

CIS 2. Project Proposal Plan  
**Evaluation of Virtual Remote Center of Motion for MIS**

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Mentors: Peter Kazanzides, Adnan Munawar

**Goal:** The objective of the project is to implement and evaluate virtual Remote Center of Motion (RCM) of a manipulator robot for Minimally Invasive Surgery (MIS) in AMBF simulator.

**Importance:** Motivation of the project is that not every research lab or clinic has access to MIS specialized surgical systems like daVinci. Though it can be substituted by conventional robot manipulators such as UR5 and Kuka manipulators. Thus, the project would help to evaluate feasibility and limitations of manipulator arms applied in bimanual MIS tasks like suturing.

**Background:**

Minimally invasive surgery operations require a remote center of motion. RCM is basically a set of constraints applied to the robot allowing motion of the tool only along and around some fixed point in space.

There can be mechanically enforced RCM which is trocar in MIS or robots joint designed in a way to impose RCM in a tool, and virtual RCM (on which this project focuses) where motion constraints are encoded in a control algorithm only [Figure 1].

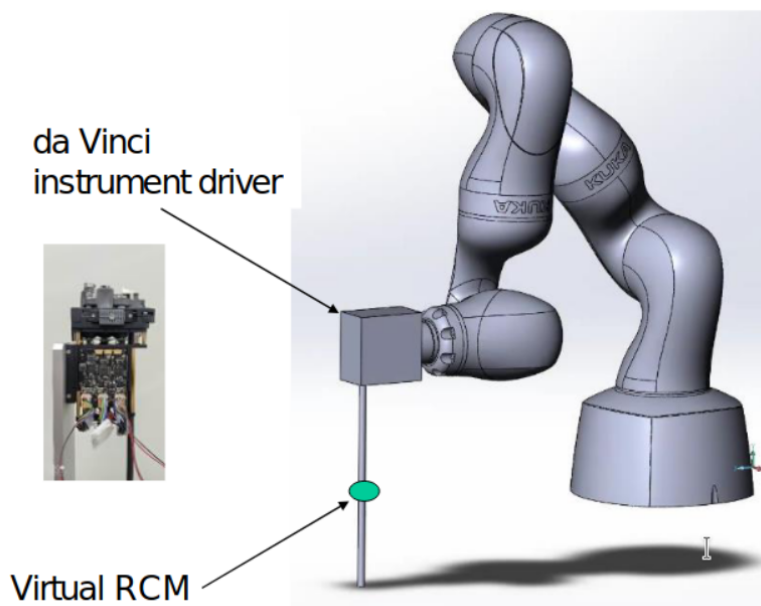


Figure 1. UR5 with daVinci instrument attached showing vRCM

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.

**Short technical summary of approach:**

RCM will be implemented using C++ in a form of AMBF plugins and ROS packages. AMBF has high-level of compatibility with ROS. Therefore, to implement UR5 control either the official UR5 ROS driver or sawUniversalRobot interface package [<https://github.com/jhu-saw/sawUniversalRobot>] will be used.

To implement virtual RCM itself we need to embed constrained optimization which will be done using sawConstrainedController package [<https://github.com/jhu-saw/sawConstraintController>] which is also

a part of SAW library developed by JHU researchers.

The final implementation stage is evaluation of the RCM using pre-recorded data acquired from PSM daVinci research kit robot while human operator was performing suturings task with it [Figure 3]. The data represents cartesian positions of the tool, in case of suturing the tool is the needle. So, while this pre-recorded data will be used as input, UR5 would try to repeat the trajectory taking into account RCM imposed constraints.

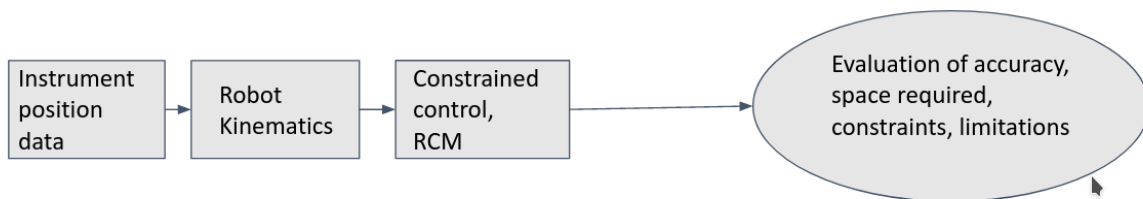


Figure 2. Flow diagram representing overall process

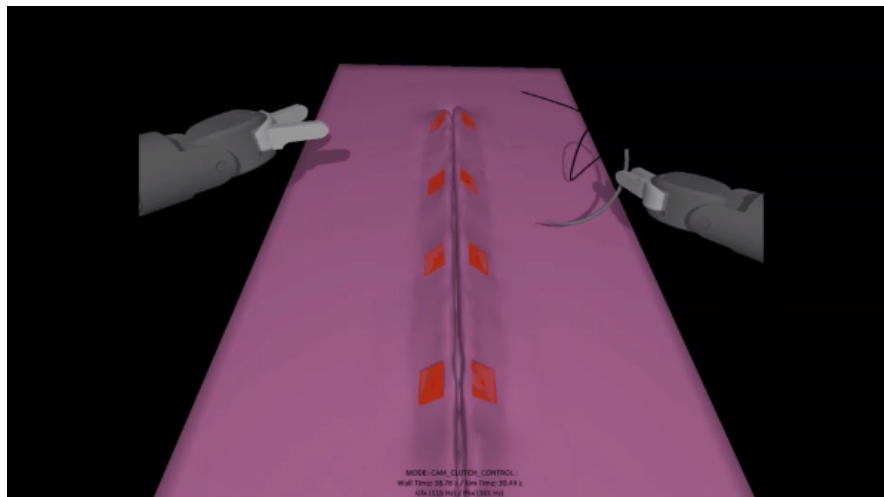


Figure 3. The source of data that will be used as input for vRCM evaluation

### **Deliverables:**

The minimum, expected and maximum deliverables for the project are provided below.

#### Minimum:

- 1) UR5+daVinci instrument kinematics models (forward, inverse, manipulator Jacobian) implementation in C++ integrated with AMBF
- 2) Plugins and ROS packages implementing virtual RCM integrated with AMBF

#### Expected:

- 1) Evaluation report using real pre-recorded data of suturing task. Evaluation will be done by Yernar and mentors in AMBF. Parameters for evaluation are space constraints (space required and possible collision between two arms when performing bimanual tasks), study of optimal instrument placement with respect to the robot end-effector and accuracy/off-set from imposed RCM.

Maximum:

- 1) Demo of implemented RCM on real UR5 with passive instrument attached.

**Key dates & assigned responsibilities:**

All tasks are to be done by the only member of the group, Yernar Zhetpissov. Milestones with weekly breakdown are provided in the table below. In case of delay in the completion of any of the milestones listed by more than 2 weeks, maximum deliverable will likely be dropped.

Table 1. Milestones Gaant chart (weekly)

		Weeks 3-5	Week 6	Week 7	Week 8	Week 9	Week 10	Week 11	Week 12	Week 13	Week 14
Setup	AMBF Installation										
	Study AMBF wiki										
UR5 model	UR5 CAD model import										
	Forward & inverse Kinematics										
	Manipulator Jacobian										
UR5 control+RCM	study sawConstraintsControl pkg										
	integration of UR5 control driver with AMBF										
	RCM implementation										
Evaluation	Testing stage										
	Evaluation stage										
	Evaluation report										
Demo on real UR5											

Table 2. Key dates

Main tasks	Expected completion data	Allowable completion date
UR5 CAD model import	March 6	March 13
UR5 full kinematics	March 13	March 20
UR5 control w/o RCM constraints	March 27	April 3
UR5 control with RCM	April 10	April 17
Evaluation report	April 24	May 1
Demo on real UR5	May 1	Final exam date

### List of dependencies & plan for resolving

- Linux workstation (done)
- Recorded Cartesian motion of two da Vinci instruments working on a bimanual task, such as the suturing task in the AccelNet Surgical Robotics Challenge (wil be provided by Adnan Munawar when the testing phase will be reached OR will be acquired by me). Data of the suturing task is ready and available. Access to the PSM daVinci kit robot will be provided by professor Kazanzides when needed.
- UR5 and instrument driver in the lab to be provided by professor Kazanzides

### Management Plan:

- Progress tracking Zoom meetings with mentors (every 2 weeks on Fridays):
  - Peter Kazanzides (RCM related questions)
  - Adnan Munawar (AMBF related questions)
- On-demand Zoom meetings for clarifications and questions
- Communication through emails
- Implementation management via Github
- File management through shared OneDrive folder

## Reading list

[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] Boctor, Emad M., et al. "Virtual remote center of motion control for needle placement robots." *Computer Aided Surgery* 9.5 (2004): 175-183.

[4] Ming Li, A. Kapoor and R. H. Taylor, "A constrained optimization approach to virtual fixtures," 2005 IEEE/RSJ International Conference on Intelligent Robots and Systems, 2005, pp. 1408-1413, doi: 10.1109/IROS.2005.1545420.