Date: Apr 05
System: DaVinci-Assisted Continuum Robot Navigation and Manipulation System

1. Introduction

The DaVinci robot arm is a state-of-art surgical robot that offers 6-DOF translational and rotational joint control. Tendon-driven continuum robots, on the other hand, use flexible, curving structures to navigate tight spaces and perform delicate tasks. They have several advantages over traditional rigid robots, including improved accuracy, flexibility, and reachability. This project has wide application in surgical domains, where we aim to build a new design of dVRK and a corresponding navigation system that overcomes the limitations of traditional rigid robots and offers improved reachability in surgical robotics systems.

1.1 Background

As for the development of dVRK system, We aim to leverage the available resources of the DaVinci platform and dVRK resources at Johns Hopkins University, and will receive technical training from Anton Deguet in the Laboratory for Computational Sensing and Robotics (LCSR) to develop our navigation and manipulation algorithm.

1.2 Goal

The primary goal of this project is to develop a continuum robot navigation and manipulation system that combines the advantages of accuracy and reachability of the dVRK robot arm and the unique flexibility of a tendon-driven continuum robot end. To achieve this goal, we will first generate a new design of dVRK with flexible endoscope, and then build a corresponding system of navigation and remote actuation, where we will re-identify the workflow of the continuum dVRK starting from IO and PID. Throughout the whole design and development procedures, we will especially focus on adapting various surgical catheters to our continuum dVRK. The teleoperation between ARM and MTM is our highest expectation in the end.

2. User Requirements

The current da Vinci system is deployed in Hackerman Hall in LCSR's lab, which is maintained by Anton Deguet. Anyone want to use this system must acquire access from him and receive technical training. For more information, please look up da Vinci Classic User Manual.

For safety issue, whenever the user is operating the robot system, the emergency braking button must be hold by one of the users to avoid system crush.

Before the users end the experiments, they should disable the power through GUI, end the roscore, quit the GUI and log out the current account, so that they won't influence others work who share the same da Vinci system. The dVRK may also be detached and stored in correct place.

3. System Architecture

All the necessary information about daVinci Surgical Robot and Research Kit can be acquired from Intuitive Surgical Website (https://www.intuitive.com/en-us/products-and-services/da-vinci/systems) and dVRK's wiki page (https://github.com/jhu-dvrk/sawIntuitiveResearchKit/wiki).
From dVRK wiki page, the dVRK hardware and software stack is composed of:

1) Firmware on FPGA/QLA interfacing IO with FireWire

2) Lightweight C library on PC side to interface to FPGA via FireWire
3) C++ components using the cisst/SAW libraries to implement IOs, controllers (PID, tele-operation), console, GUI, bridges to ROS, ...
4) ROS wrapper around dVRK topics.

Our daVinci-assisted continuum robot navigation and manipulation system is deployed on a single PSM arm of da Vinci surgical robot. MTM might also be added in the future during teleoperation process, which is based on project progress.

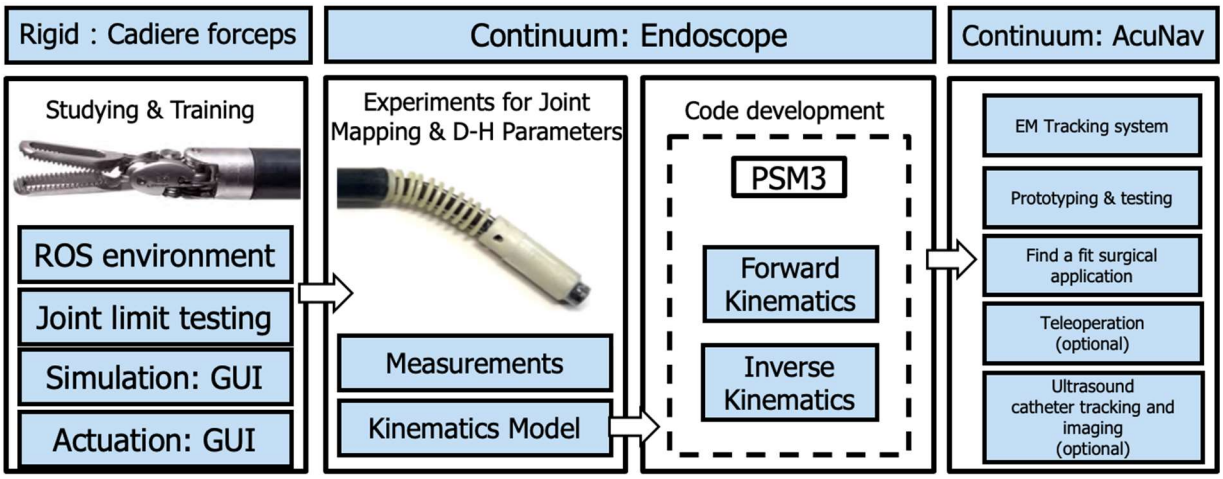
Elements: da Vinci Surgical Robot Arm: PSM #3; rigid dVRK (Cadiere forceps); self-defined continuum dVRK-endoscope; self-prototyped dVRK-AcuNav.

Operaing system: Ubuntu 20.04

ROS version: Noetic

Packages: dvrk-ros, crtk_msgs, crtk_python_client. All the packages are open source from dVRK wiki: https://github.com/jhu-dvrk/sawIntuitiveResearchKit/wiki/CatkinBuild.

4. **Workflow**



5. Validation

The testing plan for the daVinci-assisted continuum robot navigation and manipulation system will include a series of tests to evaluate the accuracy and reachability of the new design of dVRK and its corresponding navigation system. The tests will include:

1) Navigation accuracy test
The robot will be instructed to navigate through a predefined path and the accuracy of the navigation will be evaluated by measuring the distance between the actual path and the predefined path.

2) Reachability test: The robot will be instructed to reach various targets in a predefined workspace and the reachability will be evaluated by measuring the distance between the actual target reached and the desired target.

3) System stability test: The system stability will be evaluated by measuring the error in the system output over time, as well as by monitoring the system for any unexpected behavior.

6. Maintenance and Technical Support

Maintenance and Support

To ensure the proper maintenance and support of the daVinci-assisted continuum robot navigation and manipulation system, the following procedures will be followed:

1) Regular maintenance checks has been conducted on the system to ensure its proper functioning and to detect any issues early on.
2) A user manual is used to provide guidance on system operation and maintenance.
3) Technical support will be provided to users of the system to address any issues or concerns that may arise through Slack and Google groups.

7. Conclusions

The daVinci-assisted continuum robot navigation and manipulation system has the potential to revolutionize the field of surgical robotics by offering improved reachability and flexibility. The new design of dVRK and its corresponding navigation system has been developed with the aim of combining the advantages of accuracy and reachability of the dVRK robot arm and the unique flexibility of a tendon-driven continuum robot end. The system has been validated through a series of tests and found to meet the validation criteria. Proper maintenance and support procedures have been established to ensure the system's proper functioning and to address any issues that may arise. Further improvements and upgrades to the system will be made as necessary to improve its performance and functionality.