Interactive Information Visualization in Neuroimaging

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Abstract

We describe a virtual environment for interactive visualization of 3D neuroimages. The environment is implemented in VRML and we will discuss the viability and limitations of this platform.

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1 Introduction

The volume of functional neuroimaging research — the science of aquisition, analysis and interpretation of images of the working brain — is increasing exponentially [3]. The main experimental modalities in this area are functional Magnetic Resonance Imaging (fMRI) and Positron Emission Tomography (PET). Both produce volumetric datasets in the order of 100's of Megabytes, — often the data aquisition is restricted by the storage medium.

In functional neuroimaging such large datasets are often summarized by a single volume of an activity measure– the so-called *brainmap*. This 3D brainmap is, however, always to be interpreted in the context of many other information components. The context includes the immense body of neuroscience together with more specific information concerning the experimental setup. There can be multiple subjects involved in the study and we might be interested in similarities and differences among them; we can analyze data with several kinds of statistical models and study consensus and divergence; and furthermore we could be interested in how different (geometric) alignments and preprocessing procedures affect the analysis result. The current experiment can be part of a compound study involving several different types of stimuli. All these will produce brainmaps, that we would like to provide access to in a single environment. Hence, there is an urgent need for infrastructures that can smoothly integrate neuroscience information in interactive environments.

In this presentation we use the Virtual Reality Modeling Language (VRML) standard as a mean of integration. The main virtues of VRML in the present context are:

- Interactive access to 3D data.
- Hypertext organization of many multimedia components.
- Platform independent 3D visualisation.

Our presentation is based on collaborative work within an interdisciplinary group of researchers including psychologist, neurologist, chemists, physicists, engineers, and computer scientists. Furthermore these scientists are working in the US, Japan, and Europe, and on many different platforms, hence, information presentation needs to be WWW-based.

2 Visualization of 3D neuroimages

Neuroimages have usually been visualized using stacks of 2D images or possibly a few key projections, viz. on three orthogonal planes or onto the surface of the brain. While stacked 2D images do provide a faithful picture of the distribution of activation in the given volume, it requires significant talent and effort to integrate it into a 3D mental image needed to judge the spatial location and extent of activated regions.

In recent years much effort has gone into the use of volume graphics, either as 3D surface graphics or volume rendering [6]. Volume rendering does provide the most direct access to the data. However, it requires powerful computers and there does not seem to be a well-defined standard for the exchange of volume rendering visualizations.

Surface graphics has evolved considerably. Although restricted to show iso-surfaces of a volume, graphics file formats such as Inventor and now especially VRML [5] have incorporated interactivity, autonomous behaviour, hyperlinks and a limited amount of elements from 2D graphics: text and textures.

Thus we are able to create environments that are not only rendering simple activation iso-surfaces, but also symbolic and iconic components. By active use of hyperlinks, the environment can be hierchically organized, where the different layers of interpretation can be unveiled by interaction within the viewer.

Visualization with symbolic elements has been presented in neuroimaging within Rehm's CornerCube environment [9] [10], where the *blobs* can not only be rendered as surfaces,

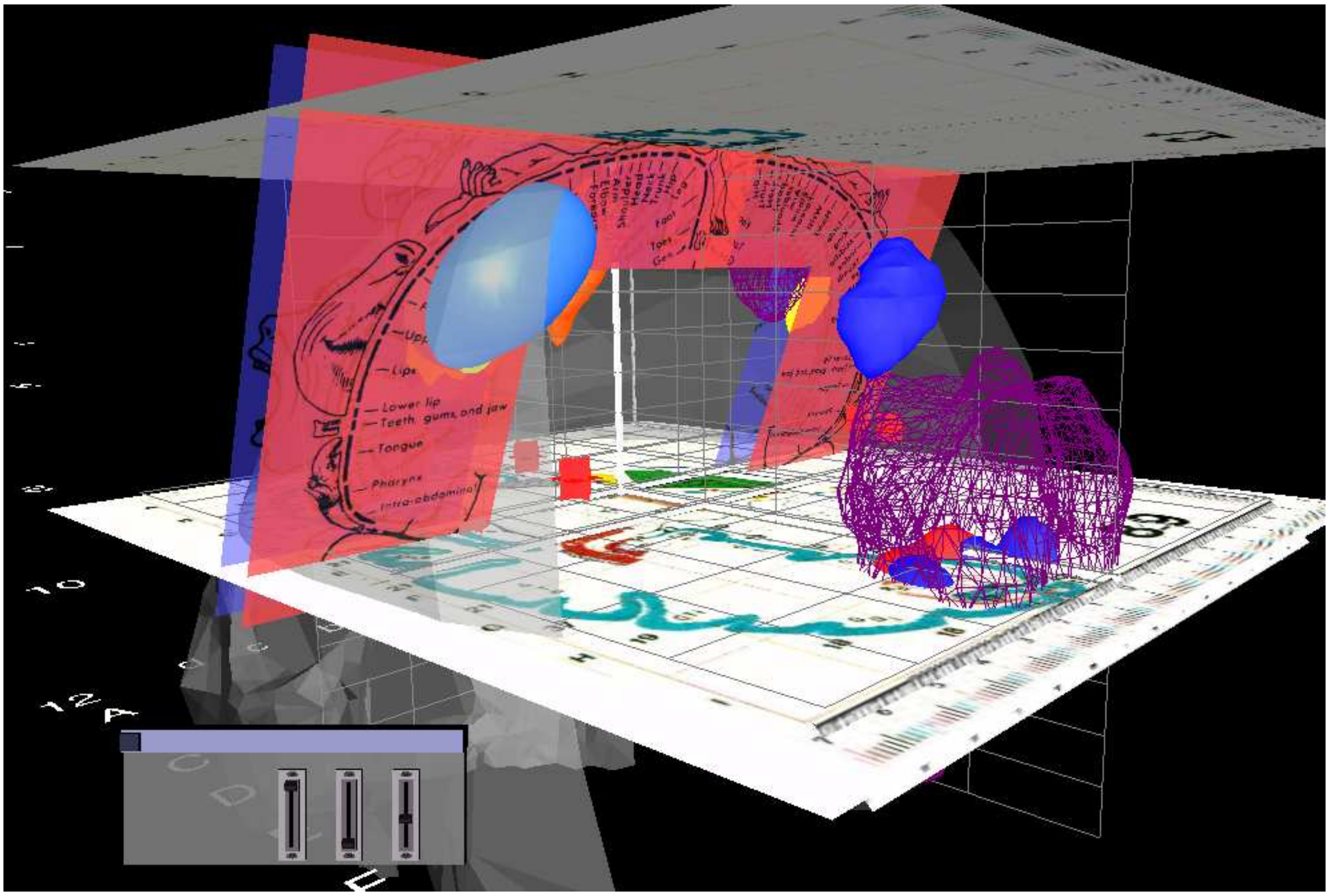

Figure 1: Neuroimaging visualization: Blobs rendered with marching cubed polygons and wireframes; 3D-crosses symbolizing entries from the BrainMap database; Talairach 3D grid and axis; Two slices from the Talaraich atlas rendered as texture on polygons — both can be translated vertically (a new texture is downloaded every time); Penfield and Rasmussen's homonculus for reference in connection with somatosensory and motor processing. At the bottom to the left is a small graphical user interface (hud) for varying the transparency and the size of some of the objects.

but also as symbolic objects such as spheres, ellipsoids and possible tori (to indicate Euler characteristics of the blob).

Color and size can be linked to the maximum or mean activation within the blob or the type of volume we are investigating: different stimuli, different subjects, different statistical models. A drawback of using the size of the object symbolizing the blob, however, can be that the depth cue through size is obscured.

We can go further in symbolic representation, beyond the sphere and ellipsoid: 2D graphics has for long been using e.g. stars, diamonds and crosses, and we can generalize that to 3D, by using e.g. polyhedras (see Vladimir Bulatov's collection of VRML polyhedra [2]) and a 3D-cross (shown in figure 1). The symbolic object will usually have the advantage over the simple iso-surface representation in that it requires fewer polygons, thus we can get a higher frame rate.

Symbols in a 3D visualization are in fact glyphs and we envision that the static glyph representation can be extended even further into a 3D dynamic and interactive object: e.g. rotation of the glyph (around a specific axis with a specific speed); glyphs that change appearance by user interaction (in VRML through a `TouchSensor` or a `ProximitySensor`) and expand information hidden in the hierarchical layer, — possibly written as text with a `Text` node or as texture on polygons. VRML is well suited for "glyph representation" due the `PROTO`types: Generic glyphs can be defined and instanced differently for the different blobs.

The so-called *BrainMap* database is an impressive collection of neuroscience information, a database that links blobs (or rather blob coordinates) with tasks (types of stimuli) together with numerous other types of neuroscience information [4] [7]. The content in this database is particularly suitable for a hierarchical interactive glyph representation.

The BrainMap database and in fact most current neuroimaging studies use the Talairach atlas [11] as the frame of reference. This atlas links a number of brain structures to a cartesian coordinate system. We have chosen the Talairach system as reference. There are two problems associated with this: Firstly, the z-axis in computer graphics — and VRML — is the depth axis, while the z-axis in neuroimaging is the top-bottom of the brain axis. This will affect the way the "Walk" and "Fly" navigation types work in the VRML browser. Second, neuroimaging researchers tend to use millimeters or centimeters as their basic unit. Conversion is needed in order to meet the VRML recommended standard which is the *meter*.

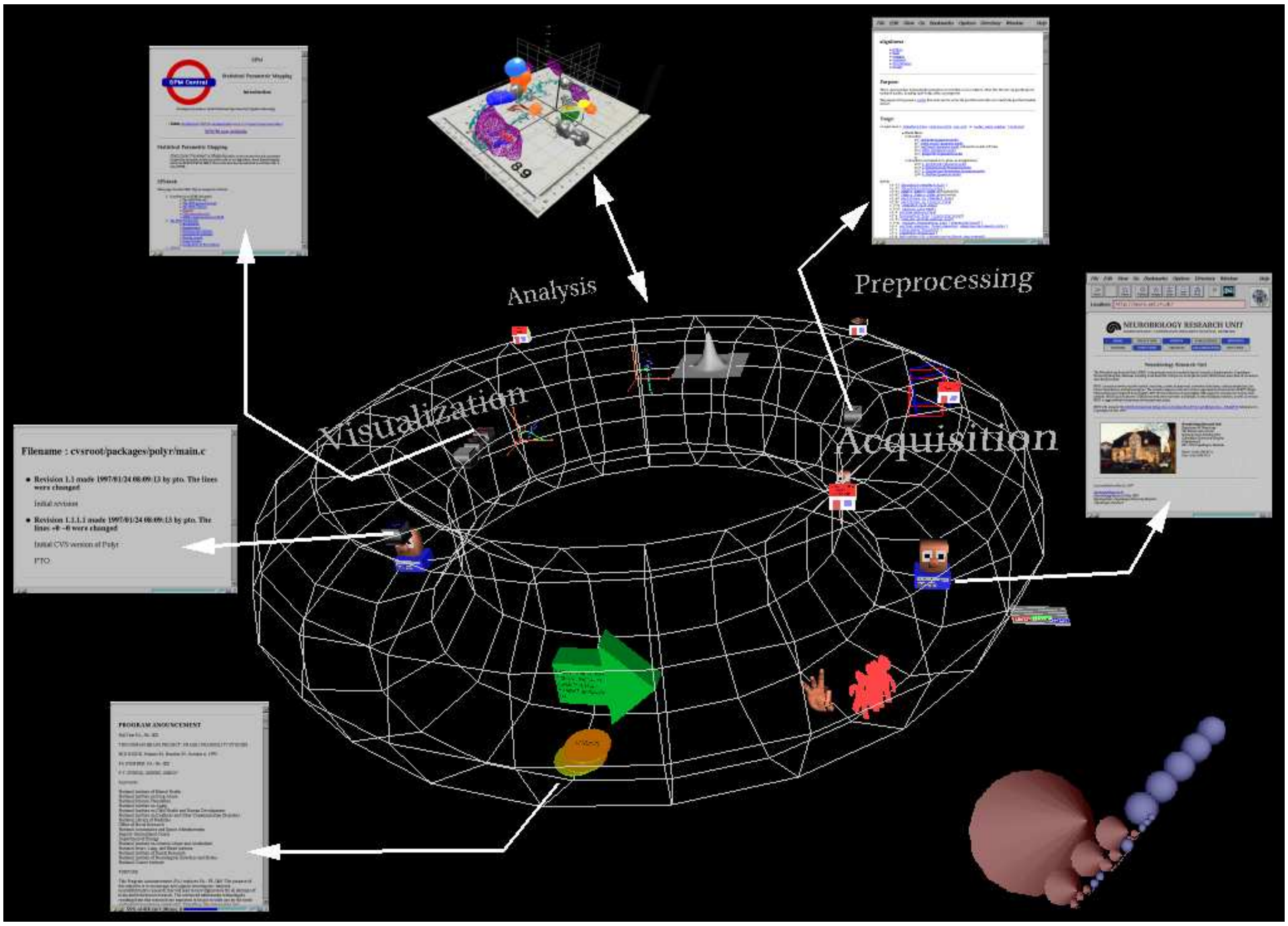

Figure 2: Process visualization: A torus is visualizing the circular nature of neuroimaging process. The neuropsychological objective initiates the process — the arrow. Then the funding is established — click on the pile of coins and get to a HTML description of the funding. The VRML world also hyperlinks to institutional homepages and analysis program packages homepages. At the bottom right is seen a first attempt at visualizing the so-called NeuroNames hierarchy [1]. The environment should integrate a rich set of media types, apart from VRML and HTML e.g. video clips from the scanning session and audio tracks with comments from the physician.

One of the nicer features of VRML is the easy inlining. This provides the ability of including vast amounts of objects (from our own and other studies, from the BrainMap database, from anatomical reference volumes, ...). Clearly this will call for a VRML user interface if we will allow inclusion to happen interactively.

3 Information visualization

While we consider the visualization of a single brainmap as visualization of more or less homogenous data, access to the context calls for visualization of heterogenous information: we wish to visualize (and possibly connect — hyperlink) the many different components mentioned earlier. This can be viewed as a realization of (Gibsonian) cyberspace. Mark Pesce has stated the problem as mapping from net topology (the information in a semantic network) to 3D[8].

In our representation of a neuroscience experiment we have used a torus as the basic 3D topology. This is based on the observation that there is a recurrent workflow in the neuroimaging proces: First the neuropsychological objective is identified, then the stimulus is constructed. This is followed by the formulation of a scanning protocol, the actual data acquisition, scanning, storing, preprocessing (alignment, coregistration, ...) and then follows data analysis before the visualization and the interpretation, which brings us back to the neuropsychologist.

4 Discussion and future work

Some of the objectives for our future work can be summarized as follows: There is a need for a *user interface* for manipulation (especially for inclusion and exclusion) of objects. We hope to take advantage of the widgets working group in the VRML consortium for building a consistent graphical user interface. In VRML a volume has to be converted to polygons and textures initially or the conversion has to be made through a CGI-script or native Java-applet

Figure 3: Virtual reality system based on a VRML-browser.

code. Neither is particularly attractive. An implementation in VRML is lacking good *interprocess communication* e.g. to a statistical program. Again the dataflow has to go through a Java-applet with calls to native code.

We have extended the visualization to a prototype *virtual reality* system using a VRML-browser, the EAI VRML interface (External Authoring Interface), a Java-applet with calls to native code relying on the Netscape Plugin library and WorldToolKit handling headset with Fastrak magnetic tracker. We will add support for glove and spaceball. A final aim we would like to mention is to establish a *multi-user environment* (virtual conference) which would be extremely helpful for geographically distributed projects.

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