Development and validation of "digital twin" models as explanatory and predictive tools in people with brain tumours

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Project Summary: Brain tumours cause many difficulties – including cognitive, neurological, and psychiatric problems – and these change over time, linked to tumour progression and treatment interventions. It is challenging to account for these problems based on available data (e.g., scans), and to predict what will happen. We have gathered multi-modal data, e.g., on speech and cognition, in people with brain tumours, alongside clinical scans. However, what is missing is a unifying framework to integrate these data at the individual patient level to produce a clinically-informative tool to predict outcomes and evaluate treatment strategies.

Recently, the advent of whole-brain simulations of brain activity has created a paradigm for integrating biological, neurophysiological, cognitive, and clinical data in individuals, via the creation of "digital twins": biophysically-inspired models of brain function, derived from differential equations underlying the biophysics of regional neural activity. Importantly, this incorporates individual-level data (e.g., MRI scans) and the model is fitted to a patient's own neurophysiological data (e.g., electroencephalography/EEG). This approach has recently been demonstrated in epilepsy surgery.

Digital twins unlock several capabilities: Firstly, by modelling the generating process, we can examine mechanistically how a tumour produces an individual's problems. Only rarely is this mapping simple, e.g., a tumour in the motor cortex producing weakness. Rather, a digital twin enables a complex systems approach to link tumour-related disruption to the brain's structure to abnormalities in the dynamics of functional brain networks important for cognitive/neurological function. Secondly, by incorporating biological information about spatiotemporal tumour spread, we can predict what problems are likely to develop. Thirdly, we can test treatments in silico, asking what would happen if the generative model were perturbed by, e.g., surgery, thus providing a means to guide individualised therapy decisions.

In this project, we will develop and validate a digital twin approach using our multi-modal data in people with brain tumours, acquiring high-density EEG to provide detailed neurophysiological signals. We will test whether digital twins can (1) explain the range of observed problems (2) predict the effects of tumour progression, and (3) predict the effects of treatment.

The student will receive excellent multi-disciplinary training covering mathematics, computer science, neuroscience, and neurophysiology

Literature references

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Key words: 1. digital twins 2. computational models 3. brain tumours 4. neuroscience 5. brain dynamics
Project suitable for a student with a background in: Life Sciences, Computer Science, Physics or Engineering, Mathematics, Statistics, Epidemiology