Team 15: DaVinci-Assisted Continuum Robot Navigation and Manipulation

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LABORATORY FOR Computational Sensing + Robotics

EN.601.656 SP23 *Computer Integrated Surgery II*

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Introduction

Building on DaVinci Surgical Robot and continuum robotic technologies, we've prototyped a continuum surgical robot that addresses the limitations of traditional rigid robots in surgical robotics systems,

The Problem

Conventional surgical robots are struggling with maneuvering in tight spaces and performing delicate tasks. The solution is needed to enhance the **reachability** and ***adaptability*** of surgical robots.

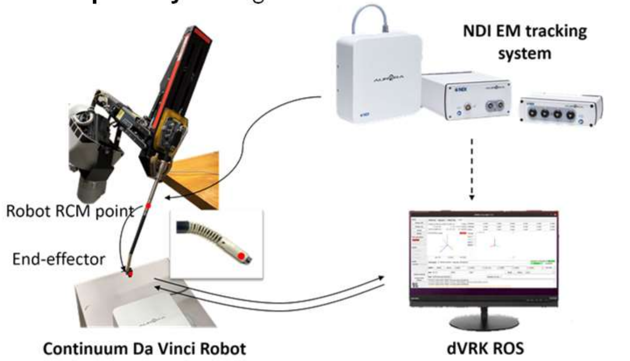


Figure 1. Workflow of the continuum dVRK

The Solution

- Prototyped a continuum robot that integrated an Acunav catheter into the dVRK baseplate. (Chenhan)
- Calibrated the NDI Aurora system for registration and precise control. (Jaspor)
- Modelled a unique configuration for continuum robot motion planning via dVRK GUI and ROS; apply forward and inverse kinematics.(Heyun)

a). Prototyping

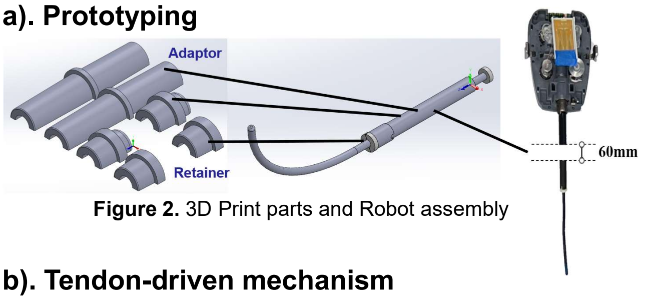


Figure 2. 3D Print parts and Robot assembly

b). Tendon-driven mechanism

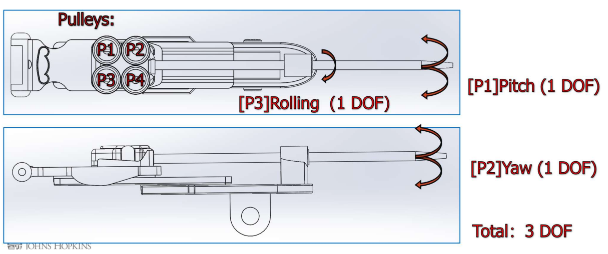
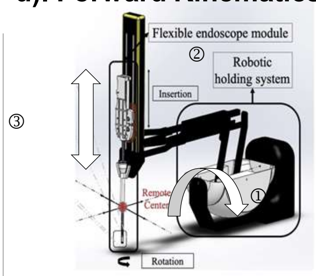


Figure 3. Mechanism

c). Calibration and registration

- NDI Aurora EM tracking system is combined into ROS with real-time response
- Use Least-square optimization to estimate RCM point

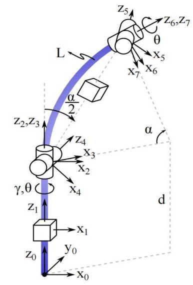
d). Forward Kinematics



q1: Yaw angle
q2: Pitch angle
q3: Insertion

D-H PARAMETERS

Link	a_i	α_i	d_i	θ_i
$0 \rightarrow 1$	0	$-\pi/2$	0	$q1$
$1 \rightarrow 2$	0	$-\pi/2$	0	$q2$
$2 \rightarrow 3$	a	$-\pi/2$	0	$q3$



α: Bending angle
Θ:Bending plane angle
γ: Rolling around Z-axis

D-H PARAMETERS

Link	a_i	α_i	d_i	θ_i
$0 \rightarrow 1$	0	0	d	0
$1 \rightarrow 2$	0	0	0	γ
$2 \rightarrow 3$	0	0	0	θ
$3 \rightarrow 3'$	0	$-\pi/2$	0	0
$3' \rightarrow 4$	0	$\pi/2$	0	$\alpha/2$
$4 \rightarrow 5$	0	$-\pi/2$	$2\frac{L}{\alpha}\sin\frac{\alpha}{2}$	0
$5 \rightarrow 6$	0	$\pi/2$	0	$\alpha/2$
$6 \rightarrow 7$	0	0	0	$-\theta$

Figure 4. Forward kinematics methodology [1] [2]

e). Inverse Kinematics

Pitch: $\phi_1 = 2R_c\alpha\cos\theta/D_{knob}$

Yaw: $\phi_2 = -R_c\alpha\sin\theta/D_{knob}$

Rolling: $\phi_3 = \gamma$

$$J^s = \left[\left(\frac{\partial g}{\partial q_1}g^{-1}\right)^{\vee} \dots \left(\frac{\partial g}{\partial q_n}g^{-1}\right)^{\vee}\right]$$

$$J^s\dot{q} = \begin{bmatrix} v^s \\ \omega^s \end{bmatrix}$$

Outcomes and Results

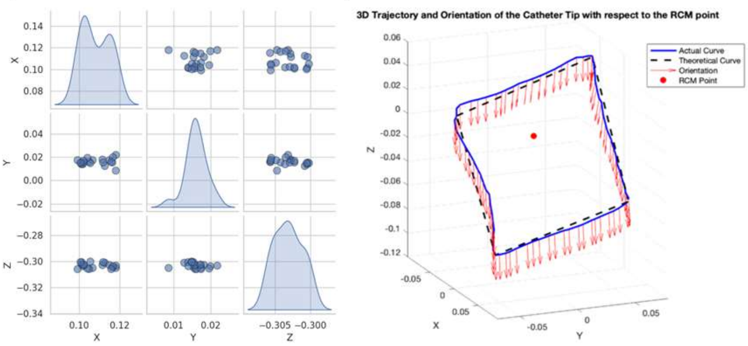


Figure 5. RCM calibration result (left); trajectory of catheter tip (right)

Future Work

Our project will be continued this summer, focusing on:

- Achieving accurate control of the integrated dVRK-AcuNav catheter system.
- Expanding our capabilities for manipulating the continuum robot through teleoperation.
- Implementing and testing ultrasound imaging on an appropriate phantom.

Credits

Heyun Wang: Kinematics modeling; Jaspor Jiang: NDI EM tracking; Chenhan Zhang: Design and manufacturing

Support by and Acknowledgements

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Reference

[1] Tobe, F., Max Planck Institute for Intelligent Systems, Frontiers Journals & Blog, International Federation of Robotics (IFR), University of Bristol, & Robotics, N. (n.d.). Intuitive Surgical da Vinci Surgical System gets big endorsement and new competition - Robohub. Retrieved May 10, 2023, from Robohub.org website: https://robohub.org/intuitive-surgical-da-vinci-surgical-system-gets-big-endorsement/

[2] Degirmenci, A., Loschak, P. M., Tschabrunn, C. M., Anter, E., & Howe, R. D. (2016, Maynconstrained catheter shaft motion in cardiac catheters. In 2016 IEEE International Conference on Robotics and Automation (ICRA) (pp. 4436-4442). IEEE.