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Senior Thesis FRAB (FIBO Robotics and Automation: Bachelor)

A study of Torque-Control system on UR5 for the drawing task

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Abstract
Industrial robot manipulators have countless applications nowadays. One of the basic tasks to test the accuracy of a robot manipulator is to perform a drawing task, which can be done with only position control alone. This project focuses on using a UR5 industrial robot manipulator to perform the drawing task. The challenge this project represents is controlling the force between the pen (end-effector) and the canvas using torque control while following a trajectory generated by the image processing method. This project is running on Gazebo Ignition physics simulation and using ROS2 as a middleware.

Keywords: Torque control, Dynamics model, Trajectory generation, Image processing, Edge detection, ROS2, Physic simulation

1 Overview

This topic will explain about what do the contribution of this work and what each topic will cover

2 Trajectory generation

This topic will explain about the methodology of trajectory generation and result

3 Inverse Kinematic

4 Dynamics and Control system

There are various type of control method available for UR5 with torque control. This work presents a motion control strategy based on the dynamics of the UR5. To generate the required torque for motion control, The dynamics equation in joint space (equation 1) is used to compute required torque respect to the Joint state[1]. To control position, velocity and acceleration of the UR5 can be done by using the PD controller (equation 2)

$$\tau = M(q)\ddot{q} + C(q, \dot{q}) + g(q) \tag{1}$$

$$\ddot{q} = \ddot{q_d} + K_p(q_d - q) + K_d(\dot{q}_d - \dot{q}) \tag{2}$$

where:

- τ is the joint torque Vector
- $M(q)\ddot{q}$ is the Inertia Matrix
- $C(q, \dot{q})$ is the Coriolis and Centrifugal Matrix
- $g(q)$ is the Gravity Vector
- $\ddot{q}$ is the computed acceleration (command)
- K_p and K_d are the proportional and derivative gain matrices
- q_d and q are the desired and actual joint positions
- $\dot{q}_d$ and $\dot{q}$ are the desired and actual joint velocities
- $\ddot{q_d}$ is the desired joint acceleration

However, In the dynamics model in joint space (equation 1) and PD controller (equation 2) are not able to control the force at the end-effector. The method for control motion and force at end-effector simultaneously is to apply the Hybrid force-motion control. Even so the hybrid force-motion control is using the dynamics model in task space make it more complicated to compute. This work presents the Z-axis elevation PI control(equation 3) method to control the force occurs at the end-effector. This method will not affect the control system to compensate the position error with stronger force respect to the time because of the motion controller is only PD controller.

$$Z = -1 \cdot (K_p(W_d - W) + K_i \int (W_d - W)\frac{d}{dt}) \tag{3}$$

where:

- Z is the elevation in Z axis (task space)
- K_p and K_i are the proportional and integral gain matrices
- W_d and W are the desired and actual force at end-effector Z axis

5 Test and Evaluation

6 Conclusion

[1] Joint state: joint position, joint velocity, joint acceleration