

Ceng 491 Project Proposal: Cognitive State Representation and Visualizing of Human Brain

Simple Labs

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Members:

1. Atakan Kaya, 1746114, e1746114@ceng.metu.edu.tr
2. Barış Nasır, 1746288, e1746288@ceng.metu.edu.tr
3. Özlem Ceren Şahin, 1746668, e1746668@ceng.metu.edu.tr
4. Bahattin Tozyılmaz, 1746395, e1746395@ceng.metu.edu.tr

1 Problem Definition and Background Information

The human brain is a complex system which is topologically represented as structural and functional connectomes¹. Mapping the human brain connectome and uncovering its underlying organizational principles are fundamentally important in neuroanatomy, neurodevelopment, cognitive neuroscience and neuropsychology. Recent studies have suggested that the human brain connectome can be mapped using neuroimaging data and further characterized through sophisticated analytic strategies based on graph theory[1].

The products invented until now is used to examine some issues such as aging, development, gender, intelligence and genetic, and used on individuals with a variety of neuropsychiatric disorders, including Alzheimers disease (AD), mild cognitive impairment (MCI), schizophrenia and epilepsy. Recently, several freely available toolkits for extracting brain network topological properties have emerged:

¹map of neural connections in the brain.

- Brain Connectivity Toolbox (BCT)[3],
- eConnectome[4],
- Graph-Analysis Toolbox (GAT)[5],
- Pipeline for Analyzing brain Diffusion images (PANDA)[6],
- NetworkX[7],
- Brainwaver[8],
- Graph-theoretical Network Analysis toolkit (GRETNA)[9]

which have greatly assisted with the investigation of the brain connectome.

However, toolkits for visualizing the brain connectome as nodes and edges are still lacking. One of such toolkits is:

- BrainNet Viewer

The main problem we will work on is simplifying the complex graph view of the brain networks and representing it in a smooth 3D neuroimage. Down sampling and quantization will be used to achieve this goal.

For this project, human brain is going to be modeled as nodes which represent voxels in neuroimaging data and edges which links nodes. With the neuroimage obtained, our aim is to show the active parts of the brain under some specific circumstances.

Given the nature of graph theoretical approaches and the huge complexity of brain networks, it is important to develop easy-to-use and efficient toolkits for graph-based network construction, analysis and/or visualization.

2 Significance of the Problem and Motivation

This problem aims to help those who want to examine the most complex machine in the universe, human brain. We will take an input which is obtained by using functional magnetic resonance imaging (fMRI) machine and convert it to a smooth and understandable 3D image. There are some challenging areas we have to deal with them. First of all, we will deal with large data. A single input could be reach up to one terabyte. We must deal efficiently and effectively with this data. Secondly, we want to visualize the brain image in 3D. This means we must work with voxels. Each one represents a tidy cube of brain tissue a 3-D image building block analogous to the 2-D pixel of computers screens. Each voxel can represent a million or

so brain cells. We will try to obtain a smooth 3D image with those voxels (group of brain cells). Finally, we will deal with human brain, which has very complex working principles. We have to be careful with our conclusions. Just because voxels corresponding to one region 'light up' when our subject sees a terrifying tiger does not mean that every time this region appears active, our subject is frightened. So, we must be careful when we try to find relationships between voxels.

We have looked up every other project ideas, talked with some of our teachers and talked with some companies. However, we thought that some of the public ideas on COW are not challenging enough for a senior computer engineering student to take it as a graduation project. Also we do not want to work with a company because we do not want to work as a free employee to any company. After talking to Prof. Dr. Fatoş Yarman VURAL, we found that this project conforms to our expectations from a graduation project. Also, three of our members are taking Image Processing course from Prof. Dr. Fatoş Yarman VURAL and two of our members have taken Computer Graphics course last year and have some basic ideas on OpenGL and other computer graphics concepts. Furthermore, we found interesting to work with human brain, analyzing it and doing it with computer graphics and image processing.

The products mentioned at Section 1 have greatly assisted with the investigation of the brain connectome. However, toolkits for visualizing the brain connectome as nodes and edges are still lacking. BrainNet Viewer is one of such toolkits but it works with only small sized data. Our aim is to create a similar tool but allows us to work with large data.

Physicians can benefit from this tool to assess how risky brain surgery or similar invasive treatment is for a patient and to learn how a normal, diseased or injured brain is functioning. They can map the brain with this tool to identify regions linked to critical functions such as speaking, moving, sensing, or planning. This is useful to plan for surgery and radiation therapy of the brain. Clinicians also can benefit from this to anatomically map the brain and detect the effects of tumors, stroke, head and brain injury, or diseases such as alzheimer's[2].

We are not planning to turn this project into a commercial/academic business/product for now. To do such a thing, we have to talk to Prof. Dr. Fatoş Yarman Vural.

3 Draft Project Plan

End product will consist of a simple user interface and three dimensional animated display of brain data recorded by a functional magnetic resonance imaging (fMRI) device.

The data recorded by fMRI device will be given as a grid to our tool by the user. Then, the program will create an image which visualizes data into a three dimensional display.

There are four major tasks in this project.

1. The first task is to represent the anatomic regions of the brain namely frontal, parietal, occipital, limbic and temporal lobes, in three dimensional geometry. For this purpose, the open source toolkit of *connectome* generated by *EPFL* will be employed. The anatomic regions of the brain will be transformed from the standard brain coordinate system (MNI) using off the shelf available packages such as *Marsbar* and *Brainnet Viewer*. Özlem will be the responsible member of this part.
2. Secondly, we are going to use the model generated by Yarman Vural to represent the cognitive processes of the brain. In this portrayal of the brain, a cognitive process is represented by a large scale graph with a set of nodes and arcs. Each node will have an attribute depending on the anatomical location of the brain. Atakan will be responsible for the second task.
3. Next, the model generated by MAD (Mash Arc Descriptor) is going to be displayed based upon anatomic regions. Scaling, zooming and translating features will be available. Barış will be responsible for the this task.
4. Lastly, visual analytic methods will be employed to extract meaningful information from the model. For this purpose graph mining methods will be employed. Bahattin will be responsible for the this last deliverable.

It should be noted that among tasks and distributions are tentative.

We will benefit from the source code of Brainnet Viewer to import five main regions of brain to Connectome. We cannot directly use Brainnet Viewer because it cannot handle large data (up to 1 TB) efficiently since it is written in MATLAB. Therefore, we aim to implement our project in OpenGL. After importing the brain regions to Connectome, we will deal with

simplifying the complex graph into a understandable graph. To achieve this, we will use some image processing and computer graphics techniques namely down sampling, quantization etc.

4 Support

We are supported by Prof. Dr. Fatoş Yarman Vural and those who are members of Pattern Analysis of Functional Magnetic Resonance Imaging Laboratory².

Contact information for Prof. Dr. Fatoş Yarman Vural:

vural@ceng.metu.edu.tr

Tel: +90-312-210-5595

Office: A305

References

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²<http://neuro.ceng.metu.edu.tr>