ME5402/EE5106R ADVANCED ROBOTICS

Part II: Dynamics

Mini Project I

Instructions:

1. Put your name and matriculation number on the cover page, and submit the hardcopy of your answer to Dr. Shuzhi Sam Ge (Room E4-05-28) or to my mail box in the ECE general office, by **21 April, 2017**. Submit the original codes of the simulation via IVLE with the file name as your registration number.

   Example: If your registration number is A0123456X then the file names must be A0123456X.rar.

2. Students are supposed to work in group of two or three. While the work is group and encourage collaboration, each student must have his/her own individual contribution and effort and should be clearly stated in his/her **individual report**. Identical reports will be subject to penalty and or disciplinary actions of the university.

3. Please submit the Groupings to me next Monday.

Background:

An aerial work platform (AWP), also known as an aerial device, elevating work platform (EWP), or mobile elevating work platform (MEMP), is frequently used in scenarios where access at a height is required, e.g. cleaning buildings' external walls, maintaining transmission-line, and fire rescuing, etc. The platform can be regarded as a system integrated with several functional components, among which the mechanical arm plays an important role. To satisfy the need of aerial work, a typical mechanical arm used in AWPs has the length over 10 meters.

Figure 1: AWPs in different scenarios.

Scenario:

In this project, we consider a simplified model of the AWP as shown in Figure 2. As can be seen, this robot is composed by a movable base and one 2-DOF robotic arm where different kinds of end effector can be placed on. Our basic goal is to control the end effector (regard as a mass at point "E") to track desired trajectory. For simplicity, we denote the two DOFs as q_1 and q_2.

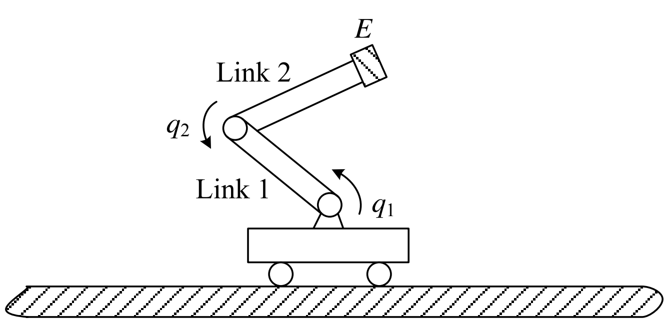

Figure 2: Simplified model of an AWP.

In the simplified structure, link 1 and 2 are assumed to be cylinders with zero radiuses and the mass of each link is assumed to be lumped in the middle of the link. For the robotic arm, assume that I_i is the moments of inertia about axes coming out of the page passing through the centers of mass, m_i of link i; l_i is the length of link i; τ_i is the driving torques at the joint i (i =1, 2). Parameters of the robotic arm are given in the table below.

Table 1: Parameters of the AWP

Parameters	Description
m_E	Mass of the end effectors E
m_1	Mass of link 1
m_2	Mass of link 2
l_1	Length of link 1
l_2	Length of link 2
I_1	Moment of inertia of link 1
I_2	Moment of inertia of link 2

Note:

1. You are free to present your work in any environment, such as C++, and ADAMS, of your choice.
2. You are free to make any assumptions needed, but with proper explanation.

List of Projects:

For the robotic manipulator in Figure 2, please accomplish the following tasks (each group member chooses one sub-project):

Project 1-1: Modeling and Animation of the Robot

1. Do a literatures review on AWP design and virtual robot simulation.
2. Develop the D-H model of the robotic arm and derive the Lagrange-Euler equations.
3. Design a CAD model for an AWP using any software or tools of your preference such as Utility 3D, ADAMS, Solid works, etc. Use the kinematic and dynamic equation to guide your design.
4. Design a simple controller to make each joint of the virtual robotic arm in Figure 2 to track a given desired trajectory.
5. Optional: List the problems that you identified, and you are encouraged to propose any new or novel methods to solve them.

Project 1-2: Trajectory Planning of the Robot

1. Do a literature review on trajectory planning of the robotic arm.
2. Develop the D-H model of the robotic arm and derive the Lagrange-Euler equations.
3. Derive and visualize the configuration space of the AWP robotic arm (you may refer to *Supplementary Material for Project 1-2, uploaded to IVLE*).
4. Given any start point and any goal point in configuration space, design a non-conflictive trajectory for AWP robotic arm using any general method. Explain the considerations when you are planning the trajectory.
5. Based on the trajectory you designed in 4 and a simple controller, do a simulation study to demonstrate the trajectory following performance of the robotic arm, using any software or tools of your preference, such as MATLAB, MRDS, Visual Studio, ADAMS, SolidWorks, etc.
6. Optional: Given any start point and any goal point in configuration space, propose an optimal trajectory planning strategy for AWP robotic arm, with obstacles in the configuration space. Elaborate how you define "optimal" and prove your answer is optimal. Use simulation to demonstrate the performance of your design.

Project 1-3: Adaptive Control of the Robot

1. Do literature review on modeling and adaptive control.
2. Develop the D-H model of the robotic arm and derive the Lagrange-Euler equations.
3. Assume the desired trajectory is a sine wave. Develop PD control that can guarantee the tracking error within a predefined range which is properly selected by the student.
4. Design adaptive control to make each joint of AWP robotic arm in Figure 2 track a given desired trajectory. Compare the results obtained from PD control and adaptive control.
5. Optional: Design an adaptive neural network control of AWP robotic arm. Use simulation to demonstrate the performance.