Robotics 41013: Lab Assignment 1

Weight: 20%.
Demo Due: Week 6 Lab Class – 16:00 Tuesday, 2 September
Report Due: Week 6 – 21:00 Friday 4 September

2020 Special Note:

Due to the COVID-19 health situation, all demonstrations will be done individually with each student via Zoom with 2 tutors being present on the call. You must have a microphone, camera and be able to share your screen, so as to show your code / simulation. If you can attend UTS and use the real robots then you may video your outcomes. There is no need to demonstrate the real robots live for this session only. However, it may impossible for some (or all students) to attend UTS to use the labs or equipment. If you can safely attend UTS within the policy/regulations at the time, it will improve your learning experience. But if you cannot attend then please discuss a slightly adjusted marking criteria with the subject coordinator (email or DM in Teams).

Background:

Your company, SafeCo, assembles small brick walls. SafeCo have recently had a significant increase in orders that the staff and existing robots simply cannot keep up with.

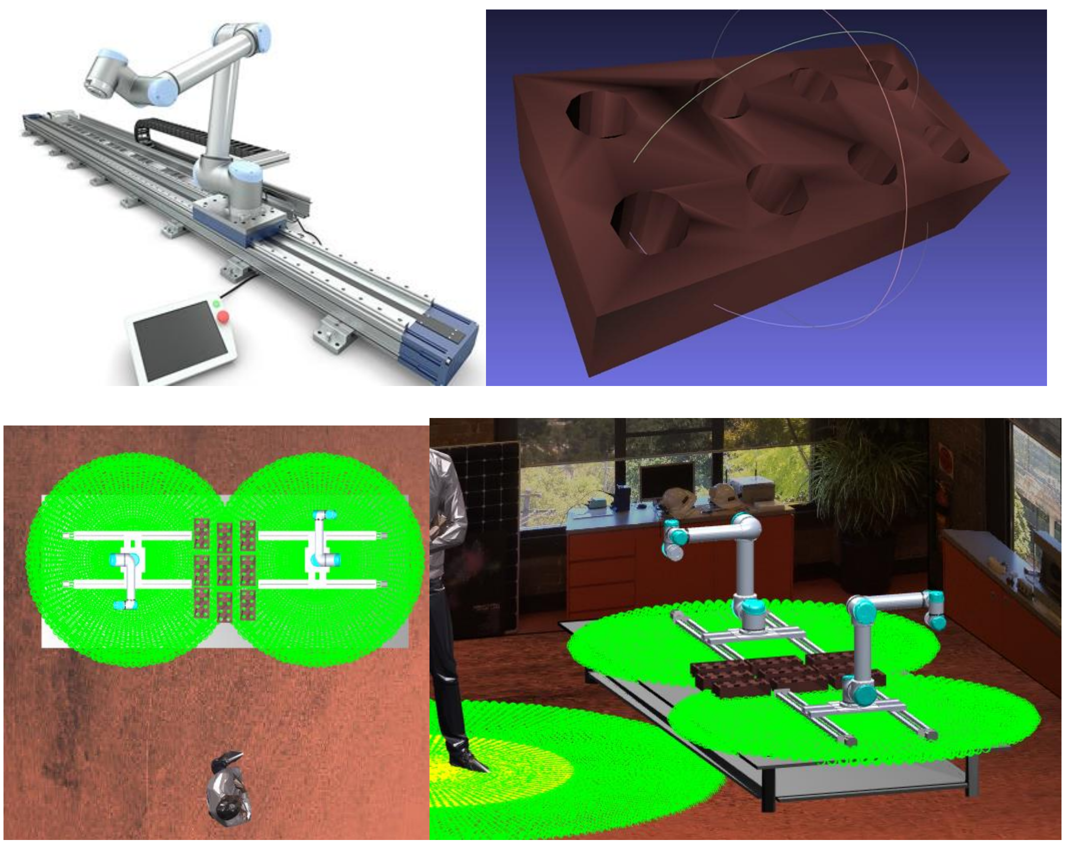

Fig 1: (a) An example of a Universal Robot mounted on a linear rail; (b) A brick to be layed; (c) Rough sketch of the layout using 2 UR5s on linear rails; (d) Same sketch different view.

SafeCo already have one UR5 robot which is mounted on a linear rail. This model is given to you (in the toolbox) and you may use this. SafeCo's management would like to introduce another robot into their production workflow to help with menial tasks such as the stacking of the bricks. Due to space limitations, it is important to management that the factory workspace is not changed significantly or rearranged unnecessarily. Additionally, SafeCo will still have many people performing various other tasks in the factory. Thus, for safety and efficiency, SafeCo have decided to buy a UR3 (not UR3e) OR a Sawyer – you must decide.

Scenario: “SafeCo Assembly Task”

The assembly task consists of picking up the 9 bricks shown in Fig 1, then fitting them together. A sensor is setup to determine the precise location of each brick (i.e. a 4x4 global homogenous transform of the end-effector required to grasp it). The bricks need to be stacked end-to-end with 3 bricks in each row, and a total of 3 rows high.

Task Overview:

Before the robots arrive, management wants some modelling done, and someone to investigate how and where to mount the robot bases, and a simulated demonstration of the assembly task being performed given a more open-ended scenario. You, as the person with the most experience working with robots, have been delegated this task. You have been instructed to use Matlab and to adhere to SafeCo’s coding standards (see UTSOnline). You will need to write a professional report describing in detail your findings, and reflections.

Specific Tasks for this Robotics 41013 Assignment

1) Build a D&H model of the UR3s. Build and customise a simulated graphical model of the chosen robot. You must include some distinctive feature such as your name or student number embossed or drawn somewhere on your chosen robot model. If you don’t customise it, or you choose to use someone else’s UR3 model, then please declare this clearly during your viva and you won’t receive marked on that section. You can add other safety features or models and customise the surrounding environment using Matlab and the Matlab robotics toolbox. Ensure the mounting location of the robot base can be easily modified.
2) On the submission day you will be given a specific mounting transform for each robot base, and for the demonstration you will need to be able to rapidly determine and demonstrate to your assessors/peers:
   a) the maximum reach of each arm (radius from top and side view);
   b) the approximate volume in m^3 that the entire arm may exist in (hint: consider the positions of each joint for a large, representative sample of joint positions) and;
   c) the updated location of proposed safety infrastructure given that mounting position.
3) The location of the 9 bricks will on the table, similarly to Fig. 1, but the actual transform of each brick will be given on the day of submission (for testing purposes you should set the locations to be random within some bounds). Assume that once the robot end-effector moves to the given part location it automatically and successfully grasps anything. You will need to demonstrate the following steps in the assembly:
   a) Determine a pose (set of joints) that can pick up each of the bricks;
   b) Simulate the robot movement in a smooth joint-position controlled motion between the starting pickup and drop off locations of the bricks (you decide how and where to build the wall, but it is suggested that you hardcode the drop-off locations)
   c) To receive full marks you must demonstrate the two robot arms moving at the same time. Partial marks are awarded if you can only move one robot at a time.
   d) Simulate the building of the wall by bringing the bricks together, without colliding so as to complete the assembly;

   e) You may use the linear rail on the UR5 since it can make the assembly easier. And you can add a linear rail for the UR3 as well, but this is not compulsory
4) Complete safety prerequisites before the demo day to unlock real robot use. Show video evidence of control of one real UR3 robot's movements through the planned task trajectory via Matlab's ROS interface. Perquisites and evidence of real-world use (i.e. videos, early live demos) will still receive partial marks.
5) Submit a zip file of your code to UTSOnline which will be checked for originality and marked against the given code standards. Note: including unnecessary files such as the Robotics Toolbox will be penalised.
6) Submit a 5-10 page (approx. 2000 words) report to UTSOnline in which you:
   a) Design the workspace (with the aid of figures) so that someone else can install the two robots including engineering considerations;
   b) Include considerations of safety in terms of a basic risk assessment that identifies hazards and their likelihood of occurrence, and Safe Work Method Statement.
   c) Reflect upon why a UR3 OR Sawyer is a good choice, whilst also investigating what sort of limitations you expect to encounter with the use of this robot;
   d) Reflect upon the usage of Matlab and the robotics toolbox
   e) Reflect upon the likely precision required, and thoughts about how you would go about controlling the robot;
   f) Reflect upon the likely challenges of sensing and grasping that you have been allowed to assume are solved problems
   g) Reflect upon the safety of the movement of the robots, such as considering if they may collide with each other or objects in the environment.
   h) Include an adequate reference list

Extension Bonus Questions:

You may wish to attempt these bonus questions for additional marks. These questions are challenging, and support is limited, but they will your demonstration impressive, your debugging easier, and enhance your understanding. Some questions are marked in the demonstration (D) and others in the report (R).

D1) Investigate Matlab's "GUIDE "to input a transform for the base of the arms, and the location of the three parts and the drop off location.

D2) Given a ROS '.bag' file of a real robot moving, playback the .bag file and demonstrate your simulated robot movements match the movements from the video of the real robot.

D3) Incorporate a sensor (e.g. camera, e-Stop, limit switch) via ROS that passes data into your Matlab system. You may like to use your SBC (e.g. Raspberry Pi) or an Arduino.

D4) Use the Virtual reality setup or the UR simulated robot on the CloudLab

R1) Use Matlab's "profile" tool to investigate which functions consume most of the time. Reflect briefly (in the report) on alternative methods to improve computational efficiency.

R2) Given the part models, select an appropriate gripper[1] and discuss with the use of diagrams the ideal way to grasp the objects.

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[1] https://www.universal-robots.com/plus/end-effectors/#/01011111111111111111

Marking Scheme:

The assignment is worth 20% of the subject. The assignment will be marked out of 100, attempting the extension bonus questions is encouraged but not compulsory, and the highest mark that can be received is still 100 (i.e. 20% for the subject).

General Task Description	Mark	When?
Given an end effector pose determine a joint state	**7**	**Demo**
Move robot to required joint states and demonstrate that the joint states satisfy the given pose	**7**	
If possible - demonstrate a real UR3 robot (in UTS lab). A pass mark is for 1 real UR3 robot safely doing the task actions. Higher marks are awarded for more interesting (but safe) uses of the UR3. If you have a valid reason to not attend UTS (OH&S or quarantined), then the other marks, without this item (out of 93%), will be scaled to be out of 100%.	**7**	
Simulate the environment around the robot	**12**	
Simulated robot model: realistic (7) or simple shape (3) or stick (1)	**7**	
Display and log transforms and status during task completion	**5**	
Calculate and plot workspace radius & volume	**5**	
Incorporate and consider safety in your demonstration	**5**	
Incorporate and consider safety in your design, code and report	5	Report
Code aesthetics: Comments & neatness	5	
Code aesthetics: Compliance to code standard provided	5	
Code structure: mainly use classes (5) or functions (2) or scripts (0)	5	
Report on the design and reflect upon the process	10	
Effectively communicate the required task information	10	
Marking self and another demo (mark based on distance to mean)	5	
Total (55 in Demo & 45 in Report)	**100**	
Demo Bonus (3 marks each): (#1) GUI, (#2) Playback ROS bag, (#3) Incorporate sensor (#4) Control VR or simulated UR	12	**Demo**
Report Bonus (3 marks each): (#1) Profile tool analysis, (#2) Gripper	6	**Report**
Total Bonus (Bonus tasks worth 3 marks each (6 x 3))	**18**	
Total max marks = min(Total + Bonus,100)	**max = 100**	