A 3D Human Brain Atlas

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Abstract. 3D representations of human physiology provide interesting options in the field of education. Understanding the human brain seems to be much easier when the anatomical structure is shown in the three-dimensional domain rather than in a 2D or flat projection. Seeing how the brain is 'wired' and how the different regions are connected to form circuits and complex networks requires a spatial understanding of the brain structure. Conclusions about how this structure evolved can be drawn more easily from a 3D model than from a 2D depiction of the brain.

Such 2D depictions are typically found in textbooks. Our goal is to make a brain atlas three-dimensional, so that different user groups can use the atlas to learn more about the brain and possibly make new discoveries.

In order to facilitate this, we have a developed a 3D human brain atlas, which serves as an educational tool for various types of students. The software is interactive and supports multiple user profiles, ranging from K-12 students to physicians and future brain surgeons.

We describe a method that combines high-resolution image data, large-scale volume visualization, and rendering on a distributed display cluster with a novel approach to human-computer interaction. The interaction with the atlas is accomplished by using barcodes, which are attached to various brain regions. The user can walk around in front of a large, 200 megapixel tiled display wall, which consists of $10 \times 5 = 50$ LC flat panel 30" displays and measures 23 x 9 ft. Using a camera-equipped cell phone as a universal input/output device the user scans a barcode and is then either prompted with a question to name the region and enter it on the handheld device (brain quiz), or will be provided with additional information, e.g. research documents about the selected region. The information that is provided to the user on this device over a wireless network depends on the user profile under which the user is registered and has identified himself or herself to the system.

We describe new interaction methods for large, wall-sized display systems, which enable every user to experience the visualization provided by the system either on their own or collaboratively. This new approach is different from existing methods which usually require one person to operate the system and take the lead, while others become merely observers. The system also facilitates the delivery of additional, specific information for each user based on their age group, educational background, or research intent.

Keywords: Brain Atlas, Educational System, Universal I/O Device, Tiled Displays, Large-scale Visualization, Visual Tagging.

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1 Introduction

Our goal is to present a method for 3D display of a human anatomical brain atlas on a large, tiled display wall, and the introduction of a new, two-way interaction method for multiple users based on camera-enabled handheld display and input devices. With the introduction of smart phones, pocket PCs and multi-touch enabled cell phones such devices have become ubiquitous. Wireless communication frees the user from any kind of wire or tether. For our two-way communication, we use either IEEE 802.11 or CDMA/GSM network connectivity, which is also ubiquitous and robust now.

The main idea of the 3D Human Brain Atlas is to use a large, volumetric model of the human brain, which is computed from high resolution cross-sectional images, so-called real-color cryosections, and to employ a software which allows various user groups to interact with this large display using a handheld device. Such a universal input/output device, which was inspired by the tricorder device from the StarTrek™TV series, serves both as a barcode scanner and as a touch-screen device, which is both a display and a key entry device. While the large screen shows a 3D rendered image of the brain, the small screen on the handheld device provides additional information, which can be personalized for each user. Using a special barcode on the side of the screen, the user can identify herself or himself to the system in order to obtain specific information or to trigger a particular program, such as a brain quiz.

A key component in this research project is a high-resolution display which is capable of 3D rendering of volumetric brain data sets. We use a distributed rendering cluster which consists of 25 rendering nodes and 50 displays in a 10×5 configuration, providing a combined resolution of 200 megapixels. High resolution is important when displaying small barcodes, which are not supposed to obstruct the user's field of view to much. On a small desktop display, the barcodes would cover a significant part of the screen, possibly hiding significant anatomical features. On a large display, the barcodes can be displayed at a sufficient level of detail by covering only a very small percentage of the screen. As an additional benefit, multiple users can interact simultaneously with the large display, each one in their own way or working together towards a common goal.

First, we want to focus on large, high-resolution displays. In recent years, such displays have become increasingly popular due to latest advances in display and hardware technology. They combine the resolution of multiple screens and are usually driven by a cluster of rendering nodes. Two basic techniques have emerged, making use of different display technologies: *Projector-based* tiled displays consist of multiple computer projectors, often arranged in a regular grid, that have been calibrated in terms of geometry, color and luminance to form one seamless display. *Monitor-based* systems consist of a set of LC panels that have been mounted on a frame and can easily reach up to several hundred megapixels resolution. For our system we have chosen the second approach.

With respect to human-computer interaction, we try to overcome the constraints posed by traditional input devices by giving each user the opportunity for untethered interaction with the data being displayed. Barcode-like visual tags are the interface between the tiled wall and the mobile devices. The tags allow us to create new interaction metaphors that facilitate collaborative work in front of large displays and particularly address the requirements of the 3D brain atlas.