Quantifying uncertainty in Diffusion MR Tractography reconstructions

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Purpose:
Diffusion MRI has been highly successful in estimating the local orientation of tissue non-invasively [1]. In the brain, these estimates have been extensively used to reconstruct the 3D structure of white matter pathways in individual patients [2]. This technique, known as tractography, has clear clinical applications, particularly in surgical planning [3]. Currently, however, there is no robust way to quantify uncertainty in tractography reconstructions: there is no way to quantify how confidently the data specifies a particular reconstructed shape or how to be sure that apparent gaps in white matter are genuine and not artefacts of the reconstruction process. Quantifying confidence in tractography is crucial if its clinical potential is to be fully realised.

This project is a collaboration between tractography experts at ICH and specialists in measurement science at the National Physical Laboratory who have expertise in error propagation and uncertainty estimation. The project also works closely with neurosurgical colleagues at GOSH to guide the outcomes and ensure that project outputs are clinically and surgically usable.

Objectives:
The specific objectives will be:
(i) perform metrological analysis and error propagation from noise and uncertainty in the underlying MR data through the tractographic reconstruction in order to quantify uncertainty in outputs;
(ii) investigate the effects of high-level considerations such as fibre length and curvature on the confidence of reconstructions;
(iii) produce clinically useful representations of reconstruction uncertainty, and work with clinical colleagues to deploy these in the surgical planning process where appropriate.

If successful, we will develop a novel tractography pipeline which includes quantitative estimates of uncertainty and software which implements it. Where appropriate we will work with colleagues at UCLB to copyright and/or patent these outputs as appropriate.

Skills to be obtained:
During this project, the student will learn key technical skills in MR physics, diffusion MRI techniques and approaches, metrology & statistics, and scientific visualisation.

The PhD student will also obtain generic skills by attending relevant courses run by UCL, particularly those run at ICH as part of the DIBS MRI and imaging foundation lecture series. The student will be supervised by a team of researchers with expertise in diffusion MRI, modelling & analysis, tractogaphy, and statistics, providing an ideal environment to facilitate their progression as a scientific researcher.

References
[1] Le Bihan D, Iima M (2015) Diffusion Magnetic Resonance Imaging: What Water Tells Us about Biological Tissues. PLoS Biol 13(7): e1002203. https://doi.org/10.1371/journal.pbio.1002203
[2] MR tractography: a review of its clinical applications. Yamada K, Sakai K, Akazawa K, Yuen S, Nishimura T, Magn Reson Med Sci. 2009;8(4):165-74.
[3] White matter tractography for neurosurgical planning: A topography-based review of the current state of the art. Walid I. Essayed, Fan Zhang, Prashin Unadkat, G. Rees Cosgrove, Alexandra J. Golby, and Lauren J. O'Donnell. Neuroimage Clin. 2017;15,659-672. doi: 10.1016/j.nicl.2017.06.011