Project title: Fairness in Cardiac Digital Twins

Project reference: DT4H_20_2024

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Aim of the Project

Digital twins of patients' hearts have the potential to enable personalised treatment and improved patient outcomes. This potential will only be fully realised if methods can be developed to create digital twins efficiently from patient data such as images. Efforts are already underway to achieve this aim using state-of-the-art artificial intelligence (AI) techniques. However, recent work has shown that AI tools for image analysis can suffer from hidden biases when trained with demographically imbalanced datasets, i.e. they can be 'unfair'. For example, AI cardiac image segmentation models can exhibit different levels of performance for different sexes and races, depending on the distributions of these protected groups in the training data of the model. Nobody has yet investigated possible biases in AI-based formation of digital twins, which relies on such technology. This project will perform the first such investigation and will focus in particular on the domain of cardiology.

Project Description

Bias and fairness in computer vision have been active research areas over the past 5 years. For example, the landmark Gender Shades project [1] showed that commercial video-based gender classification models exhibited significantly poorer performance for protected groups who were under-represented in the training data (such as women and darker-skinned subjects). Recently, research has demonstrated that such biases can also be present in AI models for medical imaging problems. Larrazabal et al [2] showed gender bias in AI-based classifiers for chest X-ray images and we were the first to show that AI-based cardiac MR image segmentation models could exhibit bias by race [3] and sex [4].

Recently, research effort has started to focus on the development of techniques to automate the formation of cardiac digital twins at scale [5]. These methods typically rely on AI image analysis tools, similar to those for cardiac MR segmentation that have previously been demonstrated to be biased. However, little is known about how these biases could impact the fidelity, utility and fairness of the digital twins.

In this project we will build on our track record in AI-based image segmentation, fairness, and cardiac digital twins. We will investigate the impact of AI segmentation bias on the downstream tasks of mesh formation and the subsequent use of the digital twins to answer specific clinical questions. The project would represent the first investigation into the fairness of digital twins in any domain.

The supervisory team have access to two large-scale databases of cardiac MR data which will be exploited in the project: (i) the UK Biobank, which currently contains more than 40,000 cardiac MR

scans, and (ii) the clinical imaging database of Guy's and St. Thomas' NHS Foundation Trust (GSTFT), which contains more than 10,000 patient cardiac MR scans.

Requirements:

The candidate for this project should have good computational skills and experience in, or a strong desire to learn about, artificial intelligence/deep learning for medical imaging. They should also be strongly motivated by a desire to reduce healthcare inequalities. Experience in physiology, medicine and/or biology would be desirable.

Suggested reading:

[1] Buolamwini & Gebru, "Gender Shades: Intersectional Accuracy Disparities in Commercial Gender Classification", Proceedings of Machine Learning Research, 2018.
[2] Larrazabal et al, "Gender Imbalance in Medical Imaging Datasets Produces Biased Classifiers for Computer-aided Diagnosis", PNAS, 2020.
[3] Puyol-Antón, et al, "Fairness in Cardiac MR Image Analysis: An Investigation of Bias Due to Data Imbalance in Deep Learning Based Segmentation", Proceedings MICCAI, 2021.
[4] Lee et al, "An Investigation Into the Impact of Deep Learning Model Choice on Sex and Race Bias in Cardiac MR Segmentation", Proceedings MICCAI FAIMI, 2023.
[5] Meng et al, "DeepMesh: Mesh-Based Cardiac Motion Tracking Using Deep Learning", IEEE Transactions on Medical Imaging, 2023.