Real-Time 3D Reconstruction of Dexterous Continuum Surgical Robots

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Goals: A class of dexterous continuum robots known as concentric tubes has been used for a wide variety of applications. Researchers in the medical field have focused on their use as surgical tools, due to their ability to reach remote areas within the body by moving in highly curved paths. They consist of a set of hollow, pre-curved elastic tubes that fit concentrically, each one inside the next. As the tubes are rotated and inserted relative to each other, their curvatures interact to change the robot's overall shape as well as its tip position [1,2]. Although there are numerous models for the mechanical behavior of concentric tube robots, in practice, knowing the actual configuration at a given instant is a challenge. We propose to design a pipeline for real-time, three-dimensional reconstruction of the (moving) robots from video images. We will begin with the approach outlined by Camarillo [3], which employs two cameras (i.e., stereovision) and consists of four main steps: (1) camera calibration, both intrinsic and extrinsic parameters, (2) extraction of the robot silhouette from the background, (3) projection of the silhouettes into a volumetric space, and (4) voxel carving to create a visual hull [4,5]. At each point in time, we will compare this visual hull with a model of the robot that is based on its known mechanical properties and actuation history.

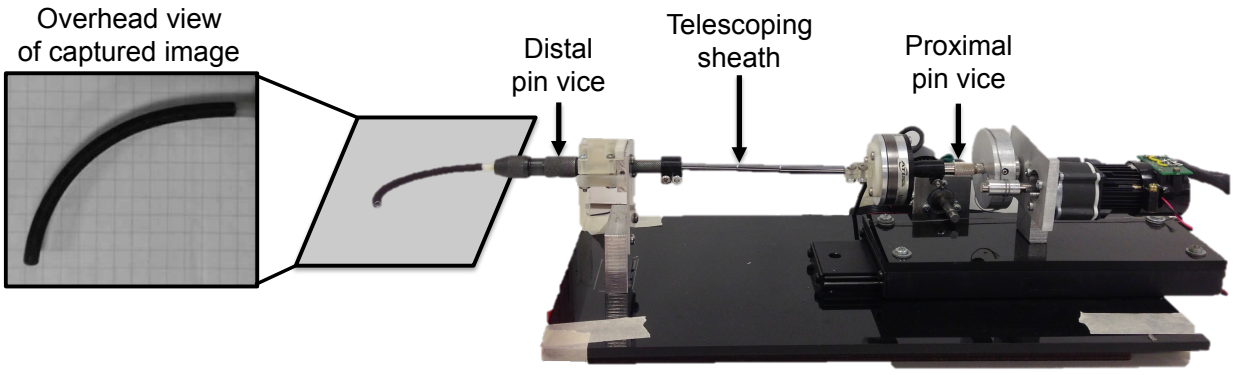

Fig. 1 – Experimental apparatus used to drive rotation and insertion of the concentric tubes. The inset image on the left shows an overhead view of the continuum robot. The proposed set-up will capture the robot from this and a second angle.

[1] R. Webster, A. Okamura, and N. Cowan, "Toward active cannulas: Miniature snake-like surgical robots," in *IEEE/RSJ Int. Conf. Intelligent Robots and Systems*, 2006, pp. 2857–2863.
[2] P. Sears and P. Dupont, "A steerable needle technology using curved concentric tubes," in *IEEE/RSJ Int. Conf. Intelligent Robots and Systems*, 2006, pp. 2850–2856.
[3] D. B. Camarillo, "Mechanics and control of tendon driven continuum manipulators," Ph.D., Stanford University, United States -- California, 2008.
[4] C. Wang, W. Yang, and Q. Liao, "A Space Carving Based Reconstruction Method Using Discrete Viewing Edges," in *2013 Seventh International Conference on Image and Graphics (ICIG)*, 2013, pp. 607–611.
[5] K. Narayan, J. Sha, A. Singh, and P. Abbeel, "Range Sensor and Silhouette Fusion for High-Quality 3D Scanning," in *IEEE Int. Conf. Robotics and Automation*, 2015.

* *We will not be using a DROID camera phone for this project.*