Project title: Development of a digital twin to aid next-generation bronchoscopy tools with autonomous motion

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Aim of the Project

Flexible robots have recently gained attention in minimally invasive surgery for their potential to navigate the body's complex natural pathways under autonomous control, allowing for precise positioning and an overall increased efficiency of the surgery. The aim of this project is to develop a digital twin for a soft robot, to provide a platform for next-generation bronchoscopy tools that can achieve high precision autonomous motion.

Key challenges will include modelling of the soft robot that forms the basis of the bronchoscopy tool and its interaction with the human body, real-time visualisation of the system for a surgeon. Additionally, the formulation of a control algorithm based of the digital twin for accurate trajectory tracking.

Project Description

Current commercially-available robotic bronchoscopy systems need to be operated by a team of highly skilled operators, including a consultant, registrar and trained nursing assistants. This is because the system requires real-time clinician control to guide the bronchoscope through the lungs to the desired location. Furthermore, these systems are expensive, bulky and require simultaneous imaging to optimise diagnostic yield. The combination of these factors has led to a limited adoption of the technology to date.

At the same time, however, there is rapidly increasing demand for such technology to improve lung cancer diagnostics. Lung cancer is the commonest cause of cancer death in the UK: each year over 43,000 people are diagnosed with the disease, and a majority of these are at stage III or IV. Current 5-year survival rates are given at 15% and 5% for those diagnosed at stage III or IV, respectively. If lung cancer can be diagnosed earlier, mortality rates can be significantly reduced; with 5-year survival up to 92% for the earliest stage disease. However, to biopsy and potentially treat these early-stage nodules, next-generation technology is needed to reliably reach the nodule site and take a successful biopsy.

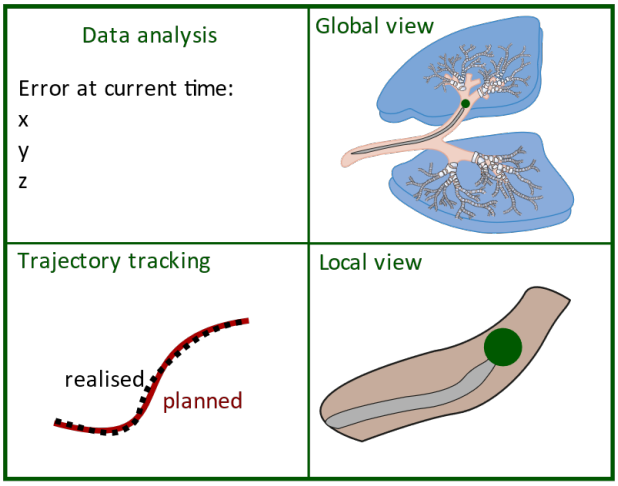
Recent technological developments provide the opportunity for a fully automated bronchoscopy tool, with guaranteed system stability, precise positioning into current hard-to-reach areas and reliable acquisition of biopsy samples from small nodules. This tool would take advantage of novel soft robotic technology, including continuum robots, and their uniquely flexible structure that can traverse natural

pathways with minimal invasiveness. This approach has the potential to improve patient outcomes through earlier diagnosis, quicker recovery times and reduced mortality rates, with no reduction in patient care.

To realise a fully automated bronchoscopy tool, one key remaining challenge is the development of a digital twin of the system. Therefore, this project aims to develop such a digital twin that can be used to automate the motion of the robot and its navigation through the lungs. The digital twin will comprise two main parts: the first for the soft robot and the second accounting for human movement due to cardiac and respiratory cycles. Data will be collected from a rig that has similar properties to a bronchoscope, together with sensors that will give the position of the robot and from which respiratory and cardiac cycles can be identified. An important aspect of the project will be to visualise the position of the human and robot in real time, as well as identifying optimal control for the robot to reach the desired location. The deliverable of this project is a 4D mathematical representation of the bronchoscopy system and the patient, capable of predicting patient-robot interaction, which can easily be visualised by medical personnel.

Requirements:

Strong mathematical modelling skills, programming/coding experience and experience of working with data.



Example visulisation of digital twin