**Machine Teaching for Robots: Problem Statement**

As the demand for the implementation of robots is increasing day by day to perform basic human tasks with more speed, accuracy, and less cost. A dynamic robot with motoring skills can complete a lot of time-consuming tasks done by humans in a shorter period and they can be automated. For example, folding clothes, manufacturing sorting objects into different categories and classes etc. The main objective of machine teaching for robots is for robots to learn from human demonstrations to learn motoring skills to perform tasks and later automate them so that they can perform the tasks independently. This is process of learning is very much like how humans learn and develop new skills, this is also known as the Learning from demonstration (LfD) approach which is widely used in teaching. This is an example of active learning in supervised learning which contrasts with machine learning. This method of teaching can be broken down in two different stages which are teaching and learning. The person who usually performs these tasks is very skilled and knowledgeable in the task that they are performing. We do this to ensure that the teacher makes very few mistakes when teaching the skills to the student. The same process is very much like how robots would learn skills from humans. If the demonstrations given to the robot are also poor, then automatically the time taken for the robot learn the task with making as less error as possible will also increase. Therefore, the quality for teaching done the human is a huge factor that can affect the efficiency of the robot’s operation. In the past few years, the algorithms implemented by scientists and engineers have improved rapidly and now enable robots to perform a lot of complex tasks but the main limiting factor that is bottle necking their progress is the quality of teaching that is received from humans. This is a field that is still evolving and therefore the methods and techniques used to approach the problem keep changing as the field moves along.

Machine teaching so far has only shown promising results for a limited number of tasks as this is an approach that uses a learning algorithm that is derived from the data that is provided to robot. If the demonstrations given by the teacher are of low quality, then the robot receives low quality data which increases the training time and costs as the experiments would have to be run multiple times which require a lot of resources. Therefore, high quality teaching is very important to reduce the errors made by the robots and increase the data given to them that will ultimately allow them to complete tasks with high accuracy and precision. Many experiments conducted over the years show that novice teacher who have increased the effectiveness of their teaching with a proposed index of (n=32) have had a reduction of 66.5% error in the skills that robots were trying to develop. However, as mentioned before not all tasks can be performed by robots so easily as their mechanical build and other physical properties limit their functionality. So, selecting the correct dynamic torque-controlled robot for the skill is also very important and teaching should be optimised with this in mind.

Source: <https://arxiv.org/pdf/2104.08631v2.pdf>

Source: <https://arxiv.org/pdf/1801.05927v1.pdf>

**Machine Teaching for Robots: Project Objectives & Feasibility**

**Aim:**

The aim of this project is to improve the quality of training that is given by humans to robots to enable them to perform tasks with less error and more speed so that they are cable enough to perform the tasks just as well as humans. There are experiments that have shown effectiveness of the training in teachers had a reduction in error of the skill the robot has learned from the human teacher. The aim is too perfect and optimise the teaching that is given to a dynamic torque-controlled robot from a human and the high-quality demonstrations can be modelled as data. They would then need to reproduce the exact same behaviour by estimating the parameters that have been given through the learning algorithm with as less error as possible. Once a suitable algorithm has been derived it must be implemented in the real world by using a torque-controlled robot which must then be able to perform the task that has been demonstrated to it by the teacher with as less error as possible. The final aim is to test my algorithm with the uArm two degree of freedom robot arm to pick up and object and move it to a different position based the observations made from me.

**Objectives:**

1. Create a model using mathematical equations and concepts for modelling kinematics of the robot.
2. Explore the open loop behaviour of the model that I created and make the required adjustments in the MATLAB simulation for the 2 degree of freedom uArm robot arm.
3. Use Raspberry Pi along with tensor flow and the appropriate servo shield for the robot arm to track the objects that I pick up and drop for it to learn the position and repeat after me
4. For this to work I need to create code in Python that will work hand in hand with Raspberry Pi and tensor flow as well as the remaining hardware
5. I need also create a learning algorithm where the robot can use the data received from the observation and reproduce it as accurately as possible
6. I must try and achieve close an accuracy of at least 66.5% for my teaching method to have been very effective

**Machine Teaching for Robots: Project relevance to module learning outcomes**

This project meets the learning outcomes of this module and is appropriate because it meets the professional engineering competencies as well as the skills that I should have upon completing the project. In this project I will need to research and integrate comprehensive disciplinary and contextual knowledge to support the project topic. Therefore, I have carried out research and gathered the appropriate data and information that will support the project. I need to analyse the problems that I will face while working on this project and formulate aims and objectives that will help me make my project feasible as well as consider the uncertainty and risks of the project. I need to consider the ethics, health and safety codes while designing the project. I need to examine and evaluate existing solutions, methods, and approaches to further improve my own project and build a foundation for it. I need to effectively monitor, manage, and communicate progress and results with individuals this includes like my project supervisor and the report that I will have to make. I will need evaluate the project’s success considering the aims and objectives and reflecting on my own learning and skill development. These are all the effective skills that I need to use for me to solve and real-world problem using the professional engineering competencies.

The project that I have chosen will help me solve and understand a real-world problem that we are facing in the real world which is automating the basic tasks that humans need to perform but, they are far too time consuming and can often be expensive to use individuals to perform these tasks. By coming with effective teaching techniques that will help robots to learn tasks through demonstrations will help save a lot of time and reduce expenses by automating the task with robots. The main area this can be very helpful is manufacturing and agriculture where robots can perform complex tasks with ease and often can be done much faster efficiently than humans. That is the reason why this is an appropriate project for me to research and develop as it will help me improve my skill set further as well as put my engineering skills and techniques to practical use.

**Machine Teaching for Robots: Project Schedule**

|  |  |  |  |
| --- | --- | --- | --- |
| Week Commencing | Day 1 | Day 2 | Hours This week |
| **October Focus: Identifying appropriate mathematical equations** | | | |
| 18/10/22 | Derive and use existing statistical methods to improve the quality of the data given to the robot – **1hr** | Derive and use existing kinematic equations that govern the behaviour of the robot arm -**1hr** | 2hrs |
| 25/10/22 | Compose the equations that I can test on MATLAB for modelling and simulation of the algorithm -**1hr** | Draw sketches and diagrams to clearly understand how the robot arm would operate -**1hr** | 2hrs |
| **November Focus: Software setup and initial testing** | | | |
| 1/11/22 | Meet with module supervisor and collect information about what software and hardware I would need to use **– 1hr** | Start setting up the software and test some pre-existing cod with the targeted hardware in mind **-2hrs** | 3hrs |
| 8/11/22 | Start MATLAB and Simulink testing with equations derived from the week and try to build a raw model **-2hrs** | Complete software testing of the initial equations and prepare to further enhance the model for more in depth analysis as well as testing **-3hrs** | 5hrs |
| **December Focus: Further Software testing and simulation** | | | |
| 6/12/22 | Build a more sophisticated model and using MATLAB run more simulations **-3hrs** | Obtain readings from the simulation and compare the data with some pre-existing as well as the initial calculations that I made before **-4hrs** | 7hrs |
| 13/12/22 | If the data doesn’t seem satisfactory then I will alter the equations more and change the model accordingly -**3hrs** | Obtain readings from the new simulation and compare the data with some pre-existing as well as the initial calculations that I made before to achieve satisfactory results **-4hrs** | 7hrs |
| 20/12/22 | Preparations for the January exams | | |
| 27/12/22 |
| **January Focus: Setup Raspberry Pi and robot arm** | | | |
| 3/1/23 | Preparations for the January exams | | |
| 10/1/23 |
| 17/1/23 | Setup Raspberry Pi and the robot for practical testing using the Python code that will be written -**5hrs** | Start coding in Python to build the initial code using the testing I have done from the MATLAB simulations -**6hrs** | 11hrs |
| 24/1/23 |
| **February Focus: Testing the code using the uArm** | | | |
| 7/2/23 | Configure the uArm with the servo shield, camera module and Raspberry Pi to test the code that has been prepared earlier -**4hrs** | Once the system has been setup, I will use the code that I have written on the Raspberry Pi to start testing my algorithm to see how the quality of my teaching is **-5hrs** | 9hrs |
| 14/2/23 | Test and make changes to the Python code to further improve the algorithm to get data from the testing. This will allow me to see how effective the teaching methods from my side are - 10**hrs** | | 10hrs |
| 21/2/23 |
| **March Focus: Finish the uArm and start working on project report** | | | |
| 7/3/23 | Finish debugging the Python code and the hardware for the uArm **-4hrs** | Show the finished uArm to the project supervisor and take any feedback that he suggests to further improve the task performed by the uArm -**1hr** | 5hrs |
| 14/3/23 | Make the final changes suggested to me by the project supervisor and makes sure the performance is adequate **-3hrs**  Start working on the final report that must be submitted and debug and comment the code for the final time -**3hrs** | | 6hrs |
| 21/3/23 |
| **April Focus: Finish the Report and presentation** | | | |
| 4/4/23 | Speak to the project supervisor and get advice from him to best present the demonstration – **1hr** | Record the video for the demonstration and make any necessary amendments. I will reshoot the video again if necessary **- 2hrs** | 3hrs |
| 11/4/23 | Continue and finish making the project report. Get feedback from the module supervisor for any necessary changes. Add the amendments to the report and do one final check. I will then make the submission on Keats. **– 3hrs** | | 3hrs |

**Gantt Chart Representation:**

**Machine Teaching for Robots: Risk Management, Ethics and GDPR**

**Risk Management:**

Most of the work that is carried out on this project will done my personal laptop, home desk setup and other workspaces. The health and safety risk that I will be facing due to this will be very few and can easily be prevented through some basic measures. The potential risk that I could face are:

1. Poor posture while sitting down at the desks. The desk that I would use to work from home are comfortable so the only preventive measure I can take is by maintaining straight posture on my chair and adjust my desk height, if possible, to make sure wrists stay at a comfortable position while typing on the keyboard.
2. Make sure the lighting conditions in the room is adjusted properly to make sure my eyes aren’t strained.
3. Make sure I take caution when working with components that have pin headers to prevent poking my fingers and cause bleeding.
4. Make sure the voltages of the power supplies that I use for the Raspberry Pi and the uArm are correct to avoid any damage to them or cause any potential explosions.
5. Be careful when testing the with uArm as it has metallic chase that could hurt my fingers or cause cut it moves too suddenly without me paying any attention.
6. Take regular breaks while working for long hours to prevent strain on my body.
7. Make sure the uArm is fixed securely to the desk and doesn’t topple over from the table and pull any cable along with it.

**Feasibility of deliverables:**

If the project deliverables get corrupted or lost, then the project schedule will be affected servilely, and it could potentially set my progress back my days or even weeks. It could also lead to me making and unrefined product due to the time constraints that this will cause me. To assure that my project deliverables don’t get lost or get corrupted I will regularly backup the data into my cloud accounts. I will setup automatic cloud backup to ensure that the files get saved as soon as any changes are made to the files, this will also be a fail safe if my laptop malfunctions. I will have a space Raspberry Pi board of lower specification as standby in case if the one currently has malfunctions or if some of the port break or don’t work. I will have at least one spare component of the of the hardware that I’m using to avoid any disruption to my workflow.

**GPDR and Research Ethics:**

I don’t require any GDPR approval as I don’t need to sample any data from humans such as surveys or obtain any organic samples from them. No one’s privacy will be compromised due to my project or the research that I conduct. The data and any source code that I use are already publicly available and their open source. The software that I will be using such as MATLAB are legally licensed under my name by the institution and software such as Raspberry Pi OS are built on an open-source platform which is Linux. Therefore, I don’t need to be concerned about GDPR or copyright clashes from others. All the research papers that I have used are copyright free and I can use the data and information in them if I change them by altering it in my own way. So, there is no need for me to be concerned about facing any copyright claims due to the research that I carried and all the papers that I used have been referenced.