Submitted on January 16, 2018 to the Notre Dame Journal of Formal Logic
Volume ??, Number ??,

Mapping the Neural Networks of Patients with PTSD or CTE

Alex Owen and David Yang and Elliot Liu

Abstract No cure exists for most brain disorders. These disorders, including traumatic injury, mental disorder, and neurodegenerative diseases, cause damage or subtle changes to brain tissues and neurons. Brain disorders affect as many as one in six people worldwide. Its treatment and its resulting loss of production represent a substantial cost. As these damages and changes are difficult to track, current treatment only focuses on management of symptoms. However, the development of connectomics presents new ways to tackle these diseases. Our group is looking to map the brains of deceased patients of Post-Traumatic Stress Disorder (PTSD) and Chronic Traumatic Encephalopathy (CTE), analyze the neural connections on a micro level, and look to shed light on a more effective and more focused approach to treating these brain disorders. PTSD and CTE are two brain disorders that affect a large number of people in the U.S., and represent two types of brain disorders: those caused by physical force, such as CTE, and those caused by mental stress, such as PTSD. We will compare brains affected by these conditions and normal brains and look for differences in neurons and synapses.

1 Scientific Question

Is there a similarity in changes of neural connections in the brain after suffering through physical or mental trauma?

2 Processes

2.1 Data Collection Process Often, the slowest process of data collection during studies is turning the raw visuals from the microscope into an actual output.[1] Therefore, we will benefit dramatically from assistance in this area. Thus, we will develop a layer of data extraction functions to sit on top of the microscope visual software

2010 Mathematics Subject Classification: Primary X001, Y002; Secondary Z003
Keywords: typesetting, guide for authors

that we will use for automated visual capturing. This will speed up the slowest step of the process, and allow for more control of the data that we collect. This data that we collect will be available for download on the site that we create for the public.

Information Extraction Process Because our pre-processed and processed data will be available online, it will make sense for us to open-source our information extraction software. We will create a suite of services to extract the exact information that we are looking for. We will first need the images from the microscope to be segmented into different areas of the brain. There can be some tuning involved, but ideally, we would like to have a clustering algorithm that would work to gather together images of each lobe in order to derive form of the brain. This can be done with the information on the location of each photo. These images will then be characterized/tagged on function in terms of how they act in regards to the condition(s) being surveyed. Then we will perform a graph extraction on the data in the areas that we care the most about. For example, one of the events that occurs with a concussion is that the "neuron superhighway" in the middle of the brain. In this case, we would be looking to make sure that the neurons in that area are packed as tightly and are as connected as the same area on other patients.

Our statistical models will cover all the areas of the brain in question (the data with the correct tags in the graphical model)

3 Hardware and Facilities

For consistency in our brain scans, brains from veterans who have suffered from chronic PTSD and athletes who have suffered from CTE, mainly football players with a history of concussions will be used. Since this is a project of such a large scale, we plan to use a large number of samples, approximately 200 brains of each type will be acquired. Although we anticipate some cost in the acquisition of samples, we hope to receive samples through donation of brain tissue as well.

In terms of facilities, the proximity of the National Institute of Health (NIH) to Baltimore makes it a viable option to conduct research. The John Edward Porter Neuroscience Research Center is one ideal place to conduct research as it is run by the NIH and would have the necessary space, equipment, and technology to conduct our research and store our data. Another option is the Johns Hopkins Applied Physics Lab (APL). These facilities would provide us with standard lab equipment that can be used to slice the brain samples into pieces that can be scanned.

Since we are attempting to scan various parts of the hippocampus, prefrontal cortex, areas that are both affected by CTE and PTSD, we will be using an EM microscope to scan very thin slices of those parts of the brain. One microscope that could be used is the ZEISS MultiSEM 505/506 microscope. ItâĂŹs parallel scanning abilities, along with its ability to scan an area of 1 cm2 at 4 nm pixel size in less than 3 hours makes it ideal for this project. Additionally, we would require computers capable of rendering images of the neurons after the have been scanned and running algorithms to find correlations between the two different types of brains.

4 Data

4.1 Data Upload: In order to foster more research in this area, we will post all of our findings on a hosted website. Our data upon collection and then extraction will be automatically uploaded to this site for use by other groups.

4.2 Data Storage: Data storage and DevOps is not the core competency of the engineers and scientists on this project, so we will use a pre-built solution like AWS S3. There might be some more functions that we need in terms of visualization and formatting, but those would be abstracted from the actual storage itself. With AWS S3, we will be able to have our public facing site and our actual analysis tools both point to the same database without any extra configuration.

5 Cost

Due to the scale of this project, we have divided up our budget into the following categories:

1. 1 billion dollars for acquisition of brain samples and SEM microscopes
   - SEM microscope is estimated to cost around 200,000 dollars each.
2. 3 billion dollars for partnership with NIH and them allowing us to use their facility
   - The large amount for the NIH is due to the importance of their facilities being available for our use.
3. 2 billion dollars dedicated to scanning and processing the data
4. 2 billion dollars for storing data
5. 1 billion dollars for salary
   - This is dependent on how many people will actually work on the project, but the maximum will be 1 billion dollars for salary.
6. 1 billion dollars for manual labeling of data for Machine Learning Algorithms

References

[1] Tran Minh Quan, "FusionNet: A deep fully residual convolutional neural network for image segmentation in connectomics," *Cornell University Library*,(2016), MR 2667904.

[CTE] "Chronic traumatic encephalopathy," *Wikipedia*

[John Edward Porter)] "The John Edward Porter Neuroscience Research Center," *National Institutes of Health*

[Reed-Guy] Lauren Reed-Guy, "Brain Disorders: Causes, Symptoms, and Diagnosis," *Healthline Media*,(2017),

[UN] "Nearly 1 in 6 of world's population suffer from neurological disorders âĂŞ UN report," *UN News Center*,(2007),

[PTSD] "PTSD Statistics," *PTSD United*

[Microscopes] "The Worlds Fastest Scanning Electron Microscopes," *ZEISS*