Karlsruhe Institute of Technology

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Health Robotics and Automation

Concentric Tube Robot

Design and Fabrication of Concentric Tube Robot
— 1st December 2021 —

Master's Thesis

Context

Flexible medical instruments in minimally invasive surgery might be of great help to surgeons while operating next to or within critical structures and organs of the human body (e.g. blood vessels). Concentric tube robots consist of 3 to 4 small, pre-bent metallic tubes that are inserted into each other. The stiffness of the outermost tube then defines the initial curvature. By rotating and elongating the inner tubes a change in direction can be achieved. However, the increased flexibility of the robot comes at a cost. Most medical applications require instruments to be small, so tube diameters are often less than 5mm. Yet, they still have to carry a payload (e.g. a camera or cannulas) besides the other tubes of the robot. Thus, the design of the concentric tubes becomes quite challenging. Additionally, both trajectory planning and control of these robots requires high precision to prevent any damage to tissue.
The expected goal of the master's thesis is to adapt and construct an existing design and make it feasible for intraoperative usage (i.e. laser ablation of brain tumors) in close proximity to an MRI-device. This entails a material study for enabling actuation inside a high-tesla magnetic field while maintaining safety regulations for patients.

Figure 1: Team of surgeons in the operation theatre. Source: © Solvay 2020.

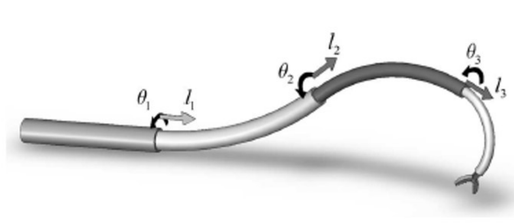

Figure 2: **Left:** Schematic control of a concentric tube robot. Source: © Dupont 2009
Right: Photo of a concentric tube robot. Source: © Mahoney 2019

Objective

Investigate, design and fabricate a conventional concentric tube robot that can be used within a MRI-device.

Task Summary

- **Study** relevant literature about concentric tube robots and MRI-related engineering constraints.
- **Design** the modified concentric tube robot.
- **Create** a mathematical model to investigate the workspace and control parameters with respect to the design parameters.
- **Fabricate** the robotic system and implement its control.
- **Evaluate** the robotic workspace and achievable forces at the distal end.

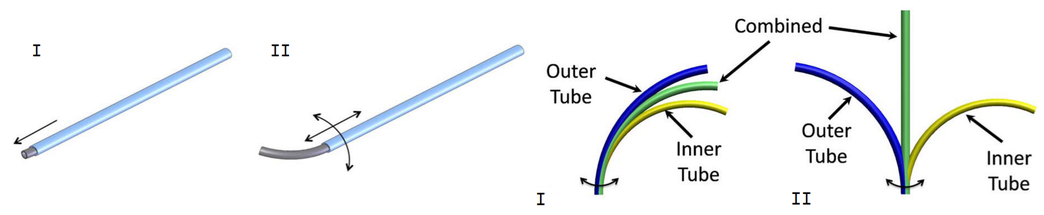

Figure 3: Two concentric tube systems. **Left:** Domination stiffness system **Right:** Balanced stiffness system. Source: © Dupont 2009

Requirements

Qualified candidates (engineering, physics, computer science) shall be interested in:

- Mechatronics
- Design, engineering
- Control
- Experimentation

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