Topology Cutting of Concentric Metal Tubes to Optimise Performance in Robotics

Thesis Proposal Outline: Kevin Ai Xin Jue Luo 998804245

Introduction

* Concentric tube robots are currently being developed for minimally invasive surgery.
* One of the main issues with concentric tube robots is that due to the high ratio between bending and torsional stiffness, the tubes can exhibit snapping behaviour, which is highly unpredictable.
* Currently, this problem can be avoided by using tubes with more gradual curvatures, however this diminishes the robot’s range of motion. There needs to be a better way of surpassing this challenge.

Research Question

* Is there a method of cutting metal tubes that is effective in improving the performance of concentric tube robots, and what is the degree of improvement?

Research Hypothesis

* There are a selection of topologies or cutting patterns that can improve range of motion by at least 20% by reducing the bending stiffness to torsional stiffness ratio on tubes with diameters of 4mm or smaller.

Research Objective

* The goal of this research is to empirically evaluate the effects of cutting tubes in order to improve the stiffness ratio and thus the range of motion of the robot.

Study Rationale and Literature Review

* The material limitations of concentric tube interactions can drastically decrease the range of motion, predictability, and controllability of concentric tube robots.
* The method of cutting patterns on tubes has been explored in the past, but the optimization of topology has not been studied.
* The snapping problem has been identified as an issue and major design limitation of such robots.

Specific Aims

* Simulate the effects of cut patterns on material properties via FEM software.
* Apply topology optimization methods and choose cutting patterns to be implemented.
* Cutting patterns onto tubes and testing their material properties via instruments and their range of motion when combined with other tubes.

Expected Outcomes/Significance

* Provide empirical data through real experiments on the effect of cutting topologies in improving range of motion and elimination of the snapping problem in concentric tube robots.
* Alleviate an impeding issue facing the design and control of concentric tube robots.
* Identifying one or two of the most effective topologies for tube cutting.