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Visualizing the Correlation between Human Brain Structure and Function

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Background

Most of the human brain's activity occurs on its outer surface, known as the gray matter. Within this outer surface is the white matter, which is composed of neural pathways connecting different areas of the brain. Modern neuroimaging techniques can produce estimates of both the changing activity within the gray matter, as well as the structure of the white matter. Scientists then use multiple software tools to visualize and investigate this collected data.
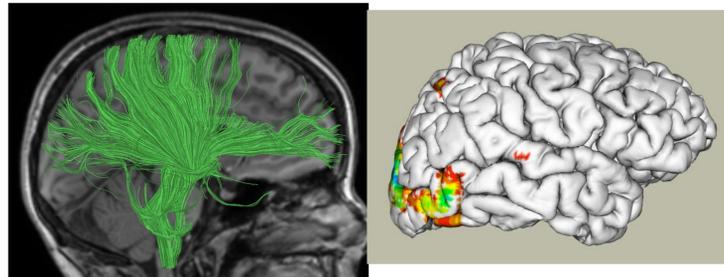
Neural pathway estimates of the white matter

Gray matter with activation data overlay

Motivation

Scientists are interested in the correlation between white and gray matter. For instance, two co-active regions of the gray matter may have a linkage within the white matter. The visualization tools used by scientists are limited in their ability to produce useful visualizations of these possible correlations. This is primarily because any visualization of the gray matter tends to occlude the underlying pathway structure of the white matter. Also, the complexity of the human brain's surface makes common techniques for solving issues of occlusion impractical. We investigated some alternative visualization techniques for solving this problem.

Collaboration

Over the course of this research we worked closely with two prominent groups of neuroscience researchers: Michael Beauchamp's Laboratory of Multisensory Integration at University of Texas Medical Center and Brian Wandell's Vision Imaging Sciences and Technology laboratory at Stanford University.

The visualization techniques were prototyped within an existing software tool used by our collaborators as part of their workflow. This allowed our collaborators to evaluate the prototypes within the context of their everyday work.

Visualization Techniques
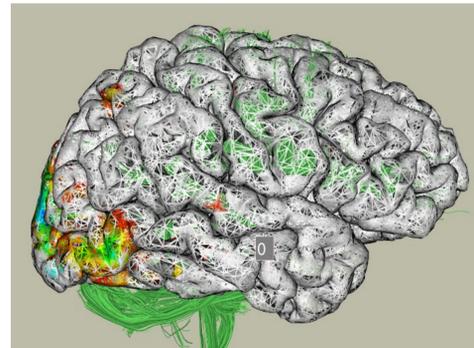
Rendering the surface in **wireframe** (left) allows scientists to visualize both the pathways and the surface within a single view. However, the geometric complexity of both the surface and the pathways makes the visualization hard to interpret.

Viewing the pathways and the surface in **separate views** (right) allows scientists to view both sets of data in full. While this makes it more difficult to understand the connections between the data sets, the viewing angle can be linked between the views to aid the user.
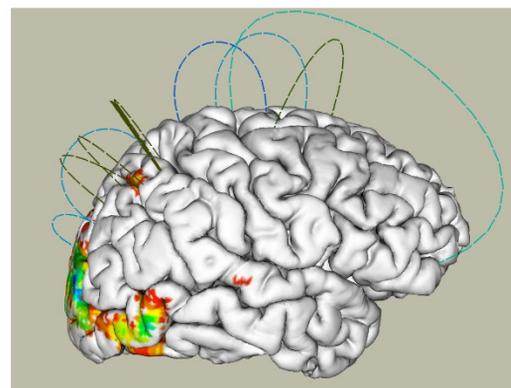
Abstraction (left) can be used to simplify the representation of brain connectivity, allowing both connectivity and activity information to be displayed in a single view. We used arcs to show pathway connections across regions of the gray matter. We then use color to encode additional information about the pathway. In this case, the color indicates the underlying pathway's length. While this technique solves the visibility problem within a single view, the information lost in the abstraction can hinder the user's ability to interpret the data. For instance, a scientist can no longer ascertain the plausibility of a pathway by inspecting its shape.

Results and Future Work

For interactive exploration of their data, scientists expressed the most excitement about the multiple view technique. This technique gave them full visibility of both data sets and allowed them to quickly understand connections between the views by linking the viewing angle.

When the goal is to produce a static illustration (e.g., for publication), the multiple view technique is not as effective, since it can be difficult to perceive the relationship between the views without interaction. We will continue to search for an effective single-view visualization that conveys the important aspects of the data, while maintaining visibility. The wireframe rendering and abstraction showed promise, but remain to be evaluated.

We are working to implement all three techniques within a new version of the DTI-Query software to be released publicly.

Acknowledgements