EEE4119F – Mechatronics II – Project Brief

2021

Catching space debris from a satellite

Introduction

You are part of a team working for NASA. Upon realising how crowded space was with 'space debris', your team decides to build a space vacuum to catch any debris that comes close to your satellite. You are tasked with designing a controller to control the robot arm. The robot arm is mounted on top of your satellite and the satellite is stationary.

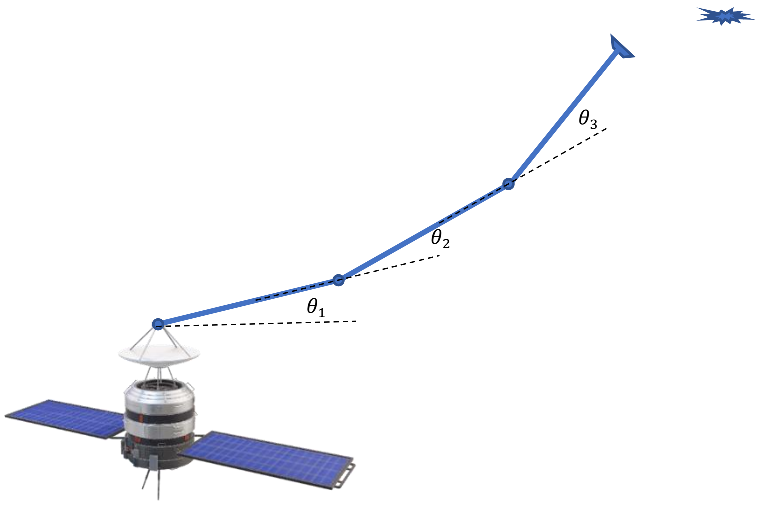

Figure 1: The robot arm can be modelled as a three-link manipulator.

Description of the robot arm model

The motion of all parts of the manipulator are confined to a vertical x-y plane. The motion of the manipulator is driven by three motors. The first one is located at the lower end of the first link, the second one is located at the joint between the first and second links, and the third one is located at the joint between the second and third link (see Figure 1).

Note that the motors can be modelled as ideal torque inputs τ_1, τ_2 and τ_3, each with limits $\mp 100N \cdot m$. Each joint has friction characterised by an unknown coefficient b and can be modelled as $b\dot{\theta}$ where θ is the angle between the joint link and the previous link. Coefficient b is the same for all three joints and is unique for each student. You will need to provide your PeopleSoft Number to generate b for your arm.

All three links are identical with length $L = 0.5\ m$, mass $m = 1\ kg$ and mass moment of inertia about center of mass $I = 0.1\ kg \cdot m^2$.

Below, we will refer to the angle between link 1 and the horizontal as θ_1, the angle between link 2 and link 1 as θ_2 and the angle between link 3 and link 2 as θ_3.

Requirements

In simulation, the robot arm must perform the following tasks:

1. Swing from a vertically down pose to a vertically upright pose i.e from $\boldsymbol{q} = [-\frac{\pi}{2} \;\; 0 \;\; 0]^T$ and $\dot{\boldsymbol{q}} = [0 \;\; 0 \;\; 0]^T$ to $\boldsymbol{q} = [\frac{\pi}{2} \;\; 0 \;\; 0]^T$ and $\dot{\boldsymbol{q}} = [0 \;\; 0 \;\; 0]^T$.
2. Intercept the debris by performing the following:
    a. End with its end-effector sufficiently close to the debris i.e $\left\| p_{debris} - p_{end-effector} \right\|_2 \leq 0.1\ m$
    b. End with the velocity vector of the debris at an angle of at most 30° relative to the axis of the third link (see Figure 2).

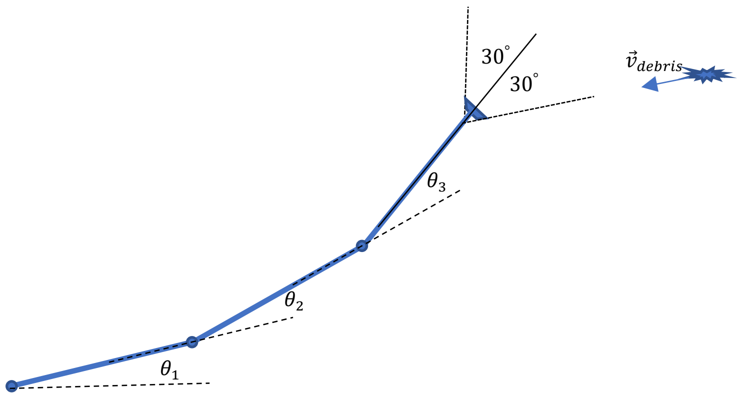

Figure 2: Showing a description of requirement 2.b.

Initial Conditions

The robot arm starts with initial conditions:

$$\begin{bmatrix} \theta_1 \\ \theta_2 \\ \theta_3 \end{bmatrix} = \begin{bmatrix} -\frac{\pi}{2} \\ 0 \\ 0 \end{bmatrix}, \begin{bmatrix} \dot{\theta}_1 \\ \dot{\theta}_2 \\ \dot{\theta}_3 \end{bmatrix} = \begin{bmatrix} 0 \\ 0 \\ 0 \end{bmatrix}$$

Modes

Task 2 must be met in the two modes described below:

Mode	**Random Debris speed**
1	-1 m/s <v< 1 m/s
2	-5 m/s <v < 5 m/s

For each mode, five random debris particle trajectories will be generated, with the debris starting $5\ m$ away from the origin in each case.

Submission and ELO

A < 10 page report summarizing your design and results is due 14 June 2021. Submit all code/models necessary to implement your controller. Note that the project is aimed at assessing the ECSA ELO 2 (see the course handout for more details).

Marking scheme

Marks will be awarded as follows:

Task	**Marks**
System Identification of friction	10
Swing upright	10
Satisfy requirements in mode 1	20
Satisfy requirements in mode 2	20
Ranking of class for Mode 2	20
Report	20

Ranking will be calculated by minimisation of the cost function:

$J = \int_0^{t_f} (\tau_1 + \tau_2 + \tau_3)\, dt + t_f$, where t_f is the time taken to catch the debris.