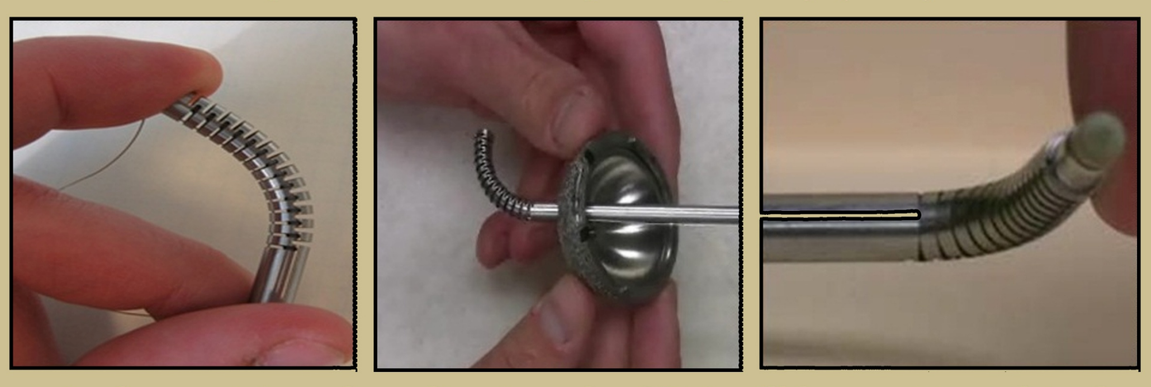
Position Control of BIGSS Lab Snake for Treatment of Pelvis Osteolysis

The Johns Hopkins University APPLIED PHYSICS LABORATORY

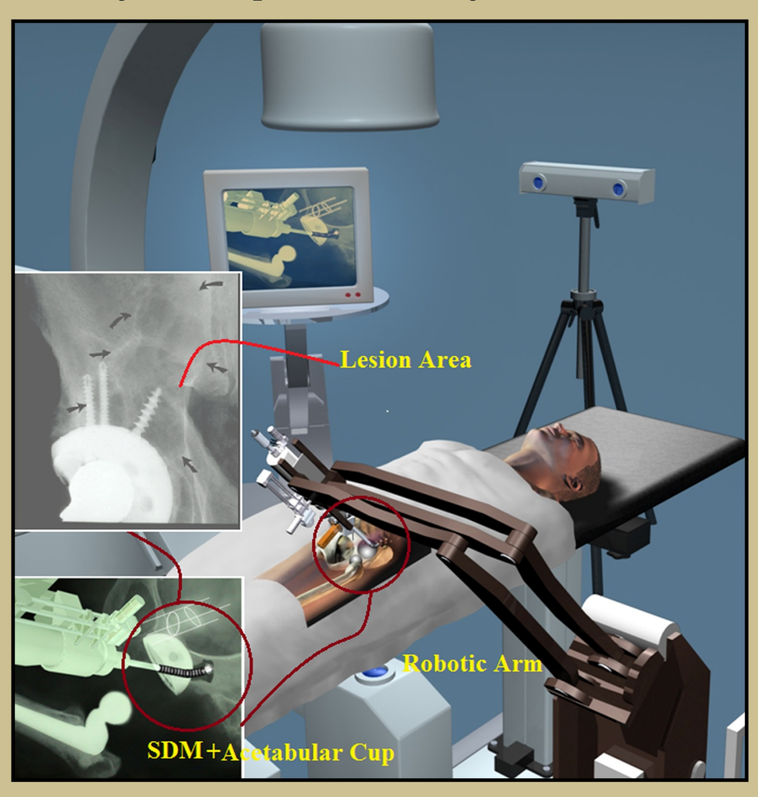
Farshid Alambeigi, Mentors: Dr. Mehran Armand, Ryan Murphy, Dr. Russell Taylor

Introduction

● The BIGSS lab has developed a Snake-like Dexterous Manipulator (SDM) to treat osteolysis (bone degradation) behind the well-fixed acetabular component of a total hip arthroplasty (THA).



● In the envisioned application, the SDM will be positioned in the workspace by a robotic arm and uses screw holes in the acetabular implant as its entry to the patient's body



● The focus of this project is:
1-Mechanical interface of the SDM with the robotic arm- which is a 6 DOF Universal Robot (UR5)
2-Position control of the tip of the SDM inside the lesion area.

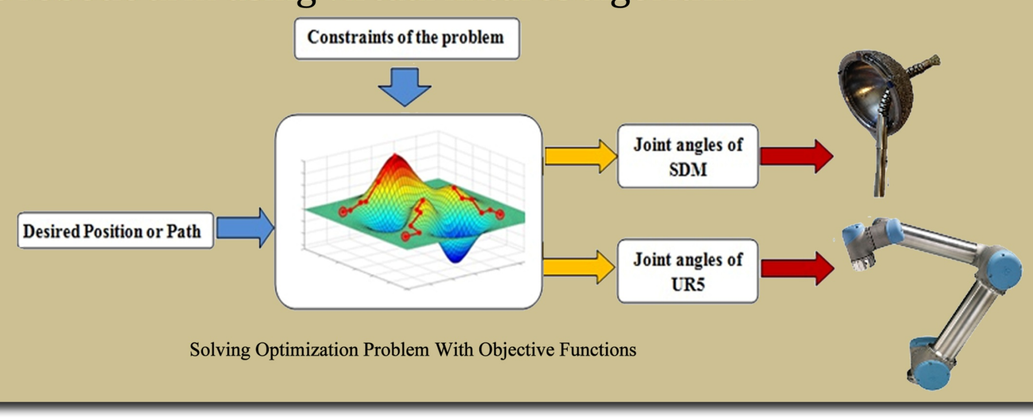
The Problem

Controlling snake tip position requires concurrent control of the coupled SDM–robotic arm system considering these limitations:

1- The screw hole acts as a RCM point, reducing the DoF of the robot.
2- The UR5 robot has not a Mechanical RCM point.
3- The BIGSS lab snake is not well-characterized by the piece-wise-constant curvature assumption and requiring an experimentally-derived kinematic model.

The Solution

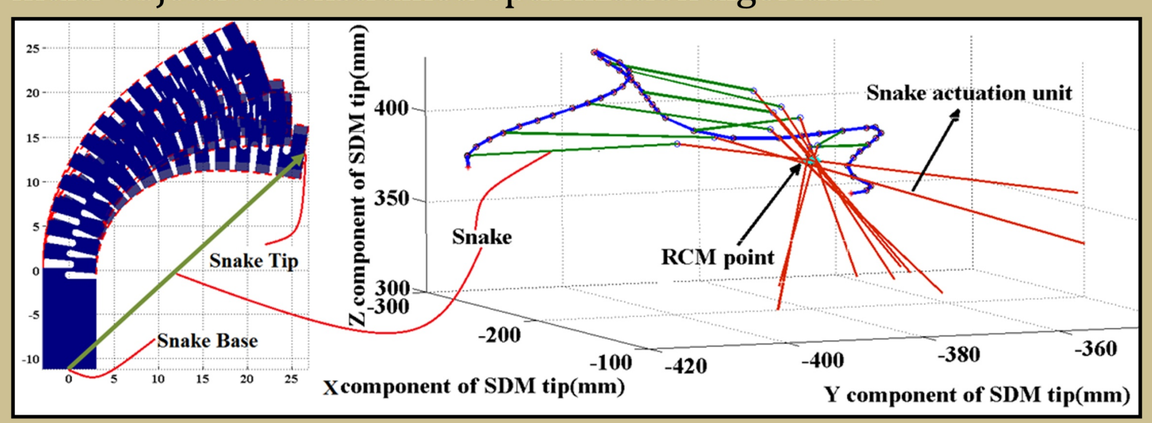
The Problem has been formulated as a constrained optimization problem where the goal is to obey the constraints and follow the desired motion as close as possible. A virtual RCM has been created for the robotic arm using virtual fixtures algorithm.



Solving Optimization Problem With Objective Functions

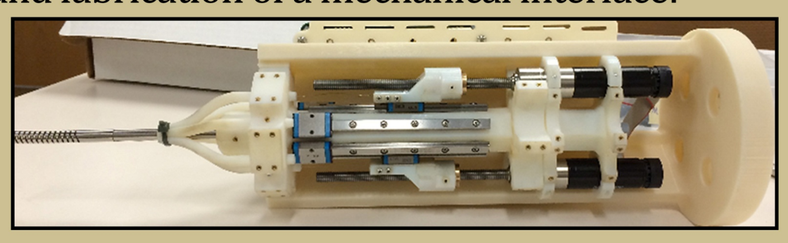
Outcomes and Results

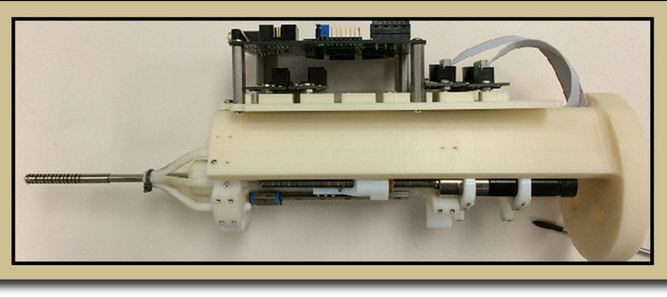
● Kinematic modeling and control of a coupled 8 DoF robots used for treatment of osteolysis in confined spaces based on a linearized multi-objective constrained optimization algorithm:



We considered a 3D path for the snake that is a specific boundary of a simulated lesion and is inside a confined cubic space with sides of 7 cm. Optimization result for configuration (Left) and orientation of the snake and actuation unit (Right) in some points of the desired path have been shown. The result shown here means that the robot changes its configuration such that with minimum joint movements the desired goal could be achieved while RCM constraint has been satisfied.

● Design and fabrication of a mechanical interface:





Future Works

● Implementing the control approach on hardware.
● Solving this problem for a snake with the flexible region outside the patient's body.
● Modeling the kinematics of SDM using solid mechanics or beam theory

Publication

F. Alambeigi, R. J. Murphy, et al., "Control of the Coupled Motion of a 6 DoF Robotic Arm and a Continuum Manipulator for the Treatment of Pelvis Osteolysis," in IEEE Conference of Engineering in Medicine and Biology Society (EMBS'14) , submitted for publication.

Lessons Learned

● Defining a complicated control problem as a constrained optimization problem.
● Application of Virtual Fixtures in surgical robot assistants.
● Achieving valuable experiences during design and fabrication of interfacing parts.

Acknowledgements

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