Assignment 1 Report

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Environment

Description

The environment consists of a conveyor belt, barricade, and two of the robots. The context behind this environment is to automate repetitive and menial task, and stack bricks upon each other.

One example is the transportation of materials from a quarry to a truck to a warehouse for storage and distribution for wholesalers or retailers. The assembly line with the robotic arms is assembling the “Unit Loads”, which are pallets of bricks in this scenario for forklifts to later pick up. This poses several hazards as movement of machinery and heavy objects in a busy environment can pose high inherent risk to people in the surroundings.

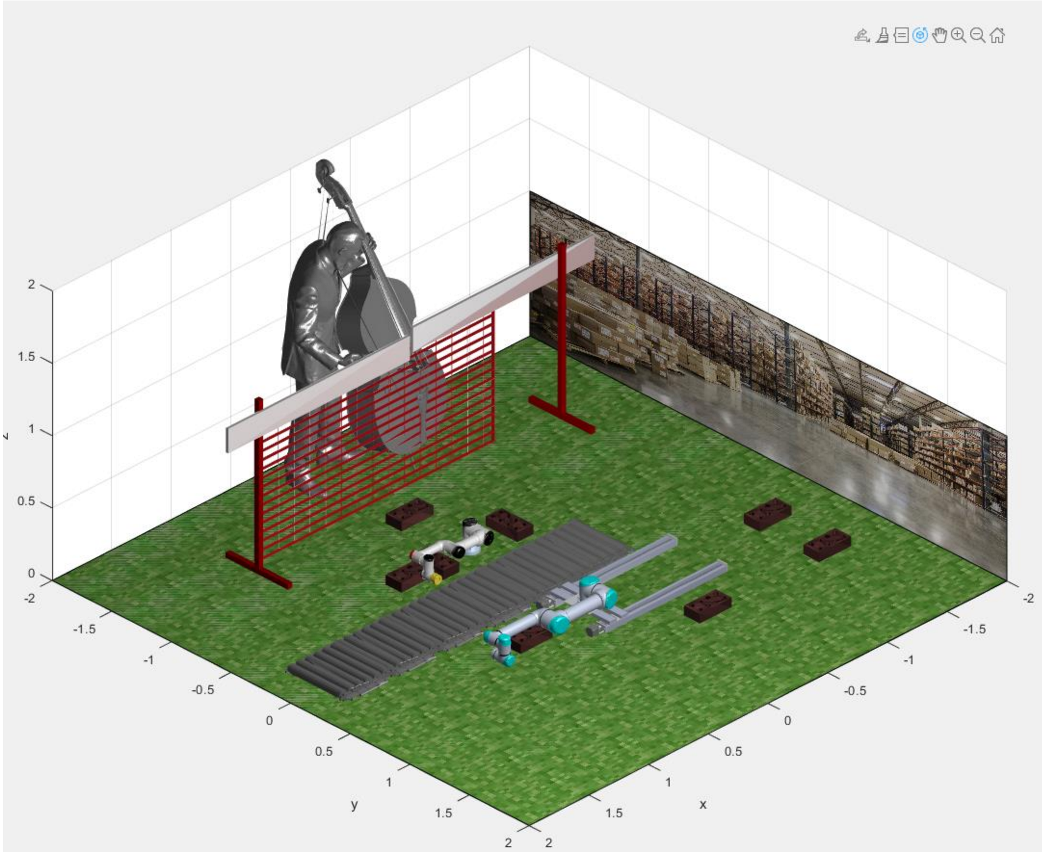


Figure 1 – Demo Environment

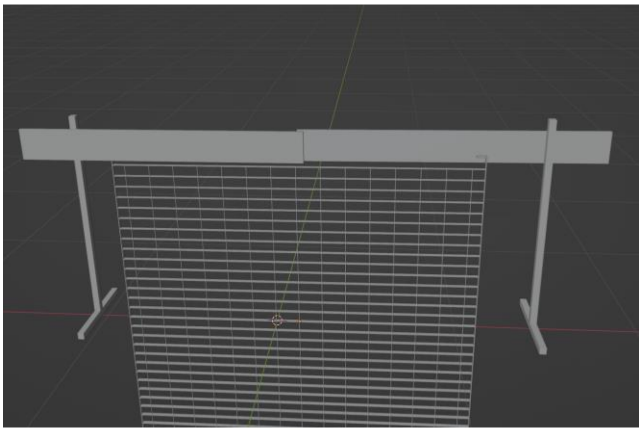
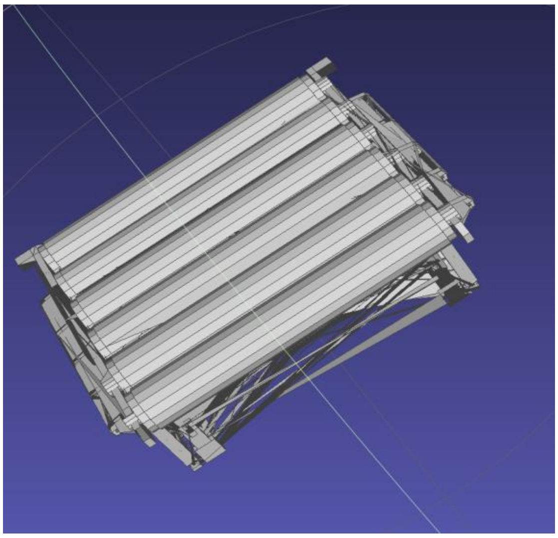
Safety Considerations

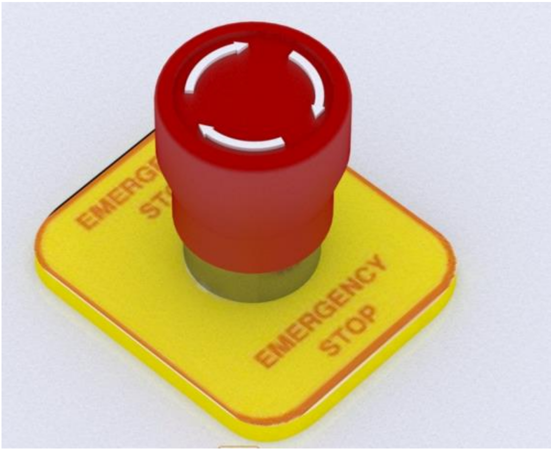
There are aspects in the environment that might present risk or hazards. Safety considerations are placed to prevent identified hazards from occurring.

The environment presented above (*figure 1*) allows engineers to develop a risk assessment, and as well as develop counter measures for preventing such events from happening. Through *figure 1*, *table 1* depicts specific assets (*table 1, item 1 & 2*) that are presented in this assignment.

Note: Due to time constraints and improper time investment in the ***Demo*** part of this assignment and rendering issues, *item 3* didn't make it in, but it is still the most important and worth including in this report.

Table 1 Assets to prevent hazards

Item. No	Hazard and Risk	Asset to prevent/reduce risk	Justification and residual risk
1	Movement of robotic arms causing collision and damage.	Barrier 	• Creates a no human access zone as depicted in *figure 1* (**human figure not to scale**). • Creates a robotic workspace with the no need to worry about people coming too close to it
	Medium		Low
2	Movement of heavy materials frequently can cause a range of injuries	Conveyor 	• Conveyors reduces manual labour - reducing the change of risk • Create a distinct space where materials can move about
	High		Low

3	Mechanical issues, unpredictable movement. Posing a risk to people near it and equipment damage.	Emergency Stop Button (not included in the **Demo**) 	• Stop button to prevent operations of robot from a distance
	High		Medium

Risk Assessment (RA)

This section presents a risk assessment (RA) of the environment developed in this assignment. The purpose of a RA is to identify hazards which a potential of harm, with risk which is a likelihood of harm, and create relevant preventable method/actions to eliminate or reduce the severity of an event. Appendix A is a RA presenting *table 1* in a more formal format.

Work Safety Method (SWMS)

The work safety method is a framework that aims to reduce hazards in the workplace. It can be structured in multiple tiers (*figure 2*). Where **PPE** is the minimum for reducing hazards and **Elimination** eliminates the hazard completely. Appendix B details the document for the SWMS for this environment.

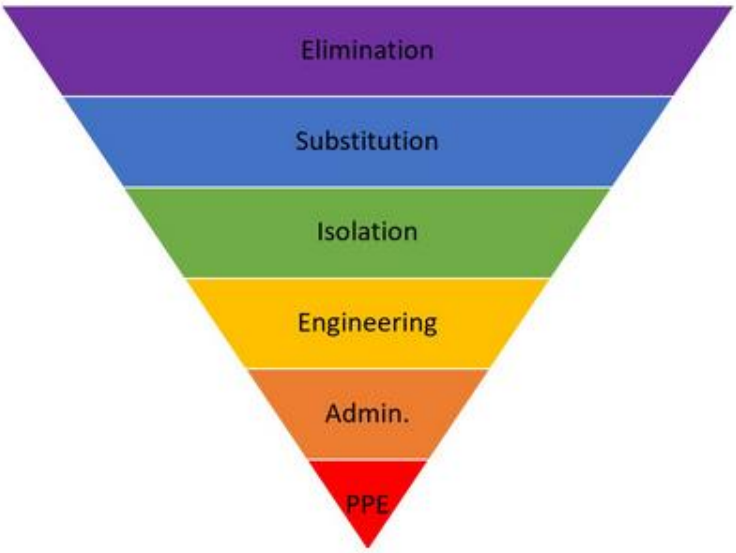


Figure 2

Workspace Specification

Specification of the environment will be covered in this section. The purpose of this section is to allow replication the Demo environment (*refer to table 2*).

Default Orientation: The UR3 and UR5 must be placed in the correct position in its rested state. This means while it is **NOT** in operation, the two units must be in the same default orientation so proper assessment of brick location can be made relative to their default position *(figure 3)*. For both robots, they are in parallel to the x-axis (*figure 3*) i.e. **0 degrees** from the **x-axis**.

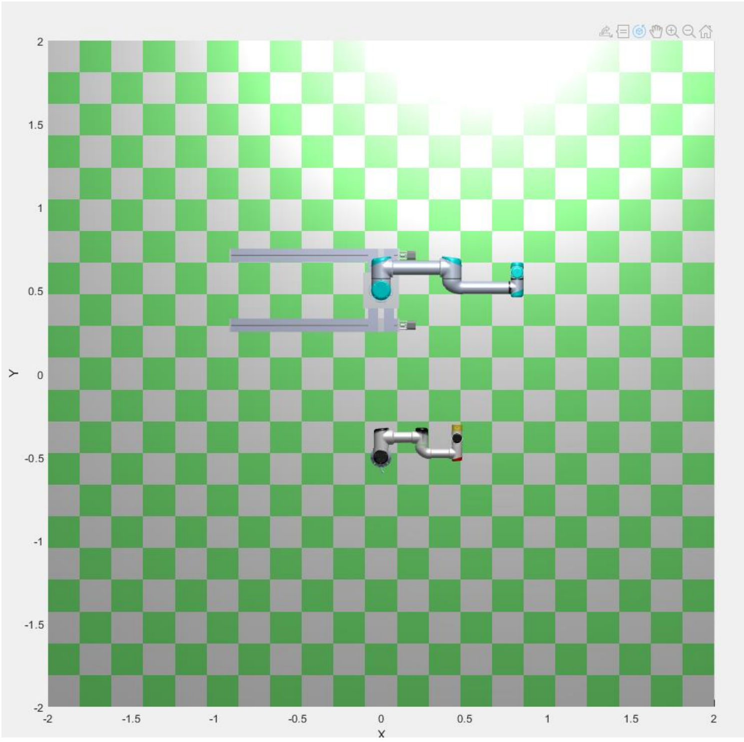


Figure 3 Default position of the UR3 & and UR5

Robot position: UR3 and UR5 position is restricted to its reach. The **drop of zone**, in this case is between both units, must be between the robot's reach and its base origin. UR3 and UR5 drop off zone must be below 500 mm and 850 mm respectively as per their specifications. *Figure 3* depicts both robots 1 meter apart from their base origin.

<u>Barrier location</u>: Through the RA and SWSM, barrier location can be placed anywhere as long as it prevents people from accessing the UR5 and UR3's workspace. The workspace is defined by its total reach volume. *Figure 4* depicts the volume cloud of the UR3, and the barrier (left) is outside of its range.

Figure 4 Volume cloud of the UR3. Barrier is outside of its radius

<u>Conveyor</u>: The conveyor's centre is the drop off zone for the bricks. The width of the conveyor is restricted to UR3 & UR5's reach. An overly wide conveyor may offset the reach of the UR3 making it unable to place the bricks in the centre.

Table 2 depicts the coordinates of the assets in the demo.

Table 2 Asset Positioning

Asset Name	Workspace positioning, metres (default)
UR3	X: 0| Y: -0.5| Z:0
UR5	X: 0| Y: 0.5 | Z:0
Barrier Frame 1	X: -1| Y: -1.2| Z:0
Barrier Frame 2	X: 0.6| Y: -1.2| Z:0
Barrier Fencing 1	X: 0| Y: -1.3| Z:0
Conveyor 1,2…n	X: 0,0.2,0.4…n | Y: 0| Z:0

Reflection

UR3

Specifications

The UR3 is an arm type robot made by Universal Robots. It has a reach of 0.5 meters, a maximum payload of 3kg, footprint of 128mm diameter, with a total weight of 11.2kg Universal Robots. (n.d).

Analysis

Benefits: Its low form factor means that it is useful in compact scenarios, lower severity in the event of a catastrophe, and a lower likelihood of catastrophic event. It will be capable in handling small and low weight payloads and an easy solution to replace costly, repetitive manual labour. Has 6 degrees of freedom (DOF), making it able translate in all axes. The end effector is a 3DOF joint making it flexible and able to grasp objects in unique angles. This makes it capable in reaching unique poses.

Caveats: However, its low form factor is also a limitation as the payload limit (3kg) and reach (0.5m) is the smallest of its counter parts, such as the ur5, ur10, and ur16. This means in this current scenario, assuming that the bricks are lower than 3kgs, then the UR3 is viable. But bricks can vary in weights ranging from 1.72kg – 5.48kg (Survival Tech Shop, n.d); hence it is important to assess the material weight before use. Reach is also a limitation as grasping objects equal or wider than the current reach will make it hard to grasp. But since bricks are small, the UR3’s reach shouldn’t be a huge limitation compared to the payload limit.

MATLAB and Robotics Toolbox

MATLAB

Coming from other languages there are many aspects in MATLAB I am still in the process of getting used to. MATLAB allows dynamic variables without the need to declare typing. This makes the debug process a lot more arduous. Error and outputs from when it came to dealing with .ply files were not useful. Documentation is sparse in this area when dealing with ply files, with a lot of time wasted trying to import them. Though my lack of coding experience and understanding on how polygon files are read would’ve played a factor into this.

However, matrix computation is excellent and easy to learn from. Combining it with Object Orientated Programming (OOP) really gave a quality of life in developing the code. I have created an object class called “PlyObject” to represent ply assets imported with their respective pose, both as a point and it’s vertices. I’ve also created a “Position” class to take advantage MATLAB’s inbuilt intellisense. This design approach is something I would want to build upon and bring into the next assignment. I also now understand better understanding of the theory and familiarly of robotics toolbox will produce cleaner code.

Robotics Toolbox

The robotics toolbox has been useful by not requiring deep theoretical knowledge to employ basic functions in the robot. But surface level understanding of the theory is still required. Its high amount of utility makes the user experience in coding a creative experience as there are many functions and ways to go about completing a specific task. Hence, I would need to read the documentation more intimately.

Precision

I think precision of a robotic arm will heavily depend on the application it'll be built for. For instance, a scenario where it doesn't require high precision are scenarios like painting and cleaning. On the other end of the spectrum, gripping intricate objects in certain positions and CNC-like scenarios will require high levels of precision. The grip type is also a factor, as grips can range from mechanism such as, vacuum, pneumatic, hydraulic, and electric grippers.

Overall, I would think precision is an ideal to have but not entirely necessary if the application doesn't dictate it. Having higher levels of precision would naturally pose a greater challenge and will require extra layers of control to be feasible in the context of the application it'll be used for. The following section contains the some of the known methodologies that could contribute to better control of a robotic arm system.

Methodologies

Computer vision

Object recognition can make a robot optimise its pose by directly identifying what it's looking at. This might increase reliability as global coordinates can only go so far to improve precision. Furthermore, by classifying what it sees the robot can optimise itself to move a particular way depending on the shape of the object. I would use this method to perform identification and pose optimisation.

Global Frame of reference

Having global awareness will allow the robot to move about the surface. If there is a need to go from point A to point B, the global frame can detect the robot's current pose. This can also be integrated with computer vision and allow the robot to obtain data and have contextual understanding on its environment. I would primarily use the global reference for making the robot go from point A to point B.

Sensing

Sensing can coincide in the two methodologies presented above as they would be using cameras. But this section will focus on the available peripheral that would be used for collision avoidance. One sensor that I would use is LiDAR sensors as they are light and ranging detectors. I would use them for pose optimisation and implement collision prevention through its depth awareness. With computer vision, picking up objects with depth awareness will add an extra layer of control.

Sensing and Grasping

Like the Precision section discussed above, a lot of the challenges will depend on the application it'll be built for. For an end-effector to accurately reach a designated pose, I would imagine a multi layered sensing system may need to be in place by have more sensors to improve reliability (Roni-Jussi Halme et al. 2018).

The biggest challenge that comes to mind is the input data. The quality of the data would instantly affect the output. There may be noise and interferences that would affect the sensing of the robotic system. We know there are already solutions out there for overcoming this issue, but its just a matter of figuring out how to put it all together.

Safety

Without considering safety, through Murphy's law, someone will eventually get hit by the moving robots. In the demo environment I've made for this assignment, I've considered objects such as barricades/gates and emergency stop buttons for safety. While I believe this is enough, there are existing solutions that makes use of the latest technologies using sensors. One method for detecting objects within a zone is by using virtual optical barriers as opposed to physical ones. A safety line is created around a workspace of the robotic arm, and when the virtual barrier is intercepted by an object, operation will cease (Roni-Jussi Halme et al. 2018). This paper further comments on how the safety zone can move and transform depending on the position of the robot. With an increase of human-robot collaboration the development of collision detection has be increasing as well leaving us with a lot of options to choose from.

Bonus

Profile

Appendix C displays the profile of my code. We can see `plyread` is taking up a significant portion of the code's lifetime. Looking at the parent classes, it is the UR3 and UR5 class that is calling this function. And within those classes they are using a function called `PlotAndColourRobot`. Then further we can see that the UR3 is taking longer to render compared to the UR5. So, after investigating their respective ply files the UR3 files contained face and vertex data nearly 10 times that of the UR5's files. For further optimization, I'll be reducing the face and vertices of the UR3 to speed up performance.

Gripper Choice

The gripper of choice is a Servo-Electric type gripper. This will be chosen over the Pneumatic and Hydraulic grips as Electric grips has smart pickup detection, local motors, and precision stacking/pelletizing (Universal Robots, 2022); making this the choice for Safe&Co's assignment.

Because the brick models are rectangular a 2-finger clamp style is sufficient for picking up a brick. Brick pay load must be picked up at the centre for both axes (refer to Appendix D) to prevent uneven distribution of load/torque when rotating or translating the brick.

Figure 5 Electric Gripper – HIWIN X SERIES

References

Universal Robots. (n.d). *Universal Robots UR3e*, Universal Robots. https://www.universal-robots.com/products/ur3-robot/?utm_source=Google&utm_medium=cpc&utm_cja=Demo&utm_leadsource=Paid%20Search&utm_campaign=HQ_AU_Always-on2021&utm_content=sitelink&utm_term=mgww&gclid=Cj0KCQjw_4-SBhCgARIsAAlegrX7l88rJxefNhv_ohzFn6edU7m2hpxDdRUzmD6cjxC_J7v8jiy3VWsaAvj0EALw_wcB

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Universal Robots. (2022, February). *Types of Grippers used in Manufacturing*. Universal Robots. https://www.universal-robots.com/blog/types-of-grippers-used-in-manufacturing/

Roni-Jussi Halme et al. (2018). *Review of vision-based safety systems for human-robot collaboration* (Volume 72). Procedia CRIP

Universal Robots. (2022, July). *Robotic Gripper Showdown: Air Gripper Vs. Electric Gripper*. Universal Robots. https://www.universal-robots.com/blog/robot-gripper-showdown-air-gripper-vs-electric-gripper/

Appendix A

Work area / operation	CB11.10.403		**Assessor's name**		
Other persons consulted	OTHER STUDENT NAMES			**Date of safety assessment**	
Subject Coordinator's Name		Lab Supervisor's Name			

ACTIVITY - Describe hazardous activities related to the work area or operation.	**ASSOCIATED HAZARDS**	**INHERENT RISK** - Harm that could occur from these hazards if controls fail or are not in place.	**EXISTING CONTROL MEASURES**	**PROPOSED CONTROL MEASURES** - Proposed action to minimise risk to an acceptable level.	**TARGET DATE** - To implement proposed controls	**RESIDUAL RISK LEVEL** (H,M,L)
Movement of machinery	Machinery, such as the robotic arm are heavy and can move about in a large area	Could collide with people and moving objects.	None.	Barrier to create a workspace for the robots	ASAP	L
Leaving the robot arm unattended	Unsupervised robot doing unsupervised things	Damage to robot, surrounding equipment, possibly other people	Supervisors, Robotic state monitor system	Stop button	ASAP	L
Physically demanding activities such as lifting and carrying heavy objects; such as bricks	Long term health affects on manual labourers	Joint or back pain from long term activity	Lumber Support	Replace manual labour with conveyors	Whenever applicable	L

Approval of assessment	I am satisfied that the residual risk with existing controls is acceptable XYes ☐No OR I am satisfied that that the proposed controls will reduce risk to an acceptable level. ☐Yes ☐No	Signature		Date	

Appendix B

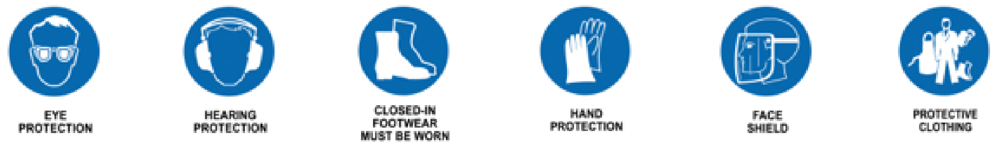
1. FACULTY/SUBJECT	
Faculty/Subject title	41013 Industrial Robotics – Assignment 1
Subject supervisor/coordinator	Gavin Paul
SWMS prepared by	Raymond Lim

2. WORK ACTIVITY DESCRIPTION	
Describe the work activity E.g. Operating, Handling, Using.. Include names of hazardous equipment, substances or materials used, and any quantities and concentrations of substance(s) or reaction products.	**Bricks for pallets to be stacked in a 3 by 3. Robotic units such as the UR3 and the UR5 will be used for stacking, with barriers placed at a minimum of the workspace of said units. Robotic units will be moving about their own workspace and grabbing bricks in range of its reach, and stacking bricks on a conveyor belt.**

3. HAZARDS: Choose those hazard types that will need to have control measures in Section 4			
Work Environment • Working in Remote Locations • Working Outdoors/fieldwork • Clinical/Industrial setting • Poor ventilation/Air quality • Temperature extremes • Working at Height • Slip/Trip/Fall hazards	**Plant** • Noise • Vibration • Working with compressed air • Lifts Hoists or Cranes • Moving parts (Crushing,friction, cut, stab, shear hazards) • Pressure Vessels or Boilers	**Chemical** • Hazardous Chemicals use • Skin/eye irritant • Sensitiser • Mutagen • Carcinogen • Toxic to reproduction • Aquatic toxicity • Toxic • Corrosive • Dangerous when wet	**Ergonomic/Manual Handling** • Repetitive or awkward movements • Lifting heavy objects • Over reaching • Working above shoulder or below knee height • Poor workstation set up
Electrical • Plug in equipment • High voltage • Exposed wiring • Exposed conductors	**Radiation** • Ionising Radiation • Non-ionising radiation (Lasers, Microwaves, Ultraviolet light)	**Biological** • Sharps/Needles • Cytotoxins • Pathogens/infectious materials • Infectious materials • Communicable diseases • Animal/insects • Work with fungi/bact/viruses	**Psychosocial** • Aggressive or violent clients/students • Working in isolation • Working with timeframes • Staffing issues

4. CONTROLS MEASURES: Choose those that apply for hazards identified		
Eliminate/Isolate/Substitute / Engineering Controls • Remove hazard • Restrict access • Redesign equipment • Guarding / Barriers / Fume Cupboard / exhaust • Biosafety cabinet • Use safer materials/substances • Ventilation • Regular maintenance of equipment • Redesign of workspace / workflow	**Admin specific: Licenses/permits Work Methods** • Training Information or Instruction • Licensing or certification of operators • Test and tag electrical equipment • Restricted access • Regular breaks • Task rotation • Work in pairs • Document Chemical risk assessment • Ladder / Sling register	**Emergency Response Systems** • First aid kit • Chemical spill kit • Safety shower • Eye wash station • Emergency Stop button • Remote Communication Mechanism
Other controls not listed		

5. PPE REQUIRED (Tick those that apply) ✓



6. EMERGENCY EQUIPMENT

7. WORK ACTIVITY STEPS

BEFORE YOU START:

- Ensure you have proper PPE equipment specified
- Idenitfy the location of the first aid kit
- Identify any machinery in operation

STEPS IN WORK ACTIVITY:

1. While robots are in operation say outside of workspace designated by the barriers in place
2. Identify any awkward movements in the robot and report observations if so, and press the emergency button
3. Admire the Robot

EMERGENCY PROCEDURES:

- Press emergency button
- In case of injury,
- Notify supervisor
- Notify security or dial 6

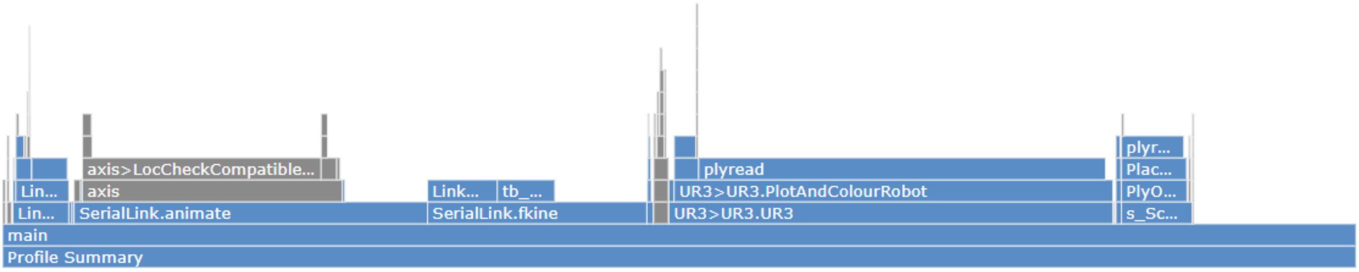
TRAINING REQUIRED:

- Induction for work and safety
-

Appendix C

Profile Summary (Total time: 37.970 s)

Flame Graph



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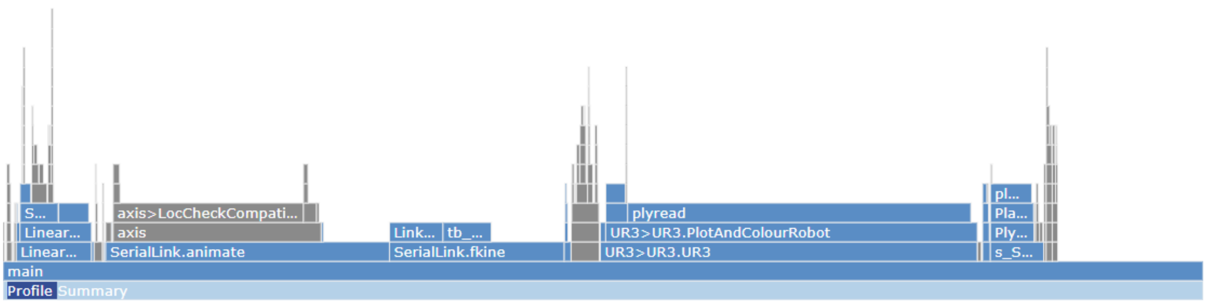
Function Name	Calls	Total Time (s)	Self Time* (s)	Total Time Plot (dark band = self time)
main	1	37.929	4.570	
plyread	33	14.278	14.152	
UR3>UR3.UR3	1	12.460	0.001	
UR3>UR3.PlotAndColourRobot	1	12.310	0.209	
SerialLink.animate	762	10.746	2.893	
axis	765	7.418	0.085	
axis>LocCheckCompatibleLimits	764	6.733	6.405	
SerialLink.fkine	95158	6.168	2.492	
Link>Link.A	577241	2.055	2.055	
PlyObject>PlyObject.PlyObject	18	1.989	0.013	
s_Scene	1	1.983	0.008	
PlaceObject	18	1.971	0.056	
tb_optparse	95643	1.724	1.706	
LinearUR5c.LinearUR5c>LinearUR5c.LinearUR5c	1	1.569	0.001	
LinearUR5c.LinearUR5c>LinearUR5c.PlotAndColourRobot	1	1.488	0.042	
SerialLink.plot3d	2	1.122	0.029	

plyread (Calls: 33, Time: 13.822 s)

Flame Graph



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Function in file C:\Users\mon3l\OneDrive - UTS\University\2022 Autume\Ind\robot-9.10Small_Modified_20220202_WithVisionTB\robot-9.10Small_Modified\rvctools\robot\ply\plyread.m
Copy to new window for comparing multiple runs

Parents (calling functions)

Function Name	Function Type	Calls
LinearUR5c.LinearUR5c>LinearUR5c.PlotAndColourRobot	Class method	8
UR3>UR3.PlotAndColourRobot	Class method	7
PlaceObject	Function	18

Appendix D