Check Point Presentation

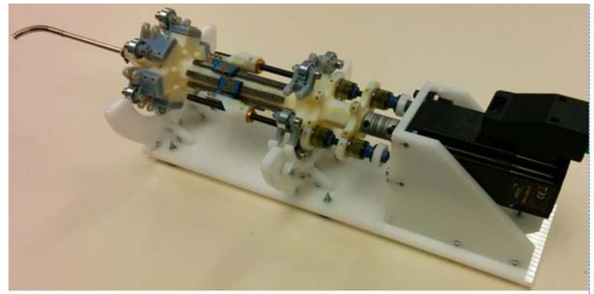
Position Control of BIGSS Lab Snake for Revision Total Hip Arthroplasty (THA) Surgery

Project 6: Farshid Alambeigi

Mentors:
Dr. Mehran Armand, Ryan Murphy, Dr. Russell Taylor

Overview of Goals

- ➢ The BIGSS lab is developing a minimally-invasive surgical workstation to treat the osteolytic lesions using using a snake like dexterous manipulator (SDM).
- ➢ The SDM will be positioned in the workspace by a robotic arm.
- ➢ The focus of this project is integrating the SDM with the robotic arm- which is a 6 DOF Universal Robot (UR5) - and position control of the tip of the SDM inside the lesion area.



Figures are property of BIGSS Lab.

Dependencies

✓ **Mechanical design:** ☹
- 3D model of the SDM: I obtained the CAD model **yesterday**.
- Machine shop and 3D printer for fabricating the interface parts: JHU and APL tools can be used using Dr. Armand or Ryan Murphy.

✓ **Robots:**
- UR5 robot: BIGSS lab wanted to buy this robot before March 1 but we bought it with 3 weeks delay. 😐
- SDM robot: I can use the BIGSS lab 2-D SDM. ☺

✓ **Kinematic model of SDM:** ☺
- ➢ I will use the available model of Ryan Murphy.

✓ **Access to Mentors:** ☺
- ➢ Weekly meeting with Dr. Armand and Ryan Murphy
- ➢ Scheduled meeting with Dr. Taylor as needed

Deliverables

Minimum
- ➢ Deriving and implementing the kinematic equations of UR5: ☺
- ➢ Interfacing the SDM with UR5 (Mechanical design and fabrication) :☹
- ➢ Coupled inverse control of robots outside the body: ☺

Expected
- ➢ Controlling the position of the coupled robots using virtual RCM when all of the SDM is in the body (Simulation and implementation) : ☺ +😐

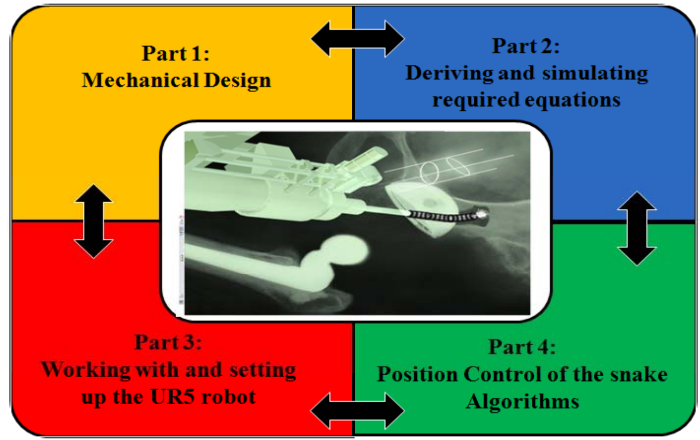
Maximum
- ➢ Controlling the position of the coupled robots using virtual RCM when all of the SDM is not in the body (Simulation and implementation)
- ➢ Modeling the kinematics of SDM using solid mechanics or beam theory

Management Plan

❖ **Detailed Task Schedule**

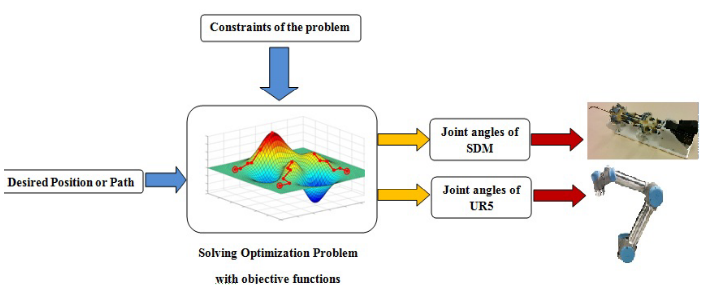
Task	9-Feb	16-Feb	23-Feb	2-Mar	9-Mar	16-Mar	23-Mar	30-Mar	6-Apr	13-Apr	20-Apr	27-Apr	4-May	9-May
Preparing a 3-D model of the UR5	☺													
Deriving the Kinematics model of UR5	☺													
Simulation of the model in Simmechanics-Matlab	☺	☺⚑												
Obtaining CAD models of Snake		☹	☹	→	→	→	☺							
Obtaining Kinematic model of Snake and working with it			☹	☺										
Literature survey for virtual fixture		☺	☺	☺										
Mechanical interface of snake to UR5			☹	☹	⚑	→	→	→	→	⚑				
Ordering required parts and actuators					☹	→	→	→	→	→				
Fabrication of first coupled robot						☹	⚑	→	→	→	⚑			
Simulation of the inverse kinematics of the coupled robots				☺	☺	☺	☺							
Working with and setting up the UR5 robot				☹	☹	☹	⚑			⚑				
Controlling the coupled robots (Minimum Deliverable)					☺⚑	←	←	←	⚑					
Simulation of virtual fixture (RCM point is not on the snake)						☺	☺	☺⚑	←	←	⚑			
Testing the algorithm on Robots (Expected Deliverable)												⚑		
Simulation of virtual fixture (RCM point is on the snake)													⚑	
Testing the algorithm on Robots (Maximum Deliverable)													⚑	
Final report Presentation														⚑

Technical Summary of Approach



Technical Summary of Approach

Part IV: Position Control of the tip of the SDM
Strategy: Using virtual fixture algorithms to control the SDM by UR5



Technical Summary of Approach

➢ **Optimization Algorithm: (<u>CIS I course</u>)**

$$Actual\ Position = \underline{forward\ kinematics}_{UR5+Snake}(\theta_{Old})$$

$$\Delta_{pos} = Actual\ Position - Desired\ Position$$

$$V = J \cdot \dot{\theta} \rightarrow \frac{\Delta x}{\Delta t} = J \cdot \frac{\Delta \theta}{\Delta t} \rightarrow \Delta x = J \cdot \Delta \theta$$

$$\Delta q = \arg\min_{\Delta\theta}(\| \underline{J_{total}}.\Delta\theta - \Delta_{pos} \| + \| w.\Delta\theta \|)$$

$$A.\Delta x \le b$$

$$\theta_{New} = \theta_{Old} + \Delta\theta$$

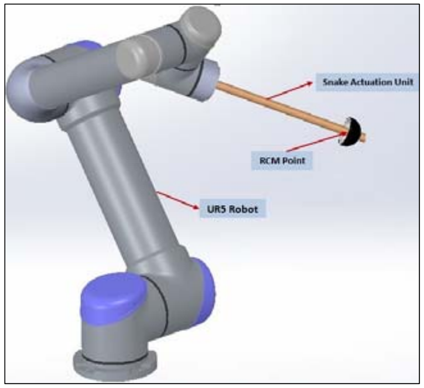
➢ **For solving this problem we need:**

✓<u>Forward Kinematics</u> of coupled robots
✓<u>Jacobian matrix</u> of coupled robots
✓Finding the <u>**A and b**</u> Matrices which are defining our constraints (RCM constraint+ Limitation on cable length and joint angles)

Technical Summary of Approach (UR5+Snake Actuation unit)

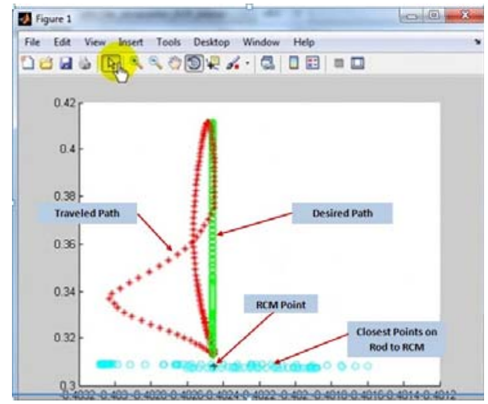
- For solving the problem, first I considered the UR5 robot and its actuation unit which can be considered as a rigid rod attached to the UR5.
- I have considered the RCM Point as a constraint: the RCM point should always be on the rigid rod. <u>(Details of the algorithm will be discussed in the Seminar Presentation)</u>
- In this problem we just need the Jacobian matrix of UR5+Rigid rod:

$$J_{total} = J_{UR5+Rod}; J_{J_{UR5+Rod}} \in \mathbb{R}^{6\times6}$$



Simulation (UR5+Snake Actuation unit)

- **Goal:**
  Tracking a desired circular path considering RCM constraint



Technical Summary of Approach (UR5+SDM unit)

- For controlling the coupled robot, first we need to obtain the Jacobian matrix of the snake From differentiating the relation between cable length and tip position of the snake.
- Using a series of the tests relation between cable length and tip position of the snake has been derived by curve fitting technique:

$$p_x = f_1(l) = B_n(l)$$

$$p_y = 0$$

$$p_z = f_2(p_x) = \sum_{i=1}^{3} a_i \sin(b_i . p_x + c_i)$$

$$p_{Snaketip}^{Snakebase} = \begin{pmatrix} p_x \\ p_y \\ p_z \end{pmatrix} = \begin{pmatrix} f_1(l) \\ 0 \\ f_2(f_1(l)) \end{pmatrix}$$

B_n : Bernstein basis polynomials

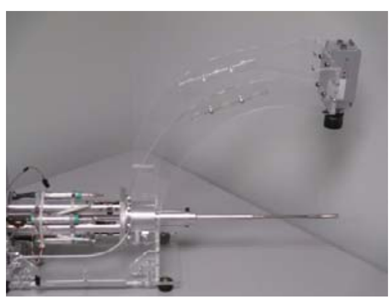


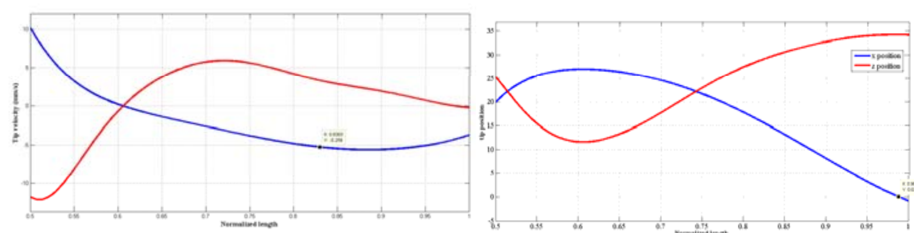
Figure is property of BIGSS Lab.

Technical Summary of Approach (UR5+SDM unit)

- Therefore we can find the relation between change in cable length and change of tip position by:

$$V_{Snaketip}^{Snakebase} = \dot{p}_{Snaketip}^{Snakebase} = \begin{pmatrix} \dot{p}_x \\ \dot{p}_y \\ \dot{p}_z \end{pmatrix} = \begin{pmatrix} \dot{f}_1(l) \\ 0 \\ \dot{f}_2(f_1(l)) \end{pmatrix}$$

- Figures show the relation between cable length and tip position and velocity:

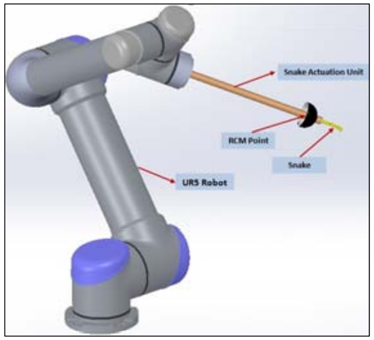


Technical Summary of Approach (UR5+SDM unit)

- Therefore we can find the Jacobian Matrix of couples robot using this equation:

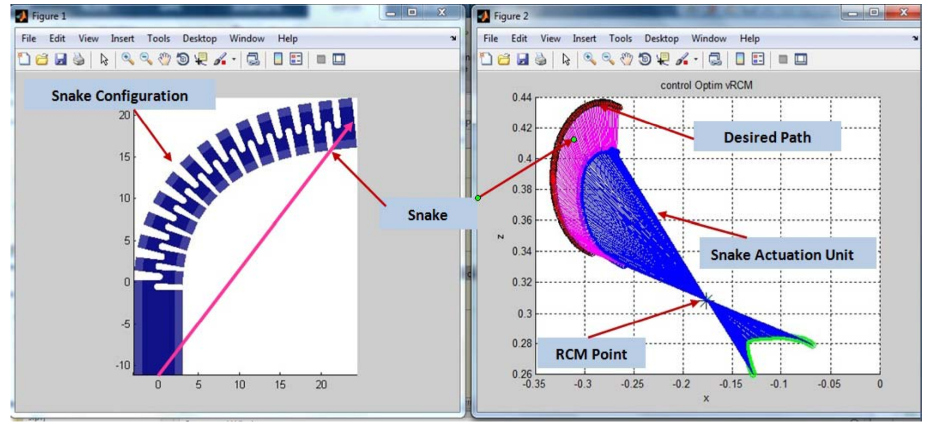
$$V^{w}_{Snake} = \underbrace{V^{w}_{Snake\,base}}_{J_{UR5}} + \underbrace{R^{w}_{Snake\,base}.V^{Snake\,base}_{Snake\,tip} + \omega^{w}_{Snake\,base} \times R^{w}_{Snake\,base}.p^{Snake\,base}_{Snake\,tip}}_{J_{Snake}}$$

$$J_{total} = [J_{UR5} \quad J_{Snake}];\; J_{UR5} \in \mathbb{R}^{6\times6}, J_{Snake} \in \mathbb{R}^{3\times1}$$



Simulation (UR5+SDM unit)

- **Goal:**
  Tracking a desired circular path considering RCM constraint and cable length limitation



Management Plan

- **Next Key Milestones**

  April 07: Submitting paper in IEEE Engineering in Medicine and Biology Society (EMBC'14)

  April 13: Mechanical interface of SDM to UR5 (**Minimum Deliverable**)

  April 23: Working with and setting up the UR5 robot

  April 23: Fabrication of first coupled robot (**Minimum Deliverable**)

  April 30: Testing the algorithm on Robots (**Expected Deliverable**)

  May 04: April Simulation of virtual fixture (RCM point is on the SDM)

  May 04: Testing the algorithm on Robots (**Maximum Deliverable**)

  May 09: Final report Presentation

Thanks for your attention

Questions??