PhD Dissertation Defense Announcement
Mechanical and Aerospace Engineering Department
University of Texas at Arlington

COMPLIANT ROBOT MANIPULATOR FOR TRANSURETHRAL DIAGNOSIS

By: Samson A. Adejokun

Thesis Advisor: Dr. Panos S. Shiakolas

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Abstract

Minimally invasive procedures employ continuum manipulators; however, the internal human anatomy presents challenges relating to size, dexterity, and workspace for these manipulators. This research presents modeling, kinematic analysis, prototyping, and characterization of a micro-robotic manipulator to assess viscoelastic tissue properties of the bladder through transurethral palpation towards the diagnosis of bladder dysfunction, urinary incontinence, and early-stage bladder cancer.

The proposed micro-robot consists of two subsystems; a unique 4mm outer diameter tendon-driven continuum segment made from assembled "vertebrae" components with male and female snap-in features for joint assembly, an elastic tube encompassing each joint for controlled compliance and structural integrity that enters the bladder through the urethral, along with external prismatic and hyper-spherical joints to ensure higher dexterity and manipulability. The developed kinematic analyses avoid motion discontinuities and singularities for the desired poses anywhere in the confined space of the interior of the bladder wall.

The compliance of the tendon-driven proposed joint architecture was characterized as a function of the encompassing tube geometry and material properties using different modeling approaches (a strain energy model, a quasi-static model, and the principle of virtual work) and applied to a multi-joint continuum segment.

Limited functionality continuum modules with different joint lengths and multiple joints were prototyped for tension-bend angle characterization using a computer vision outfitted experimental setup. A comparison of the results from the experimental analysis and theoretical models shows high fidelity in predicting the continuum robot behavior. In addition, multiple existing additive manufacturing technologies were investigated for improving the fabrication quality of the continuum segment components while the pose error is evaluated using geometric manufacturing uncertainties.

This research demonstrates the proposed novel continuum segment module and its characterization for use in confined spaces in the human body for diagnostics purposes, employing the presented modeling approaches corroborated with experimental results.