Ecole Doctorale STIC

Sciences & Technologies de l'Information et de la Communication

MINES ParisTech

Université Nice Sophia Antipolis

ED STIC - Proposition de Sujets de Thèse

pour la campagne d'Allocation de thèses 2015

Axe Sophi@Stic :	BioSanté|
Titre du sujet :	Quantifying Brain Connectivity Through Diffusion MRI
Mention de thèse :	Informatique
HDR Directeur de thèse inscrit à l'ED STIC :	Rachid Deriche

Co-encadrant de thèse éventuel :

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Laboratoire d'accueil :	INRIA

Description du sujet :

Human brain function remains one of the greatest quests taken by current science. Recent evidence shows that the brain can be divided into different areas, each one with a
specific function such as hand movement, vision, etc. However, analyzing complex brain functions involving several areas remains one of the most important open problems in
the field. This underlines the need to understand the architecture of brain connections, or structural connectivity, and how it influences information processing in the brain.

In this PhD project, we will develop techniques to quantify structural connectivity and relate this connectivity with electrical conductivity in the brain.
We will use two different datasources. First, a large public database of brain images: the Human Connectome Project. This database includes high-quality MRI images, including

diffusion and functional MRI and detailed demographic information from 220+ subjects. Second, in close collaboration with the neurosurgery and radiology departments of the University Hospital Center of Nice (CHU Nice), we will validate the developed connectivity quantification models against intrasurgically-acquired measures.

Background

The functional areas, or nodes, of the human brain and their inter-connectivity, collectively the “connectome”, remain poorly understood. Critically, there is a dearth of computational methods for reliably identifying structural nodes of the brain and quantify their inter-connectivity in vivo, despite an abundance of high-quality data from the Human Connectome Project (Barch et al., 2013; Ugurbil et al., 2013). Devising and validating methods for investigating the human connectome has therefore taken added significance.

Structural connectivity patterns provide important insight into the physiological mechanisms of network organization and its functional role (see e.g. Hagmann et al 2010). In particular, structural connectivity adds important information to the understanding of the anatomical substrate of brain regions which function synchronously, i.e., are functionally connected (e.g. Ford et al. 2010). The Inria Athena lab (https://team.inria.fr/athena) has already implemented different measures to explore the white matter of the human brain through the analysis of Diffusion MRI (dMRI) images (Descoteaux, Deriche, Knösche, & Anwander, 2009; Papadopoulo, Ghosh, & Deriche, 2014; Sanguinetti & Deriche, 2014; Girard et al 2015). In this project, we will take these measures one step further to bring them closer to the quantification of brain connectivity and relate them to the microstructure and electrophysiology of the human brain.

Anwander, A., Tittgemeyer, M., Cramon, von, D. Y., Friederici, A. D., & Knösche, T. R. (2007). Connectivity-Based Parcellation of Broca's Area. Cerebral Cortex, 17, 16–825. doi:10.1093/cercor/bhk034

Barch, D. M., Burgess, G. C., Harms, M. P., Petersen, S. E., Schlaggar, B. L., Corbetta, M., et al. (2013). Function in the human connectome: Task-fMRI and individual differences in behavior. NeuroImage, 80, 169–189. doi:10.1016/j.neuroimage.2013.05.033

Behrens, T. E. J., Johansen Berg, H., Woolrich, M. W., Smith, S. M., Wheeler-Kingshott, C. A. M., Boulby, P. A., et al. (2003). Non-invasive mapping of connections between human thalamus and cortex using diffusion imaging. Nature Neuroscience, 6, 750–757.

Descoteaux, M., Deriche, R., & Anwander, A. (2007). Deterministic and Probabilistic Q-Ball Tractography: from Diffusion to Sharp Fiber Distributions. INRIA.

Descoteaux, M., Deriche, R., Knösche, T., & Anwander, A. (2009). Deterministic and Probabilistic Tractography Based on Complex Fiber Orientation Distributions. IEEE Transactions on Medical Imaging, 28(2), 269–286.

Hagmann, P., Sporns, O., Madan, N., Cammoun, L., Pienaar, R., Van Wedeen, J., et al. (2010). White matter maturation reshapes structural connectivity in the late developing human brain. Pnas.org.

Jbabdi, S., Woolrich, M. W., Andersson, J. L. R., & Behrens, T. E. J. (2007). A Bayesian framework for global tractography. NeuroImage, 37(1), 116–129.
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regions in human medial frontal cortex. Proceedings of the National Academy of Sciences, 101(36), 13335–13340. doi:10.1073/pnas.0403743101
Papadopoulo, T., Ghosh, A., & Deriche, R. (2014). Complete Set of Invariants of a 4 th Order Tensor: The 12 Tasks of HARDI from Ternary Quartics (Vol. 8675, pp. 233–240).
Presented at the Medical Image Computing and Computing Assisted Intervention, Cham: Springer International Publishing. doi:10.1007/978-3-319-10443-0_30
Sanguinetti, G., & Deriche, R. (2014). Mapping Average Axon Diameters under Long Diffusion Time. IEEE International Symposium on ….
Ugurbil, K., Xu, J., Auerbach, E. J., Moeller, S., Vu, A. T., Duarte-Carvajalino, J. M., et al. (2013). Pushing spatial and temporal resolution for functional and diffusion MRI in the
Human Connectome Project. NeuroImage VL -, 80(0), 80–104.
Wassermann, D., Makris, N., rathi, Y., Shenton, M. E., Kikinis, R., Kubicki, M., & Westin, C.-F. (2013). On Describing White Matter Anatomy: The White Matter Query Language.
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English version:

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