Competitive Tractography for Extracting Brain Connectivity from Diffusion MRI

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Introduction:

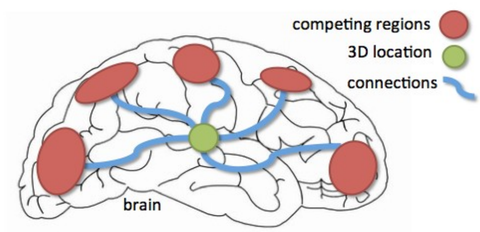
Diffusion magnetic resonance imaging (dMRI) provides us with the ability to non-invasively infer the directions of coherently aligned axons in the brain's white matter. This innovation has led to the computational problem of tractography: the delineation of neural connections in the brain. We introduce the notion of competition into tractography algorithms and use it as a mechanism to reduce the likelihood of discovering erroneous connections.

Methods:

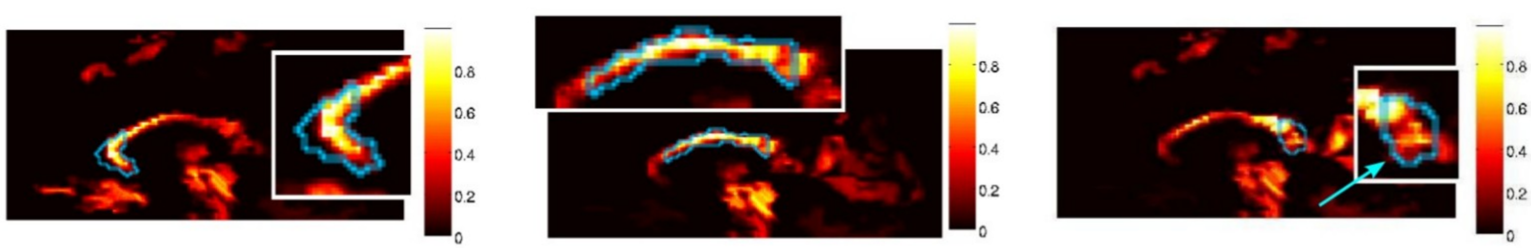
For every location x (green in figure a) in the brain, we wish to compute the probability of an axonal connection (blue) between x and a set of target regions (red). Virtual particles are inserted at location x and their diffusion is simulated according to the dMRI data until they reach one of the target regions. The likelihood of an axonal connection to a target region becomes the fraction of particles that reached that target region *before* any other target region. This temporal aspect of the simulation is what introduces the competition into our algorithm. The resulting algorithm is an example of the random walker technique and allows us to solve the problem without simulation, but instead through solving a system of equations [1].

Experimental Results:

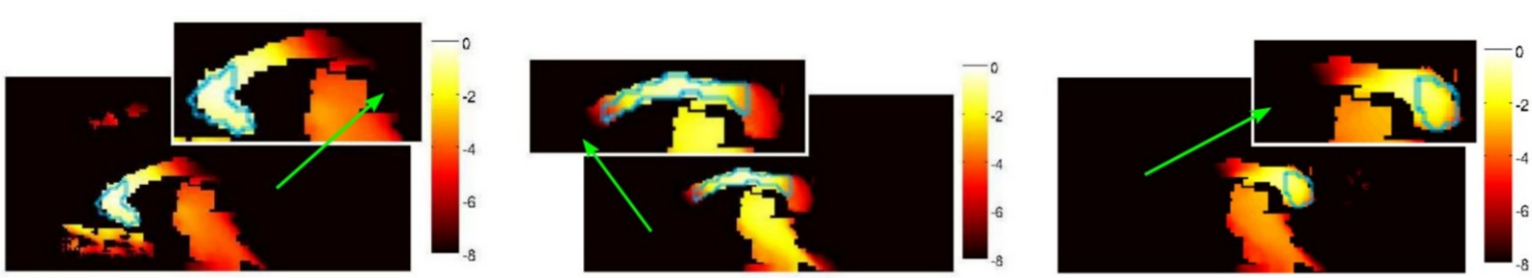
Results on the analysis of the Corpus Callosum in figures (b) and (c) shows the connection probabilities from our algorithm are more robust to noise (see blue arrow) than [2] while reducing erroneous connectivity outside the targeted tracts (see green arrows).



(a) Schematic diagram of the tractography problem being solved. The goal is to find the strength of the connections (blue) between the seed (green) and the competing target (red) regions.



(b) Connection probabilities to each target region using minimal path tractography (without competition) [2].



(c) Proposed competitive tractography. Connection probabilities shown in log-space.

References:

[1] L Grady, IEEE Trans. Patt. Anal. Mach. Intel.:28 (2006) 1768-1783.
[2] A. Zalesky, IEEE Trans. Med. Imag.:27 (2008) 1458-1571.