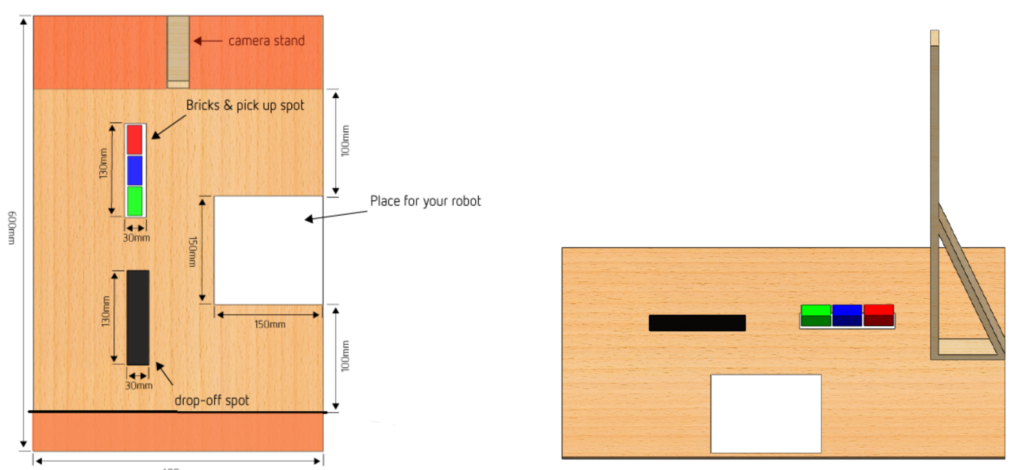
Robotics practicum

Robot Builder - Building walls with robots

1 Introduction

Your goal is to design a three degree of freedom serial chain robotic manipulator (RRR) that can build a colorful wall based on a predefined pattern. The system will be comprised of a USB camera, a RRR robotic manipulator and a magnetic end effector attached to a passive joint (4th joint of the robot). The system is depicted in Fig 1.

The task workspace is defined as a board with dimensions 400x600mm. Above the workspace, a monocular camera is placed, looking downward. Somewhere on the board, but not in the light red area, a drop off spot will be placed (wall location). The drop off spot is defined as black area with dimensions 30x130mm. Scattered around the workspace, there will be a maximum of nine bricks of different colors and sizes. You are free to position your robot anywhere within the white area.



(a) (b)

Figure 1: Workspace for pick and place manipulation tasks.

2 Factory Acceptance Test

In order to test your robot, the customer has defined the following Factory Acceptance Test, which encompasses all aspects of the manipulator design, control and operator's interaction with the system.

2.1 Robot workspace and construction

The proposed robotic system must comply with the following requirements:

2.1.1 Physical robot

(10 points) The final product must be designed as a chain RRR manipulator, with three active joints. It must be equipped with a magnetic end effector, which will attach to the bricks. You are free to use your hands to remove the objects from the end effector once it reaches the *drop off position*. The robot must be designed using the provided mechanical components and the 3D printed parts. Please consult with your lecturers before using any additional equipment and/or materials.

2.1.2 Machining components

(15 points) Your components will be machined for you, by a 3D printer. Upon submission of your designs, only feasibility of manufacturing will be checked. If design is acceptable for 3D printing, it will be printed. Students are ultimately responsible for the design (dimensions, construction, etc...). Your design will be compared with other groups based on the amount of material used to print objects. The amount of material is measured according to how many filament meters have been used to print your parts. The team that prints the least amount of material for a functional design gets the most points in this category. All designs will be printed with the same printer settings on several 3D printers of the same type, with the same filament type.

2.1.3 Camera

(5 points) The camera frame and the robot base frame must be properly calibrated. You may use passive markers, both mechanical or algorithmic, to calibrate the camera with respect to the robot base coordinate frame.

2.1.4 Direct kinematics

(5 points) You must derive a direct kinematics algorithm which calculates the position of the end effector from input joint values. You must take into account the size, shape and the structure of the robot. You must be able to position the robot precisely within its workspace.

2.1.5 Inverse kinematics

(5 points) You must derive an inverse kinematics algorithm which controls the joints given the position of the end effector of the robot. You must take into account the size, shape and the construction of the robot. You must be able to position a robot precisely within its workspace.

2.2 Graphical User Interface

Your final product must include a practical and effective user interface, so that an unskilled operator (aka a professor) can operate the robot.

2.2.1 GUI design

(10 points) The graphical user interface must be designed using MATLAB. It must include the standard GUI elements, such as buttons, sliders, etc., in an intuitive, logical and easy-to-use design.

2.2.2 Manual control - direct kinematics

(10 points) In manual control, the GUI must be designed so that the operator can directly enter the joint values, both via textbox and via slider. The robot must move to the designated values, and the GUI must output the 3D position of the end effector for the current joint values.

2.2.3 Manual control - inverse kinematics

(5 points) In manual control, GUI must be designed so that the operator can enter the value for the position of the end effector. The robot must move to the designated position, and the GUI must output the value of all joints at all times.

2.3 Autonomous wall building

2.3.1 Robot vision

(5 points) Your robotic system must be capable of recognizing and localizing bricks and dropoff area, which can attain different positions and orientations within the workspace of the robot.

In autonomous mode, the robot must be able to recognize brick, different colors and the drop of point. It must be able to differentiate bricks according to their color and size. Your algorithm must be able to place the object on its respective drop-off point.

2.3.2 Autonomous mode

(10 points) Once the system receives the wall pattern it needs to sort the bricks and build the wall according to the pattern.

2.4 Time challenge

(20 points) At the final test, you will be provided with a new pattern to build a wall. You will have 30 minutes to complete this task. The total time to completion will be measured. The best ranking team will receive 20 points, second best team will receive less than 20 points and so on. In case of a tie, both teams will receive the points that would be awarded to the higher rank. You can complete some parts of the task manually, however, every autonomous result is ranked higher than all attempts that are deemed manual. Taking bricks off the magnetic manipulator once the dropoff has been reached does not count as manual labor.

Points

There is a total of 100 points in the FAT. When calculating the total cumulative for the final grade, the points will be scaled as announced at the beginning of lectures.