| Project Details | |
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| Project Code | MRCNMH25Ca Slator |
| Title | AI-enhanced Quantitative MRI for Multi-Scale Multi-Modal Neuroscience |
| Research Theme | Neuroscience & Mental Health |
| Summary | This project will develop advanced machine learning methods for medical imaging to non-invasively characterise brain tissue structure and function. The project focuses on quantitative MRI, which produces maps of biologically meaningful values, such as axon diameter, blood flow rates, and cell sizes, enabling earlier and more specific disease diagnoses. However, its clinical use is limited due to sensitivity to noise, affecting reproducibility and repeatability. This project will enhance noise robustness in quantitative MRI through new machine learning techniques, and apply them to a unique and comprehensive neuroimaging dataset to improve brain insights and advance quantitative MRI's impact on patient care. |
| Description | This project will drive groundbreaking innovation in the field of quantitative MRI, addressing a critical need for precise and efficient non-invasive neurological measurements. These developments can reduce scanning costs, increase patient comfort, detect more subtle pathological effects, and facilitate earlier access to treatment.<br>Quantitative MRI (qMRI) offers the potential for precise measurement of brain tissue properties but is not yet used clinically due to issues with speed, noise robustness, and reproducibility. This project aims to develop a new machine learning framework to address these challenges and make qMRI viable for neurological applications. The key innovation is to move beyond the assumption that each pixel in an image is independent, which will enhance the calculation of biologically relevant parameter maps, improve noise robustness, and detect subtle changes in brain tissue composition. These techniques will be applied to a cutting-edge neuroimaging dataset to reveal new insights into brain structure and function. By advancing qMRI methods, this project seeks to enable more accurate, rapid, and non-invasive quantification of neurological conditions, ultimately enhancing patient care in neurology.<br>The overall goal of quantitative MRI techniques that are newly sensitive to neurological structure and function will be attacked by completing the following overlapping objectives.<br>Objective 1: New deep learning framework for quantitative MRI<br>The student will conceive, develop, and implement a new machine learning framework to enhance quantitative MRI (qMRI) maps. They will have the flexibility to choose the best approach, leveraging recent advances in machine learning for qMRI analysis, including unsupervised (e.g., Slator et al., 2021), supervised (e.g., Palombo et al., 2020), and self-supervised (e.g., Sen et al., 2023) methods. The core idea is to develop techniques that consider qMRI images holistically, accounting for interdependencies across images. The student will explore and develop new architectures for both self-supervised and supervised analysis, including variational autoencoders (VAEs), convolutional neural networks (CNNs) and vision transformers.<br>Objective 2: Testing and validation of framework on simulated data<br>The student will demonstrate the effectiveness of their new machine learning framework in a controlled setting by using realistic simulated |

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| | quantitative MRI data from Monte Carlo simulations. The goal is to test the framework where the ground truth is known and to show that it provides more precise results and exhibits greater robustness in the presence of noise.<br>Objective 3: Application to Welsh Advanced Neuroimaging Database (WAND) dataset<br>The new framework will be applied to enhance the quality of brain structure and function maps derived from the Welsh Advanced Neuroimaging Database (WAND) dataset, previously acquired at the Cardiff University Brain Research Imaging Centre (CUBRIC). By applying advanced machine learning methods to this dataset, the goal is to produce more accurate and detailed maps of brain tissue properties. This improved mapping will enable more precise biological insights into brain structure and function, ultimately advancing our understanding of neurological processes and potentially leading to better diagnostic and therapeutic strategies.<br>These three objectives will lead to several key project deliverables: a new machine learning framework for quantitative MRI and accompanying open-source code to facilitate broader community use of the new methods. Additionally, the student will be expected to present the results at national and international conferences and publish findings in relevant journals.<br>The student would be based in the world-leading Cardiff University Brain Research Imaging Centre (CUBRIC) and be an active member in the Medical Image Computing and MicroTeam groups. |
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