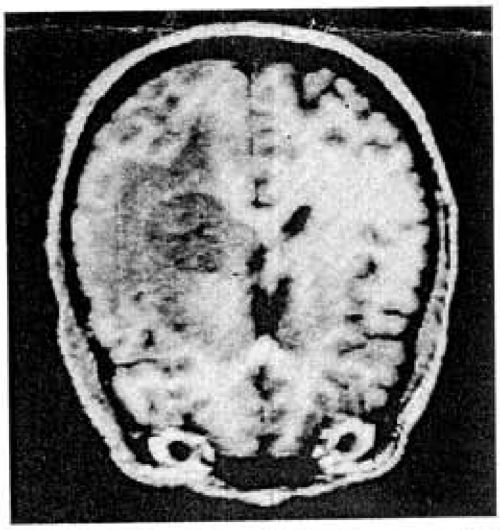

Figure 5a. One of 128 MR slices of a head. (Material: 128 MR slices, 256x256)

Figure 5b. Result of the segmentation with the 3D-Marr-Hildreth operator.

We have applied the operator to MR-FLASH-data sets of the head containing 128 slices with a matrix size of 256 x 256 pixels. Fig. 5 illustrates the quality of segmentation. In the case of head data the coarse morphology of the skin, bone, brain and the ventricular system are found. Nevertheless we are still far away from an exact segmentation. If, however, we correct the results interactively, we can obtain images like those shown in figs. 6 and 7.

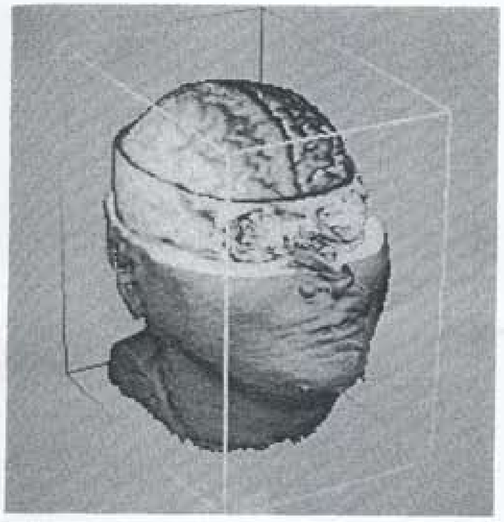

Figure 6. View of a head with bone and brain surfaces as segmented with the Marr-Hildreth operator. (Material: as in fig. 5)

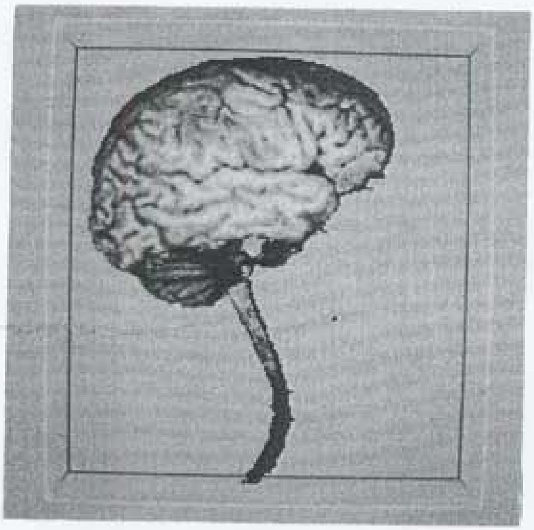

Figure 7. 3-D view of the isolated brain. (Material: as in fig. 5)

2.2 Multiple Parameters

Since MR delivers more than one parameter per voxel it seems to be meaningful to offer the choice of these parameters also in the 3D environment. Fig. 8 shows the brain with a cut along a metastasis showing once the FLASH (T_1-weighted) and once the FISP (T_2-weighted) parameter. Even parameters computed from the original data as those gained by a principle component analysis can be displayed. Another case is demonstrated in fig. 9. The basis of this image are a flow compensated and an uncompensated MR-data set of a knee. The vessels are detected through subtraction of both data sets. Merging vessels with one of the original data sets allows the display of the vessels in the surroundings of the other tissues.

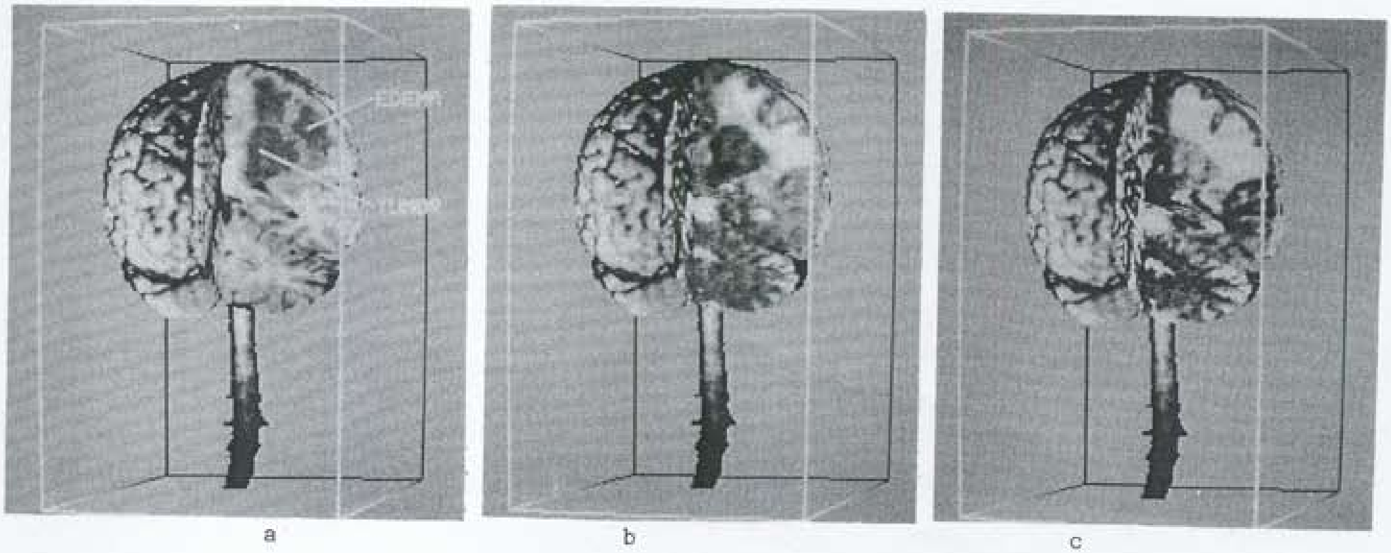

Figure 8. Display of different MR parameters on a cut surface: FLASH (a), FISP (b), and the result of the principle component transformation (c) (Material: as in fig. 5)

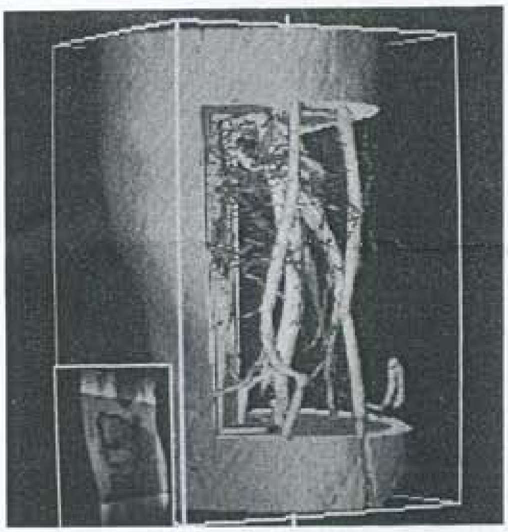

Figure 9. Combined 3D-display of conventional and angiographic MR data. (Material: 64 and 32 MR slices, 256x256)

3. CONCLUSION

Using the generalized voxel-model it is possible to generate 3D-views from MR-volume data that are very similar to what we know from anatomy. The shown results may be considered as a step towards a way of medical imaging that allows us to explore organs more like the real object than as 2D-images of them.

There are, of course, unsolved problems. At a first glance the vast amount of data and the required computing power seem to be the major obstacle. We are convinced that this problem will be overcome in the near future through the advances in technology. As far as segmentation is involved the situation is not as hopeful. But when we restrict ourselves to easily detectable surfaces, at least an anatomical frame can be generated in which lesions with low contrast can be viewed in the conventional way. The major problem to be solved is the design of a man - computer interface that allows the easy interaction of the physician with the system.

Since the generalized voxel-model is a relatively simple data structure, it is easily adaptable to a variety of other applications as MR-PET registration or 3D radiotherapy planning.

4. ACKNOWLEDGEMENT

We thank Siemens (Erlangen) for the MR data from which the images of this paper have been produced, and Carsten Schiers and Gunnar Wiebecke for their support.

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