Compliant Insertion, Motion, and Force Control of Continuum Robots

VANDERBILT UNIVERSITY
CTTC Center for Technology Transfer & Commercialization

Summary

Vanderbilt researchers have developed a framework for compliant insertion with hybrid motion and force control of continuum robots. This technology expands the capabilities of robotic surgery by providing continuum robots with the ability to autonomously discern, locate, and react to contact along their length and calculate forces at the tip, thus enabling quick and safe deployment of snake-like robots into deep anatomical passages or unknown environments.

Addressed Need

Minimally invasive surgical (MIS) and natural orifice procedures are limited by the absence of tools that can safely and precisely navigate the delicate passageways of the body. Passively compliant devices have the necessary flexibility to traverse some of these environments, but their inability to dynamically adapt to the curvatures of the passageways and lack of force control leave them an unsuitable option for many procedures. The present technology enables continuum robots to actively comply with external forces applied by the surrounding anatomy on the robot's body while analyzing the force at its tip, providing surgeons with the unprecedented ability to safely maneuver tortuous anatomical paths, explore unknown and constrained environments, and palpate and telemanipulate tissue with haptic feedback.

Technology Description

The novel combination of a hybrid force and motion control framework lays the foundation for full characterization of the interaction of the robot with its environment. This includes discerning collision, localizing contacts, estimating interaction forces, and autonomously complying with the environment along the entire robotic structure. Prior to insertion, a force threshold is set based on the properties of the surrounding tissues. This provides the robot with the necessary data to safely adjust its body shape to relieve the reaction forces upon contact with a force greater than or equal to the set threshold. At the tip, force sensors are integrated into an algorithm that yields force, shape, and stiffness estimation, ultimately creating a proprioception proxy previously unknown to continuum robot operators.

Unique Features and Competitive Advantages

- With this system, flexible robots can now take advantage of the benefits of flexibility while also possessing the stability to perform precise procedures
- The system is able to safely brace itself against the anatomy while ensuring that the tissue it contacts isn't damaged
- Bracing increases the stiffness and accuracy at the tool tip while ensuring that sensitive tissue isn't damaged for increased functionality
- Because the system keeps the robot from damaging surrounding tissues, the robot can be safely and rapidly deployed into unstructured or uncertain environments
- The force control algorithms provide a method for estimating forces at the tip which enables palpation, stiffness estimation, and shape estimation of unknown flexible environments

Intellectual Property Status

- Issued US Patent: US 9,539,726
- Issued US continuation: US 10,300,599
- Copyrighted software for force control algorithms
- Motion Control Publications: IEEE Transactions on Robotics (Vol. 30, Issue 4), International Journal of Robotics Research (Vol. 34, Issue 4), ICRA 2013, Compliant Insertion Video Example
- Force Control Publications: International Journal of Robotics Research (Vol 35, Issue 4), Force Controlled Shape Exploration Video Example

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