Advanced joint 3D visualization of functional and anatomical data

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Abstract

In the emerging field of functional biomedical imaging, there are two kinds of data to be visualized: The conventional anatomical data and the functional data.
To fully understand the functional information and to bring features found in the functional data into the spatial context of the anatomical data, it is necessary to jointly visualize anatomical and functional data. Usually, 2D techniques are used. While these are easily implemented and provide high precision, they lack global information and the observer has to mentally reconstruct the 3D context. To overcome these problems, we present a 3D technique for the joint visualization of anatomical and functional information. The images produced using this technique provide a very good 3D overview and allow the precise localization of features and the finding of relations between anatomical and functional data.

Purpose

- For visualizing anatomical data sets, 3D techniques like direct volume rendering and surface rendering are well established
- For joint visualization of 3D data sets describing different properties of the object (like anatomical and functional information), 2D visualization techniques are dominant
  - Hybrid methods play an emerging role
- Visualizing 2D slices is the most common approach, but:
  - 2D information is quite local
  - Often difficult to understand how different features inside the object are positioned relative to one another
  - Difficult to put features found on a 2D image into global 3D context of the object
  - → User is required to mentally reconstruct the 3D context

→ It is desirable to visualize such data in 3D as well, in order to improve the spatial understanding of features

- Main problems in visualizing functional data in 3D:
  - functional information only makes sense in conjunction with its corresponding anatomical reference
  - Visualizing functional data alone often just results in some blurry clouds
  - → Both properties have to be visualized jointly

- We present a system that allows joint visualization of two data sets, describing anatomy and functional information of an object
- Both volumes are visualized in full 3D, using an extension to direct volume rendering, the dependent volume rendering technique developed earlier by one of the authors
- Purpose of the system: Improve the understanding of both the global arrangment of features in the object and their spatial relations to each other and to their anatomical reference

Method

- Dependent rendering technique is based on the assumption that the anatomical data provides a spatial reference for the functional data
  - → Only those regions in the functional volume shall be visualized that have been visualized in the anatomical data
  - → They serve as a spatial reference for the functional data
- This can be accomplished by using the rendering pipeline shown in Fig.1, the effects of which are shown in Fig. 2:

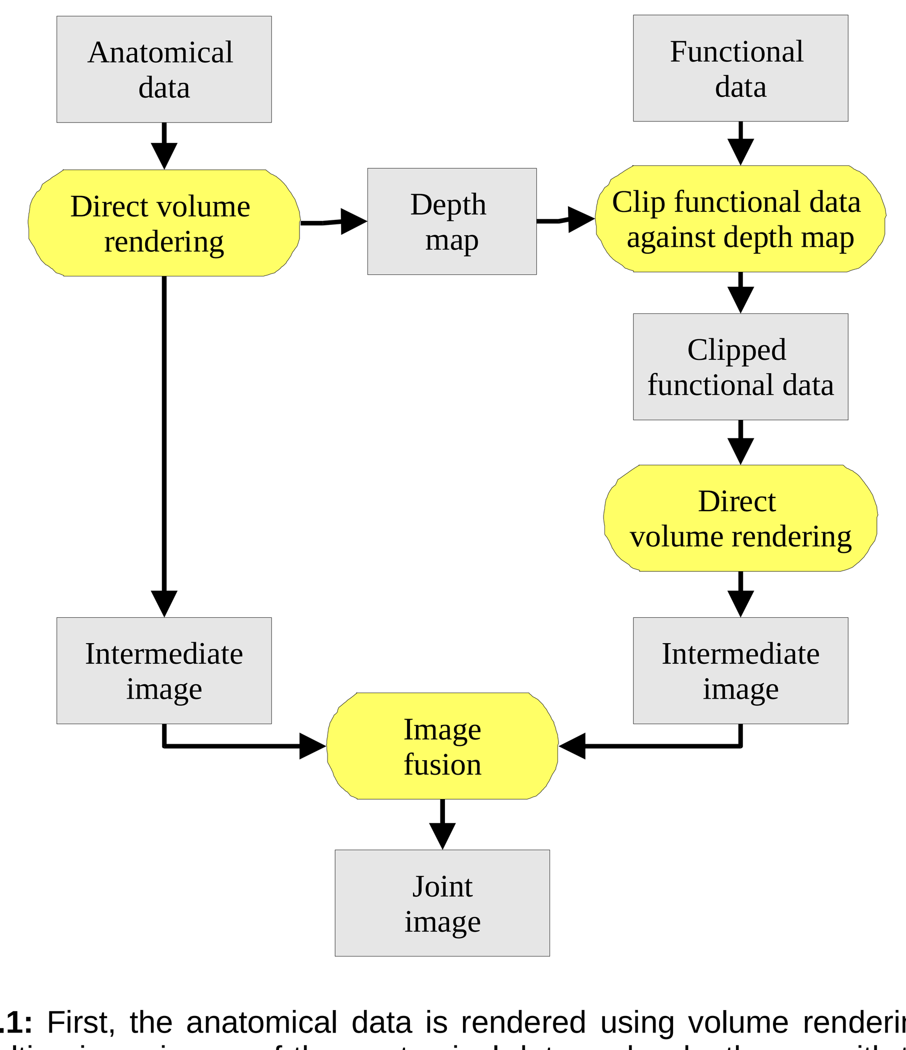


Fig.1: First, the anatomical data is rendered using volume rendering, resulting in an image of the anatomical data and a depth map with the viewing depth for each pixel in the anatomical image.
Then, the functional data set is clipped against the depth map to cut away all regions in the functional data that do not contribute to the anatomical data rendering. The functional data is rendered and the two intermediate images are fused to yield the combined 3D rendering.

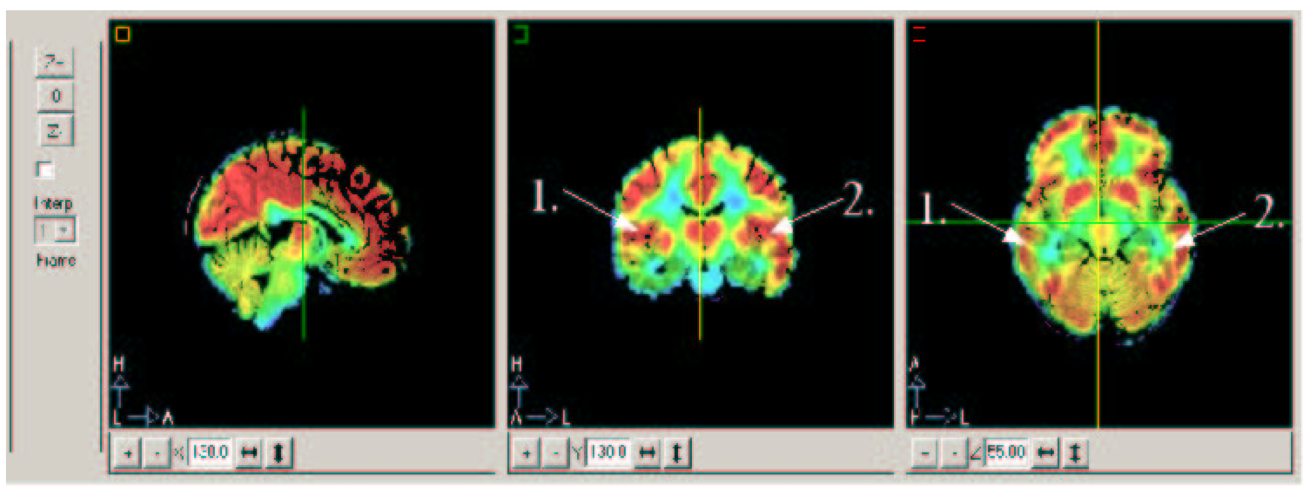


Fig. 3A (above) and 3b (right): Comparison between the 2D and 3D joint visualization of a MRI and a PET data set. Note how well the asymmetry between the regions labeled with arrows 1. and 2. can be perceived from the 3D rendering. The 3D cursor in the Fig. 3. is located exactly at the intersection point of the three slices in Fig. 3a.

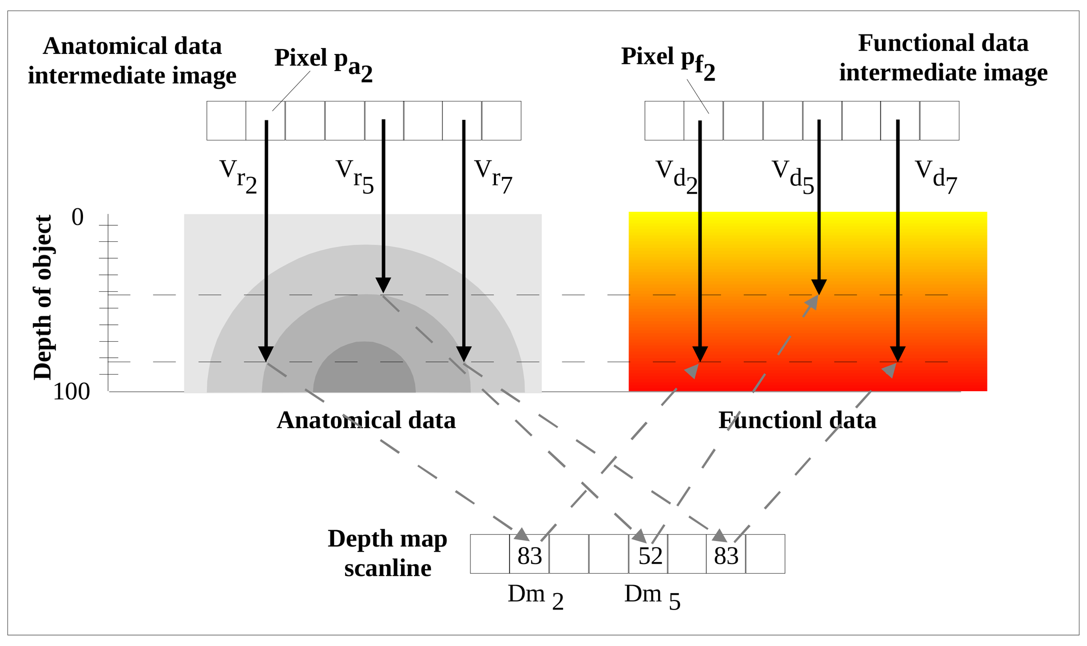
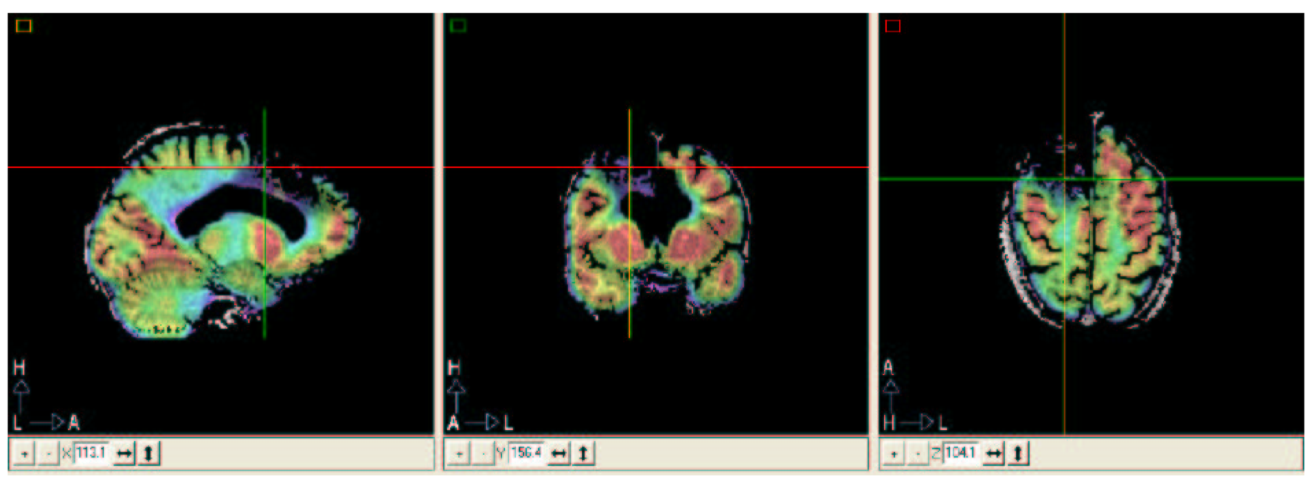
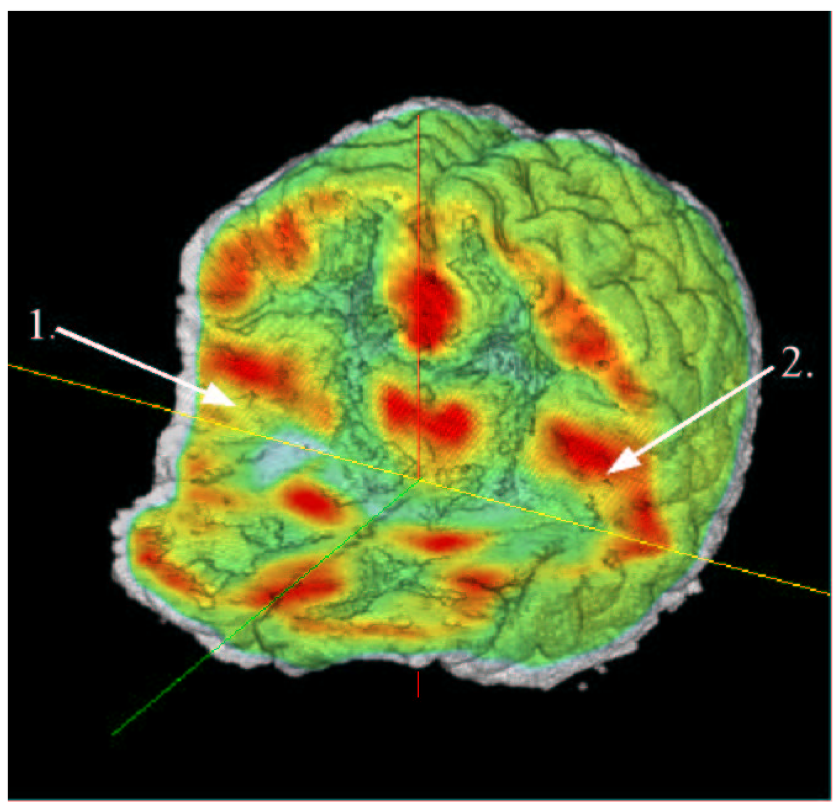


Fig. 2: Only those parts of the functional data are rendered for which there is a contribution from the anatomical data.

- We used the dependent volume rendering technique for a 3D joint anatomical and functional data volume rendering module for our existing biomedical image analysis and visualization platform
- Based on an orthoviewer, i.e. a system that visualizes three orthogonal slices of the volume in a row
  - User can scroll through the slices, with the position of one slice always beeing marked on the other two slices
  - This orthoviewer is able to handle two registered volumes of the same object
  - Anatomical data is visualized as graylevel images with the functional data layed over or modulated into it, using a user-configurable color scheme

- Using the orthoviewer, the user can select and de-select parts of the volume, highlight interesting voxel value ranges and define the coloring of the dependent volume
- In both volumes, voxel value ranges that the user de-selected in the 2D interface are eliminated by adaptive rescaling
  - By adaptively scaling the selected voxel value ranges into the de-selected ones, the dynamic range effectively useable for the voxel values of interest is higher
  - Transfer functions do not have to design mapping "holes" for uninteresting voxel ranges as the scaled volume only contains voxel values of interest
- The orthoviewer's settings are used to initialize the volume rendering system and to automatically create volume rendering transfer functions
- The volume rendering module contains a 3D cursor which is interactively updated from the positions of the slices in the interface. Thus the user can easily relate the position of a feature found in the 3D rendering to its position on the 2D viewer





Results

- The system is currently being tested with MRI and PET images of the human brain
- Fig.s 3 and 4 show comparisions between the 2D viewer and the 3D joint volume renderer
  - The rendered images show both the anatomical and the functional information
  - Both the global arrangment of features in the object and their spatial relations to each other and to their anatomical reference can be perceived better than from the 2D images
- The automatic mapping from 2D settings to transfer functions proves very useful:
  - Even without further manual tuning, meaningful images are generated
  - These can than be further improved by slight changes in the transfer functions

Discussion

- The presented system allows full 3D volume rendering of two properties of an object in a single projection
- Improves the spatial understanding of the data and facilitates the finding of spatial relations between features in 3D
- Easy to use:
  - Most settings relevant for the 3D visualization can be done in 2D in real-time, thus providing instantaneous feedback
  - Cumbersome fiddling with transfer functions is not neccessary for creating meaningful images, but still possible for the expert
- While the system helps the investigator to better understand the global arrangement of features in the object, it is still neccessary to further investigate the features found using high-precision 2D slice images
- The system is a valuable enhancement to the 2D imaging solutions into which it seamlessly integrates

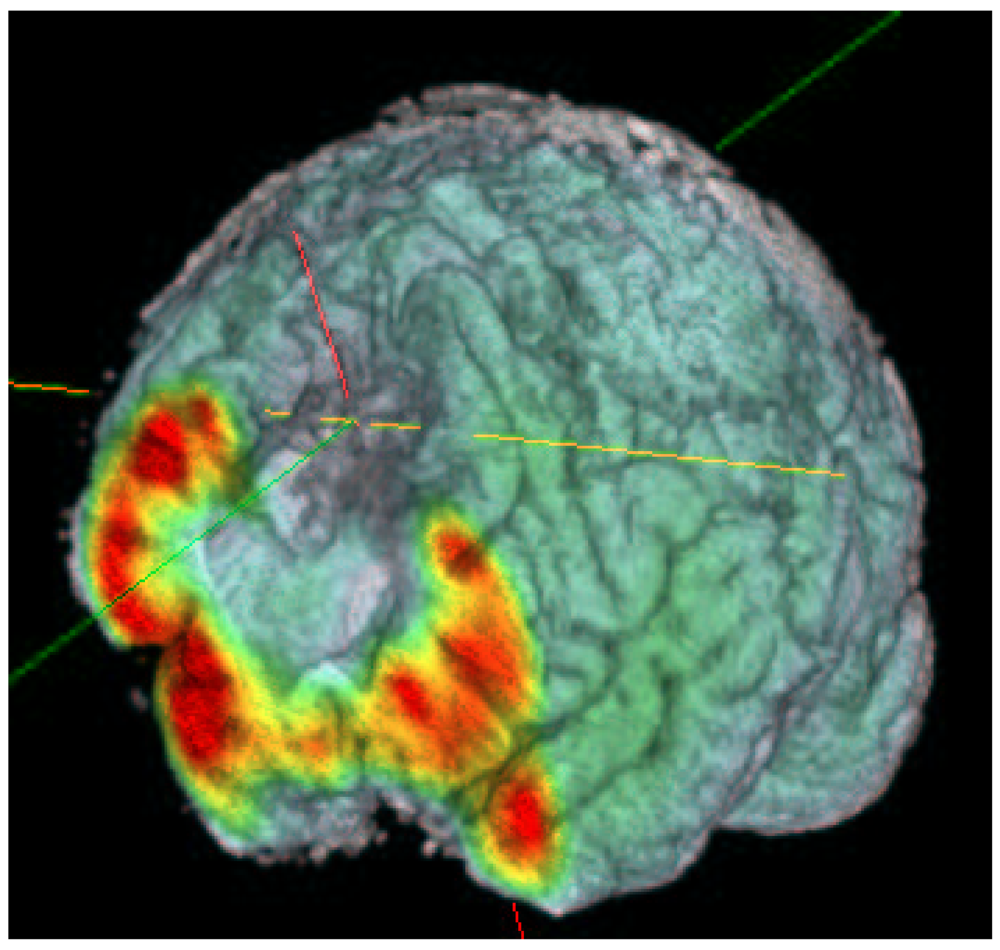


Fig.4 a (above) and b (right): MRI and PET data sets of a patient with parts of the brain removed by surgery. From the 3D rendering it is very easy to perceive which region of the brain has been removed by the surgery.