MTRN4230 Robotics Individual Assignment 1 (Asst1) Description Version 3 (edits in red)

Asst1 requires you to work individually to implement a program in Matlab to simulate the robot following a path extracted from an image, using the simulation model of the robot arm. It is worth 40 course marks.

Aims

The following assessment aims are derived from course learning outcomes 1, 2 and 4

- 1.2. Simulation software
  - 1.2.2. RVCTools / Matlab
- 2.1. Knowledge of kinematics and kinetics
  - 2.1.1. Calculate the DH parameters for a manipulator
  - 2.1.2. Model manipulator in a simulator, calculate forward and inverse kinematics
  - 2.1.3. Calculate joint and end effector velocities for a given DH model and relate these to one another
  - 2.1.8. Describe limitations of kinematic parameters (singularities, workspace constraints, manipulability
- 4.3. Implement image processing techniques to solve basic/more advanced image processing tasks
  - 4.3.1. Demonstrate ability to break a complex problem down into subcomponents
  - 4.3.2. Demonstrate ability to combine one or more basic or advanced techniques to solve an unknown problem

Getting started

Begin by attempting all the tutorial exercises, which are not assessed but which guide you through the steps for many of these assessed tasks. Two images are now available on Moodle to get you started:

- Empty grid image
- Example path image 1

Assessed Tasks

Image Processing (10 points)

1. Given an input image from the camera in the IRB120 robot cell, extract a path through the grid in image coordinates, starting at a location indicated by a tile with a red circle, and end at a location indicated by a tile with a green square. Tiles with letters or the black face upwards will be placed at locations forming a continuous and unique path between these start and end tiles, with each tile on the path aligned and oriented with the grid. There is no need to identify the letters, they are irrelevant. Tiles on the path will connect horizontally or vertically, but not diagonally, see the example image. Tiles with other shapes and colours may be placed randomly in the field of view, but not in cells adjoining (sideways or diagonally) the specific path. Display this path overlaid on the image with the start and end location and centreline of the path annotated. An example image is provided on Moodle which you can use in your report.
   a. (5 points) Report: Write a report explaining the program flow used in your image processing algorithm.
   b. (5 points) Demo: Demonstrate this task to your tutor using an image provided at the start of your tutorial.

Calibration (5 points)

1. Calibrate the camera intrinsic parameters using a chequerboard.
2. Calibrate the camera extrinsic parameters using measured points in the robot cell (see “ABB IRB120 Setup Data” under “IRB-120 Resources” on Moodle).

3. Create a GUI for the user to click on a displayed image from the robot cell camera and output the position of the point on the table in the robot coordinate frame (x, y, z). You may assume the table is flat.
    a. Demonstrate this to your tutor using an image of the empty grid (see Moodle)
        i. (2 points) Demo: Working GUI.
        ii. (3 points) Demo: Accuracy of points clicked (accuracy to be specified).

Modelling (25 points)

1. Calculate the table of DH parameters for the IRB120 using the dimensions on page 12 and rotation convention on page 10 of the IRB120 Product Specification (document 3HAC035960 in the ABB Robot Manuals available on Moodle). Check this result with your colleagues. Do not use the *modified DH parameters* like ABB's RobotStudio. The origin and orientation of the base frame (frame 0) should be defined as in the ABB manuals, at the very bottom of the robot, with the robot facing in the positive x-direction when all joint angles are zero. The end effector frame should be frame 6 - ie. the current suction cup should be modelled as the end effector. Use SI units for all units (metres and radians).
    a. Document this model in your report
        i. (1 point) Report: DH table including theta offset value
        ii. (2 points) Report: Draw and label one or more diagrams indicating all coordinate frames (x_i, y_i, z_i), links (1-6), origins (O_i) and joints (q_i)
2. Calculate the joint positions corresponding to four exterior corners of the large grid with the end-effector 50mm above the table and pointing directly down.
    a. (2 points) Report: Write these joint vectors in your report. Note that there can be multiple solutions. Ensure that your selected solution obeys the physical limitations on each joint motion. As the orientation of the end effector hasn't been fully specified (about a vertical axis), the value of joint 6 will be disregarded in this Asst.
3. Calculate a Cartesian trajectory, moving in a horizontal plane at 20mm/s, which will move the end effector along the path specified in example path image 1, ensuring it passes over the centre of each block. Begin and end the complete path from rest, but do not stop at any of the intermediate points, ensuring a constant speed of 20mm/s is maintained throughout the motion.
    a. (3 points) Report: Write the joint vectors and corresponding velocity and acceleration vectors corresponding to poses when the end effector moves over the centre of each of the first three blocks.
4. In a figure in Matlab, visualise the table, camera and the robot arm (a simple model using the RVC Toolbox is sufficient) in 3D as well as their corresponding coordinate frames.
    a. (6 points) Demo: Demonstrate this model to your tutor.
5. Plot the extent of the reachability of the arm on the surface of the table, assuming the end effector is facing vertically down and touching the table
    a. (2 points) Demo: Draw a top view of the table including a circular arc showing the extent of the reachability of the arm and calculate the radius of the end effector about the robot origin.
6. Simulate the motion of both a joint space (jtraj) kinematic trajectory and a Cartesian trajectory (ctraj) in RVCTools to follow example path image 1, ensuring it goes through the centre of each block.
    a. (5 points) Report: Compare the Cartesian and joint space trajectories over the first three blocks in your report, showing the position, velocity, acceleration and jerk over time and discuss the differences.
7. Calculate Yoshikawa's manipulability for the poses as the end effector passes over the centre of each block and describe how this changes as the manipulator moves about the workspace. Again, use SI units for all units (metres and radians).
    a. (2 points) Report: Show and discuss the results in your report.
8. Simulate the motion of the Cartesian kinematic trajectory in RVCTools from a path image which will be supplied during your tutorial, showing the entire path of the end effector in 3D during the animation.
    a. (2 points) Demo: Demonstrate this path to your tutor.

Report total 20 points, corresponding to 20 course marks.

Demonstration total 20 points, corresponding to 20 course marks.

Due date

Submit your individual report to Moodle by 5pm Friday week 9 (all students including those in Monday tutorial times). Show your individual solutions to the above tasks to your tutor within your tutorial time in week 9 (due to the public holiday Monday tutorial groups have until their tutorial time on Monday week 10).

Resources

Use the course discussion forum for getting help.