Evaluation of Virtual Remote Center of Motion for Minimally Invasive Surgery

Computer Integrated Surgery II
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Introduction

- UR5 model is imported to AMBF environment
- Virtual Remote Center of Motion (vRCM) was implemented for 9 DoF system (6 DoF UR5 + 3 DoF needle driver)
- First stage of evaluation reveals drawbacks of the mathematical RCM formulation, room for improvement.

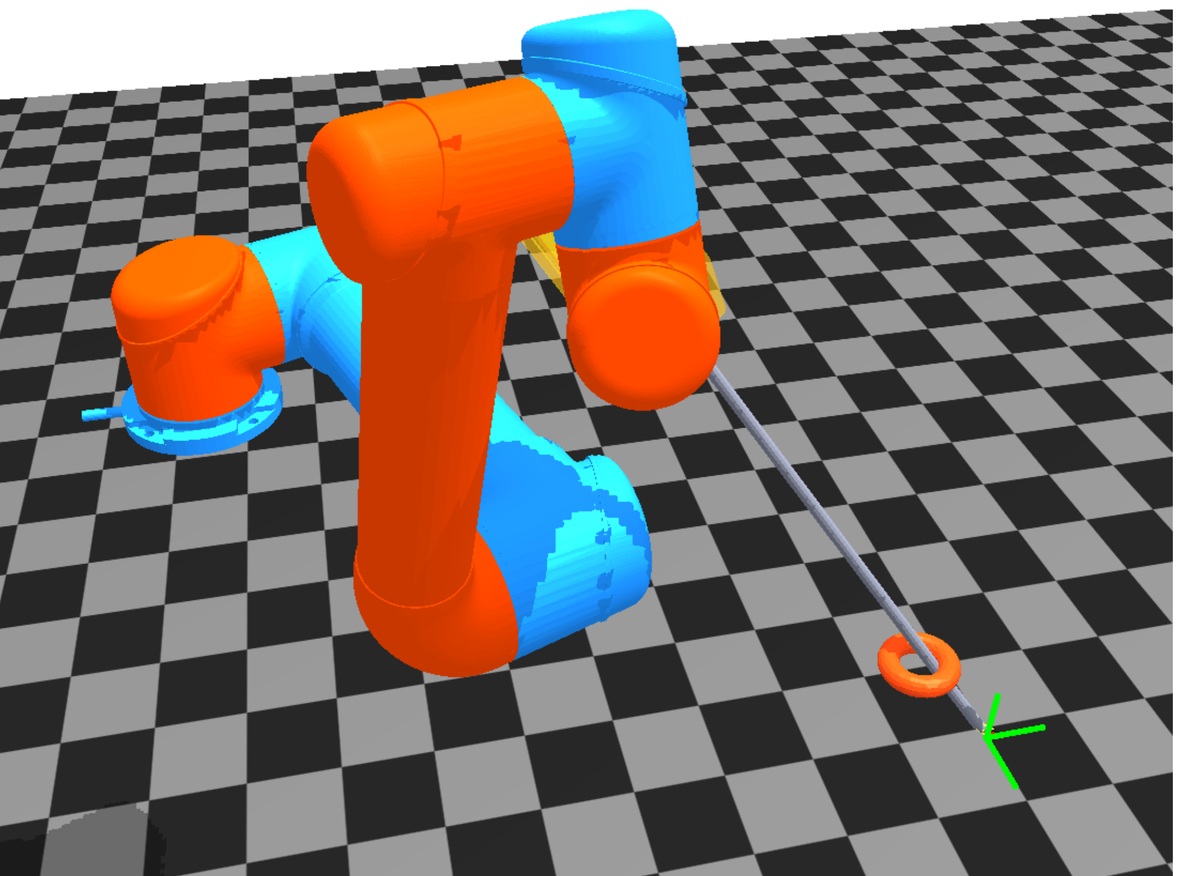
- **Importance:**
- The project would help to evaluate capabilities and constraints of manipulator arms applied in (bimanual) MIS tasks
- Would open the door for MIS related simulations using manipulator arms

The Problem

- Motivation of the project is that not every research lab or clinic has an access to MIS specialized surgical systems like daVinci.
- But, they can be substituted by conventional robot manipulators, e.g. UR5 or Kuka manipulators. At first, we should evaluate its feasibility, accuracy of RCM and target tracking, evaluate space constraints, optimal tool placement, etc.
- Evaluation on the robots is costly in terms of time and effort required to build and test different MIS task-specific setups

The Solution

- AMBF: dynamic multi-body framework offering a real-time dynamic simulation of robots real-time haptic interaction via several haptic devices developed by Dr.Munawar.
- In the simulator, performance tests of RCM constraint scenarios when provided with pre-recorded positions of surgical tools will help to optimize MIS-applied manipulator systems.
- vRCM for UR5 was implemented in AMBF in a form of a plugin with GUI for target position teleoperation.
- Real demo was conducted with mock passive instrument.



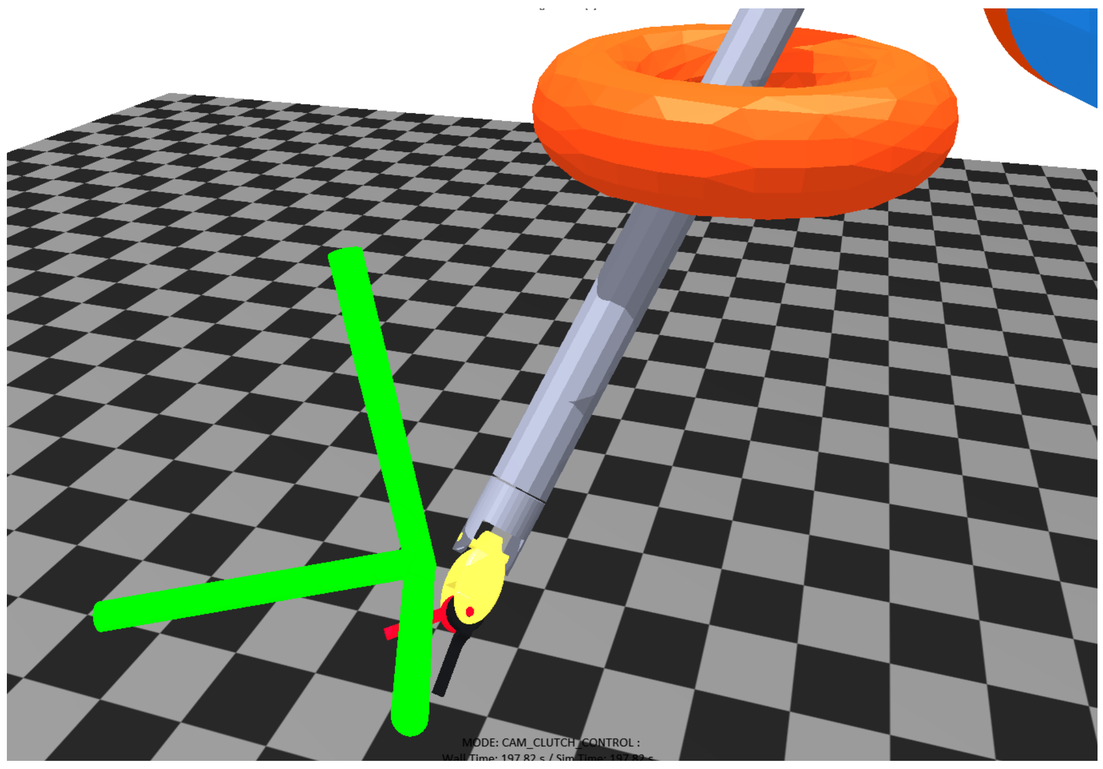


Figure. Close-up view of the tool tip and vRCM

$$\Delta q = argmin||J_{tip}\Delta q - (x_{des} - x_{curr})||$$
$$||x_{cl} - x_{RCM} + J_{cl}\Delta q|| \leq \epsilon$$

Mathematical formulation of the VRCM

Outcomes and Results

- Python script implementing the system was
- produced.
- With epsilon=0.01 the robot tracks the input
- position with accuracy of 0.00001 m while
- deviation from the RCM is on average 4mm.

Future Work

1) Consistence between kinematic description and CAD model will be improved during future work by manual checks during repeated conversion to ADF description.
2) Decreasing the value of epsilon in the equation of the constraint makes the input tracking along z-direction slower. It might be improved by introducing some gain on that term and by changing RCM constraint formulation to cross-product formulation.

Lessons Learned

- The project allowed me to gain hands-on experience in software development
- ! Try to work on the projects more from the start, rather then rushing closer to the deadlines

Acknowledgements

- Thanks to my mentors for devoting their time during meetings, debugging problems with me

References:

[1] A. Munawar and G. S. Fischer, “An Asynchronous Multi-Body Simulation Framework for Real-Time Dynamics, Haptics and Learning with Application to Surgical Robots,” 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2019, pp. 6268-6275, doi: 10.1109/IROS40897.2019.8968594.

[2] A. Munawar, Y. Wang, R. Gondokaryono and G. S. Fischer, “A Real-Time Dynamic Simulator and an Associated Front-End Representation Format for Simulating Complex Robots and Environments,” 2019 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS), 2019, pp. 1875-1882, doi: 10.1109/IROS40897.2019.8968568.

[3] B. Mitchell et al. “Development and application of a new steady-hand manipulator for retinal surgery” Proc. IEEE Int. Conf. Robot. Autom. pp. 623-629 2007.