Detection of Ocular Dominance Columns

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The primary visual cortex or V1, is a centre for visual stimuli processing in the brain. Extensive research trying to understand the function and anatomy of the V1 is of paramount importance when trying to describe how the brain processes visual information. Two pioneers in the field, David Hubel and Torsten Wiesel studied the V1 of cats during the 1950's and 1960's. Using an electrode while presenting visual stimuli, they found that at certain areas of the V1 neurons only respond to certain types of visual stimuli. This was in agreement with studies conducted by Vernon Mountcastle, who studied the somatosensory cortex, a location of the brain which is responsible for the sense of touch. Mountcastle called these type of clustering neurons columns, thus the idea of columns in the V1 was born.

Hubel and Wiesel found two types of columns: Ocular Dominance (OD) columns which respond either to left or right eye stimuli and Orientation Columns which respond to the orientation of the presented stimuli. The structure of OD columns are often described as a zebra like pattern on the V1 where the black and white stripes represent either left or right eye neurons. Although OD column structure has been measured in several species including humans, their function still largely remain a mystery.

Since Hubels and Wiesels discovery different techniques for revealing OD structures has been invented, the problem with these techniques is that they are highly invasive and are very impractical if the studies are to be conducted on many individuals. fMRI however is a non-invasive medical imaging technique with the possibility of studying sub-millimetre structures such as OD columns. Although several articles have reported OD columns using fMRI, it is difficult to quantify how well this technique performs since we are actually not able to physically peek inside the brain.

mVibe is an fMRI simulation environment, which is designed to mimic the measurements of an fMRI. A realistic simulation environment such as mVibe enables the possibility to see how well OD detection using fMRI performs. The two main research question of the thesis was to purpose a model to extend mVibe to take into account binocular OD columns and to simulate the fMRI responds using the biophysical models from mVibe.

The proposed binocular model showed great similarities to real measurements of the behaviour of OD columns. The model also purposes a few predictions that could possibly be used to test the assumptions of the model. The simulated fMRI activity showed that although possible to measure OD columns, the overall structure will tend to cluster together making it difficult to image OD columns at certain locations.

Using fMRI to study small scale structures such as cortical columns not only opens the possibility to better understand their function, but is also more ethically viable for humans and animals. The obtained results might also be used to create other techniques of analysis which are more sensitive to OD column like structures.