MCT-551 Robotics and Automation

Semester Project

Assigned on:	Oct 11, 2017
Deadline:	Dec 20, 2018
Place:	Seminar Hall

Objectives

The central theme of this semester-project revolves around designing a redundant robotic manipulator for the restoration of art-works and architectural details on historical buildings. The robot's ability to move, both kinematically and dynamically, will be tested to execute tasks on 2D and 2D surfaces while ensuring the position and force. It is also expected that the students will be able to model and simulate the robot in MATLAB, and in the process will also modify the model, if needed.

Project Assignment

Mariyam Zamani Mosque (aka Begum Shahi Masjid) is one the earliest surviving mosques of Mughal-era in Lahore. It is an absolute visual delight, and whose architecture and art-work greatly influenced the builders of Wazir Khan mosque. But sadly due to years of misuse and neglect, including its use as ammunition store during sikh-era and currently by our-very-own encroachers, it has lost its glory. One example of this neglect, to shame us, is visible in the following Fig. 1 where one can see the partially lost inscriptions and fresco. We obviously need to restore it.

In an hypothetical scenario, the Walled City of Lahore Authority (WCLA) has called the Mechatronics Engineers of UET Lahore to suggest a simple robotic system to restore the surfaces, re-write the lost inscriptions and paint the floral frescos once again. But we as Mechatronics Engineers know that the task is not that simple.

However, one possible solution can be as follows:

- A versatile robotic manipulator may be designed to accomplish the task. The robot will be mounted on a platform to conveniently perform the following major operations:

Figure 1: *Mihrab of the mosque, indicating the partial destruction.*

  - Surface cleaning operation on flat and curved surfaces. This operation requires delicately preparing the surface for subsequent operations. This will require an effective position and force control capability.
  - Calligraphy operation on the flat surface to write the lost inscriptions. We know the original text; however, we'll need sufficient dexterity of the robotic end-effector to write the intricate script requiring position and orientation control in addition to the force control.
  - Fresco drawing operation on the inner 3D surface of the prayer niche (mihrab). This will also require the robot to perform the task in a position and force controlled fashion.

- The manipulator should have some degree of redundancy (i.e. $>$ 6DOF) to allow the avoidance of singularities during robot motion. It will also ensure implementation of a better control strategy.

- The robotic manipulator must be able to cover the space, as indicated in the Fig. 2. The work-envelop should be designed accordingly.

In this context, students in a group of two will model, simulate, revise and thus design the desired robotic manipulator. The robot must necessarily have more than 6 DOF. The simulation will be developed using MATLAB. The whole activity can be subdivided in the following phases:

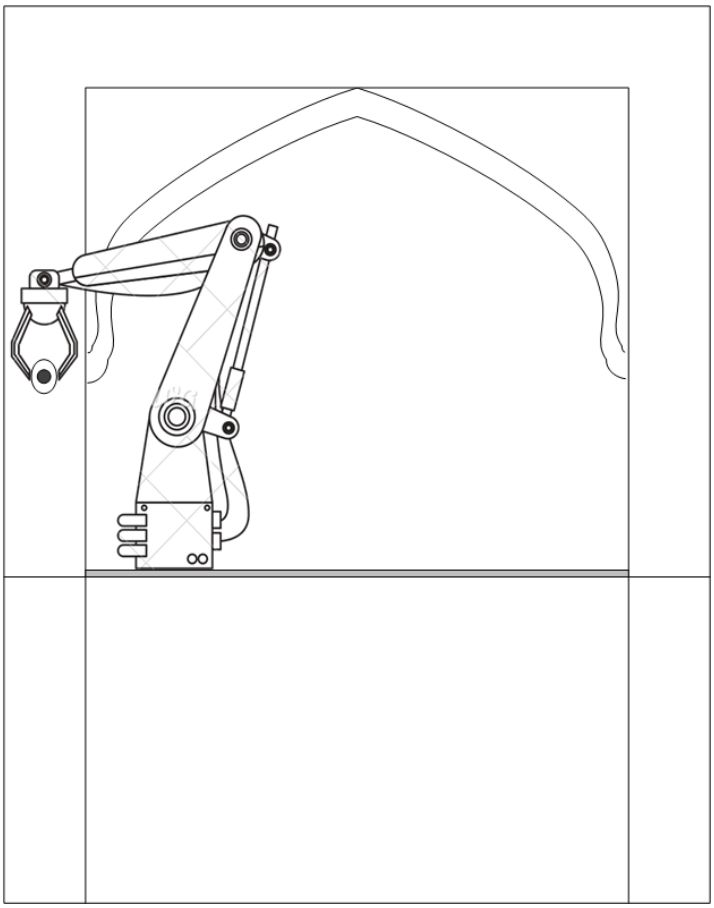

Figure 2: *The schematic illustration of one possible solution. The robot is preparing to write the inscriptions on the front surface.*

1. Modeling and simulation of forward and inverse kinematics of the redundant manipulator. The model must be derived using homogenous transformations and Denavit-Hartenberg conventions, as discussed in the class. For simplicity, one can also assume that a spherical wrist is mounted on the manipulator whose forward and inverse kinematics have been already derived in the class. Avoid singularities.

2. The path-planning exercise to write the missing inscriptions (2D) and draw the parting lines for Muqarnas (3D). One may visit the mosque to completely understand the task.

3. Modeling and simulation of the robot-dynamics. The modeling will preferably be done using the Euler-Lagrange's method. The calculations of inertia tensors may require help of some solid modeling software (such as Solidworks). The response of the robot will define the control objectives.

4. Implementation of position control loop for the robotic manipulator. The controller must be designed in a fashion that it eliminates the steady-state errors and reduces the over-shoot and rise-time.

5. Implementation of force control loop for the manipulator. It is vital to ensure that the end-effector exerts only the requisite amount of force on the surfaces being restored.

Each assignment, mentioned above, contains 10 marks each. Students are advised to go through the literature, including the book we are following, to completely understand the background of robotic manipulators.

Deliverables

D1 Demonstration of all the tasks

D2 Project Report: A detailed project report containing schematics, models and simulations is expected. It is absolutely necessary to have a section of *critical analysis* in the report to further improve the robot. The report should contain the following sections:

1. Introduction
2. Related work on redundant robotic manipulators
3. Methodology
   - Robot's kinematic model
   - Robot's dynamic model
   - Controller design for the robot
4. Extensive simulations with different initial conditions
5. Visualization of the robot movement
6. Critical review of the findings

D3 Project Code

Scholastic Ethics:

It is *emphasized* that students should submit their own work. If part of an existing text is needed to be used it should be rephrased/paraphrased and properly cited/credited. Plagiarism, cheating or collusion will not be tolerated. Remember, *copy-paste* is worst form of plagiarism.

Document drafted by Dr. Ali Raza, dated: October 11, 2018