**Project title: Supporting the creation and maintenance of digital twins of healthcare contexts combining heterogeneous data sources**

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**Aim of the project**

The potential for using Digital twins of healthcare systems, to transform operations and outcomes is increasingly evident. The rate of benefits realisation, however, is limited by challenges in implementation. Digital twins of healthcare systems can be enhanced through the integration of real-world data alongside models, but these datasets are often large and intractable, having very different formats (eg CAD data vs process descriptions vs time and resource-usage data streams from routine monitoring). Building and updating these integrations is labour-intensive and error prone. This project will develop techniques to automate (part of) the integration, ensuring links can stay consistent over time. This research has the potential to unlock use-cases for digital twin models. You will research to what degree annotation-based mechanisms can be used to control the integration of heterogenous models.

**Project description**

Designers of healthcare systems aim to balance the cost and efficiency of healthcare delivery against outcomes and overall value for patients, carers, and other stakeholders. Modelled scenarios must be set against the reality of healthcare systems, which can be a dynamic situation—for example during winter pressure and pandemic circumstances, where clinical demand profiles and even physical infrastructure may rapidly change.

At the onset of the COVID19 pandemic, the modelling of pathogen transmission became mission critical [1]; one of several opportunities afforded by digital twins, for example, is to enhance and apply approaches like this to model and prevent wider plethora of healthcare acquired infections—which annually kill ~30,000 UK patients and cost the NHS ~£3bn [2]. Phenomena like pathogen transmission, medical device demand and workforce pressures are perturbed by high-demand situations like the pandemic, exacerbated by winter pressures and supply issues from resource depletion, international conflict and cybersecurity breaches [3]. In each of these very real challenges, Digital twins can simulate scenarios to test and optimise system robustness and performance, building on modelled realities of healthcare services that have sufficient fidelity, and ideally based on 'live', real data sources.

This requires good digital representations of buildings, resources, staff, patients, and processes, that are easily integrated and amenable to analysis and simulation. For example, optimising the placement of O2 containers across a hospital would be significantly enhanced by the analysis of typical transport routes for critical patients to help identify places where they may require access to O2 resupply. This may in turn be informed by true admissions bookings, historic data on usage patterns for oxygen. If such data can be incorporated into a digital twin *a priori*, simulations can be prepared more promptly, making digital-twin use more prevalent and accessible.

Many useful data sources exist, but they are in very heterogeneous formats and currently rely on labour-intensive manual integration. For example, consider the following scenario: we want to construct a digital twin of a hospital's physical infrastructure, the resources (e.g., medical devices, beds, materials, etc) available and their locations, and the staff workflows and patient flows that are enacted over this infrastructure. Such a digital twin can enable *what-if* analysis of proposed changes to processes or infrastructure via simulation experiments or *if-what* analysis [4][5] by searching the space of possible changes to identify the best response to a sudden change (e.g., a broken elevator blocking a typical route for transporting patients to an operating theatre). It must integrate multiple different data sources: CAD and BIM models of the hospital's physical infrastructure, models of the *logical* infrastructure (that is, how each area of the hospital is configured and used), models of the processes enacted in the infrastructure, and databases about the availability of resources in different locations. All these models need to be interconnected explicitly (e.g., we need to say which process steps rely on which resources in which logical spaces, which are allocated to which physical spaces) – this is currently a manual and labour-intensive process. Every time a model changes (e.g., because an elevator breaks down or because a process change is implemented), all connections must be checked and updated. Given the complexity of the models, this is a slow and highly error-prone task. If-what analysis, where many variant models must be generated and kept consistent, is impossible with the current manual model-enrichment processes.

The project aims to change the time cost of model integration from weeks to hours by exploring, in the context of specific scenarios provided by Guy's and St Thomas' Hospital Trust, to what degree it is possible to automatically generate integrated models from minimal high-level annotations of the existing independent models. What meta-data needs to be added to the different models and how realistic are the integrated models thus generated? How well can the generated integrated models support *what-if* and *if-what* analyses to improve the speed of decision making about changes to workflows, improving patient outcomes and delivery costs in a constantly changing hospital environment?

References:

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