AEEM 6117: Intelligent Robotics

Course Project Option #3

Control of a flying space robot to reach out and touch a floating object:
Many space junks or out-of-control satellites are floating in orbit, which pose huge risk to many space assets. The international space communities are increasingly demanding countries to put more efforts to clean up the space junks. Removal of those space junks from their orbits is a huge challenge. Robotics solutions are being developed for capturing, servicing, or removing them from their orbits. However, controlling a robotic arm from a floating or flying space vehicle is difficult because the reaction force from the robot motion will push the vehicle away from its target and also cause disturbance to vehicle's attitude. This unwanted reactive motion on the base of the robot will then make the robot difficult to position itself for the capture task.

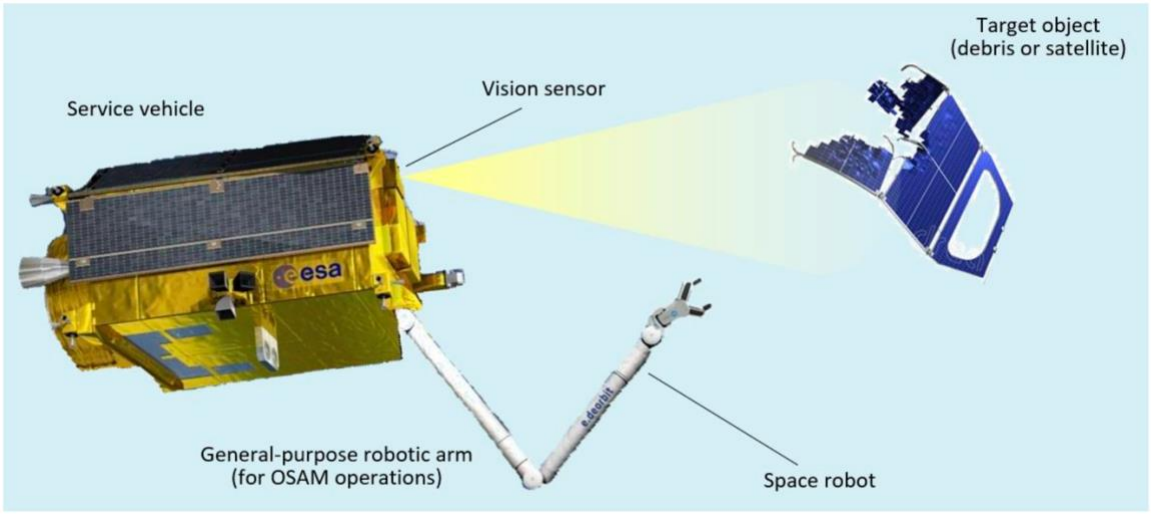

Fig.1 Capture a space junk using a spacecraft-based robotic arm

Problem Definition:
Simplify the problem to a 2D planar dynamic system and its corresponding control problem as shown in Figure 2. Assume the space vehicle can fire thrust forces and torque to control its 3-DOF motion and the robot can apply torques to its three joints to control its tip motion. The anticipated operation is to first make the vehicle approach the target object until a distance such that the target point is within the arm's workspace. Then control the vehicle in station keeping mode (trying to keep a constant distance to the target object) and use the robotic arm to reach out to the target point and gently touch the target point at a small relative speed (see requirement). The following tasks are required:

(a) Implement a 2D dynamics and simulation model. The modelled dynamic system includes a space vehicle, a 3-joint robot, and a target object, shown in Fig.2. The model is capable of simulating the dynamic motions of both the vehicle-robot system and target body. Since in space, the gravity force is ignored.
(b) Design a feedback control system including a 3-DOF space vehicle control and a 3-joint robot control for approaching to the target body and safely touching the target point.

(c) Implement the control system designed in Task (b) and test the control performance using the simulation model from Task (a).
(d) Demonstrate the capability of your control system (using both data plots and animations) to ensure that the task is successfully done.

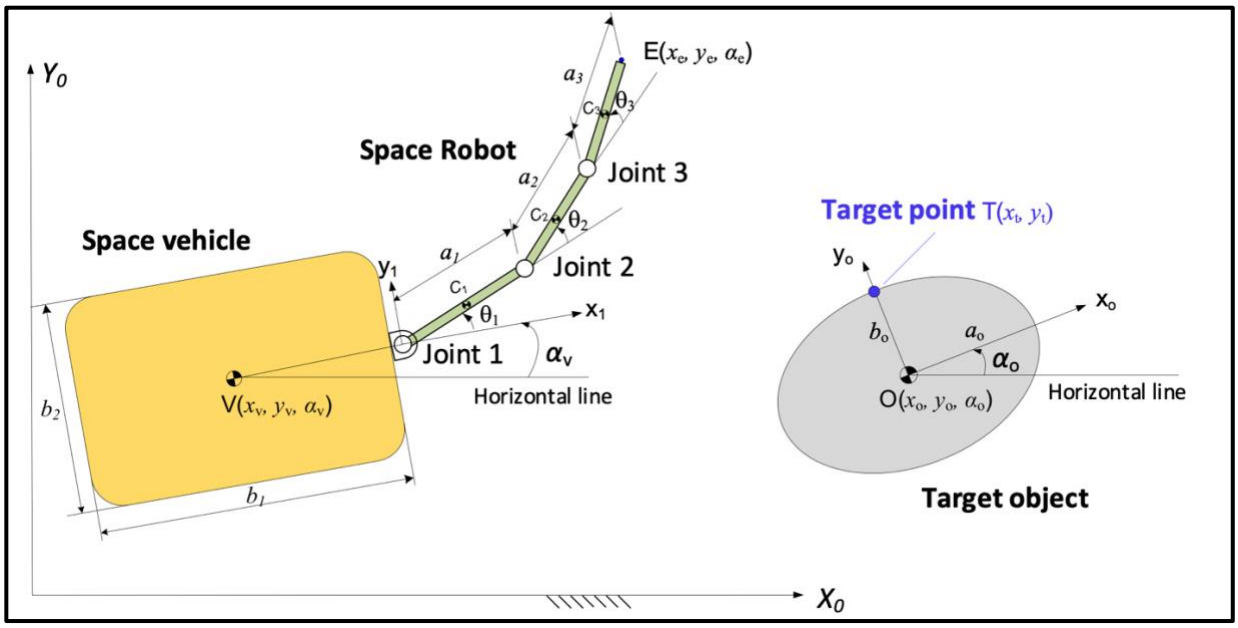

Fig. 2 Sketch of 2D model

3. Requirements:

(a) The physical parameters of the servicing system are assumed as
m_v = 500 kg, b_1 = 2m, b_2 = 1m; m_1 = 20kg, m_2 = 10kg, m_3 = 5kg $a_1 = a_2 = a_3 = 1m$
m_o = 100 kg, a_o = 1m, b_o = 0.5m where a_0 and b_o are the major and minor axes of the object
(b) Start with the following initial conditions of the system

Positions/angles	x_v	y_v	α_v	θ_1	θ_2	θ_3	x_o	y_o	α_o
(m or deg)	0	0	0	0	45	45	5	0	0
Velocities	$\dot{x}_v$	$\dot{y}_v$	$\dot{\alpha}_v$	$\dot{\theta}_1$	$\dot{\theta}_2$	$\dot{\theta}_3$	$\dot{x}_o$	$\dot{y}_o$	$\dot{\alpha}_o$
(m/s or deg/s)	0	0	0	0	0	0	0.02	0	0

(c) The touching velocity (relative velocity between the robot tip and the target point) shall be less than 0.01 m/s. This requirement is to assure a safe touch (instead of a more difficult but more meaningful contact force requirement).
(d) The task shall be completed in no more than 100 seconds.
(e) To simplify the problem, no limits on control forces or torques as well as joint angles and rates.