Project title: Digital Twin-driven Cognitive Architectures for Adaptive Robots in Care Settings

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Aim of the Project

The aim of this project is to build a simulation environment for human-robot interaction in care settings. Specifically, it focuses on developing generative models to create virtual, holistic representations of human physical and cognitive behaviours. This simulation environment will be used to train an assistive robot to adapt to individual user profiles, including their capabilities and preferences.

Project Description

This project draws inspiration from a trial of a service robot conducted in the home of Anthony Walsh, an individual living with Motor Neurone Disease. During the trial, Anthony conveyed how the disease had drastically affected his physical and emotional wellbeing, sharing, “It has been very, very hard to cope with, especially because it means that I've lost my mobility. I must be dependent on others, which is not the person I was. I was very, very independent.”

Anthony also offered a vision of how assistive robots could support people like him with limited mobility, saying, “Things like reaching to pick up tissues, opening the fridge, and retrieving items from the shelf. It gives you back a little bit of your independence. It would free up time for others so they wouldn’t always have to be at your beck and call, allowing them to have some of their own time back.” This highlight the crucial need for independence that assistive robots could provide, especially in caring for those with physical limitations.

Assistive robots hold immense promise for society, offering potential benefits such as scaling social care services, fostering independence, and reducing loneliness. Yet a critical challenge persists: today’s robots still struggle to understand, anticipate, and adapt to the nuanced behaviours of their human partners. Human behaviours are rich, varied, and often unpredictable. While tasks like manipulation benefit from vast internet-scale datasets, no equivalent exists for human-robot interactions. Collecting data on real human-robot interactions is costly, complex, and poses ethical and privacy challenges, particularly in sensitive environments like personal care.

However, recent developments in motion synthesis present an exciting solution. Models based on transformer or diffusion techniques have shown they can generate realistic human behaviours using minimal input, such as text commands or user-defined trajectories. These advancements open opportunities to simulate human behaviours digitally, enabling the creation of "digital twins" of both humans and robots. Such simulations could provide robots with varied, controlled training environments, allowing them to develop adaptive behaviours before deployment in real-world settings.

In alignment with this vision, this PhD project will focus on developing adaptive human-robot interaction capabilities within social care environments. Specifically, it will concentrate on scenarios where robots work alongside individuals with varying motor abilities, such as older adults or those with neurodegenerative conditions. The project aims to address three main research questions to drive this field forward:

1. How can we generate realistic and diverse human behaviours with limited data by leveraging Large Language Models (LLMs)?
2. How can robots learn a cognitive architecture that adapts their control policies and planning to accommodate diverse human movement capabilities and preferences in the simulated environment?
3. How can these approaches be successfully transferred to real-world environments?

The anticipated outcome of this research is to progress the functioning of assistive robots within real-world social care environments. Through simulated environments and adaptive cognitive frameworks, this project aims to develop robots that can adapt to the individuals they assist, ultimately enhancing both independence and quality of life.

Requirements:

This project requires a strong computational background (e.g. C++/Python strong competency) and a general understanding/enthusiasm to learn the biology of the system as well as strong communication skills required for cross-disciplinary research.