

## Servosystems & Robotics - Project P1 - Spring 2022

For the manipulator in the figure it is requested to develop and document in a report:

1. direct and inverse kinematics analysis (position, velocity, acceleration);
2. analysis of the singular configurations;
3. inverse dynamic analysis (evaluation of the actuators forces/torques);
4. working space determination according to ISO 9946;
5. design a control structure to follow a trajectory (a standard decentralized control or a centralized controller of free choice (in the working space, inverse dynamics, precomputed torques,...));
6. simulation of the assigned task. When executing the assigned trajectory (and whenever advisable) assure the continuity in velocity and acceleration as well as the respect of maximum motor limits;

The report must include

1. description of the algorithms and the adopted notation;
2. results of the simulation (xyz trajectory of end-effector; position, velocity and acceleration of gripper and joint coordinates, motor torques/forces versus time);
3. comparison between theoretical and simulated motion (effect of control);
4. description of methodology used for kinematics and dynamics debug (including graphs);

It is possible to use analytical or numerical methods, and SimScape SW. The students will freely assign the geometrical dimensions, the joints ranges, their maximum velocities, accelerations (positive and negative), and torques. Inspiration for the data may be taken from real robot data that can be found in internet. The TASK to be simulated is:

1. The manipulator is in point  $P_1$ .
2. Then, it moves to point  $P_2$  with minimum actuation time. In this position, the end-effector starts painting the surface shown in the figure below.
3. To evenly dispense the paint, the manipulator must move with constant velocity and, to complete the painting, it must perform a forward and backward movement as reported in the figure. Note that the end-effector must keep the paint erogation direction always orthogonal to the surface.
4. Once the painting has been completed, the manipulator returns rapidly to  $P_1$  with minimum actuation time.

At the exam bring a PC with a working copy of the SW and a printed copy of the report. A pdf copy of the report must be also sent to the professor 5 days before the discussion of the project.

**Note** If the project is developed by a couple of students both of them must be able to answer any question during the exam.

For general information on the project, please write to [giovanni.legnani@unibs.it](mailto:giovanni.legnani@unibs.it), while for Simsape you can also refer to [roberto.pagani@unibs.it](mailto:roberto.pagani@unibs.it)



Figure 1: Scheme of the manipulator and description of the movement.