# ***Introduction:***

Welcome to the ROCO318 Lab sessions. The topic of mobile and humanoid robots can cover an absolutely massive span of subjects and details. These sessions have been designed to set you up in a way in which you are able to tackle the topic and the challenges in a method where you can breakdown any task and piece together a realistic tactical approach. You will also have the opportunity to design and build your own prototype whilst staying within the design limitations.

With the wonders of the internet, it is often very easy to find the "pinnacles of engineering" out in the world. From Boston Dynamics with Atlas and Spot, to Tesla with the model 3. There are many companies out there which have found a place and have dived down the rabbit hole to make themselves the world leaders in that field. You can even find almost every idea or concept has been made or duplicated by someone else on YouTube. However, there is often a very big discrepancy between the two.

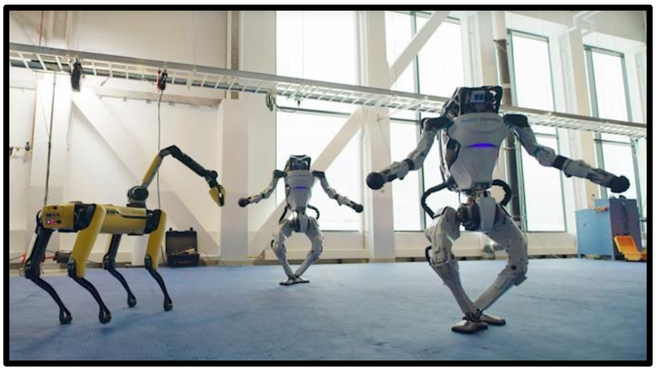

*Figure 1 - Spot and Atlas from Boston Dynamics video 'Do You Love Me?' https://youtu.be/fn3KWM1kuAw*

Just because two things may look alike, does not mean they perform alike.

So how would you go about designing a mobile robot? What are the considerations that need to be made? What's the difference between prototypes and manufacturing for production?

With these labs you will be expected to work in pairs. Every group will receive a kit of standard parts, however what you do with those parts and what you build is quite open. The only limitation is that your robot and your design will need to be justified and broken down at the end. Each key decision described and why you did it that way explained. Your robot is also expected to be a legged platform consisting of either 2 or 4 legs.

At the end of these labs, you will be graded based upon a final presentation and a project report.

Final submission date: 16/12/2021

Presentation date: 16/12/2021

***Coronavirus Contingency's***

Without further Coronavirus interruptions you will be designing and building prototype robots, which you will then be able to 3D print, construct and practically test. Code for control will be a mix of embedded and simulation.

If further lockdowns or restrictions are implemented, your marking will be adjusted accordingly. Practical elements may become unviable to pursue, as such they would then be replaced with simulation alternatives. E.g. 3D printing replaced with physics engine based collision simulation.

# ***Aim:***

To design and build a legged robot that can walk 1 meter un-aided.

To achieve this:

- The physical components must be designed and modelled in CAD.
- Your interconnecting components must be designed, modelled and tested in CAD.
- Your complete robot must be fully assembled with appropriate tolerances in CAD.
- The robot must be assembled with clear iteration and design improvements
- The robot must be programmed, simulated and practically tested.

In summary, you will be expected to design multiple iterations of your robot in CAD before then committing to rapid prototyping. You will then construct your robot and test it.

# ***Breakdown:***

| Element | Percentage* % |
|---|---|
| **3D Design inc. Dynamics** | 10 |
| **Prototyping & Build** | 10 |
| **Programming Simulation & Control** | 20 |
| **Application & Testing** | 10 |
| **Final Report** | 20 |

*These percentages relate to the overall percentage for the module.

# ***The Kit:***

For this module, your kit consists of the following items:

- 12x MG90S Servo Motor
- 1x PCA9685 16-channel 12-bit PWM module
- 1x Arduino Nano
- 1x 5V 3A Power supply
- 1x Barrel Jack Connector

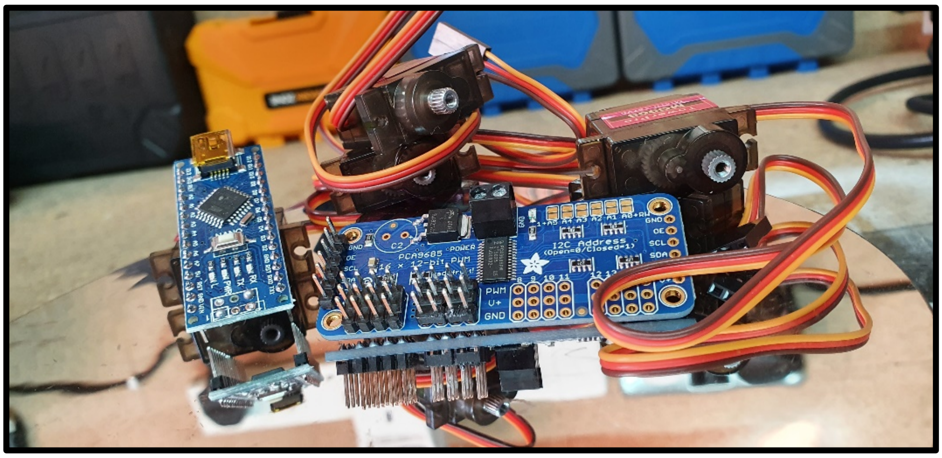

*Figure 2 - Arduino Nano on the left, PCA9685 in the middle and several MG90S servo motors which you will find in your kits*

## ***Limitations:***

"Why aren't we using Dynamixel servo motors or a pi/jetson nano for the main controller?"

*Figure 3 - Ender 3 3D printer by Creality*

Often when building robots, there are two common categories of builders. Either money is not an issue so you can pay to achieve a goal, or money is the issue and instead it is argued that the project couldn't work because there wasn't the money to make it happen. Both statements are poor perspectives to have and can negatively impact the project.

With technology now, processing is cheap, sensors are cheap, and fabrication has never been simpler. 3D printers are common tools for engineers as they allow for very rapid prototyping and testing of components, and fantastic 3D printers can be bought for between £100 - £150. 10 years ago, this was not possible and simply creating a single part would have taken an order of magnitude longer to manufacture and cost 40x the amount.


*Figure 4 - Dynamixel MX-28 by Robotis*

The components were selected as they allow for a minimum viable product. This means, the goal can be achieved with minimal waste. They can also be replaced if something goes wrong.

All servo motors consist of a motor, a gearbox and a processor. Servos such as Dynamixel servos are a great example as you will find them on many research projects. They are often used as they have a serial communication protocol, reducing the amount of wiring needed as they can connect in series, and there are libraries which allow for control of them directly. They are also able to perform 360-degree rotations. On the other side, they are far more expensive and offer much lower torque for their size. In fact, for a lower price, you can now purchase FOC BLDC servo motors which have far more features and capabilities. These can be seen on the MIT mini cheetah, Xiaomi Cyberdog and the Unitree Go1.


*Figure 5 - AK80-9 FOC BLDC Servo motor by T-motor*

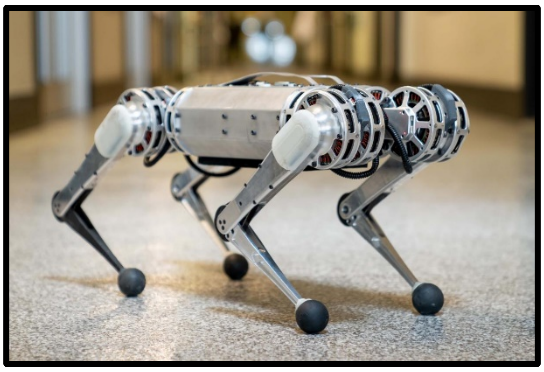

*Figure 6 - MIT Mini Cheetah*

*Figure 7 - Xiaomi CyberDog*

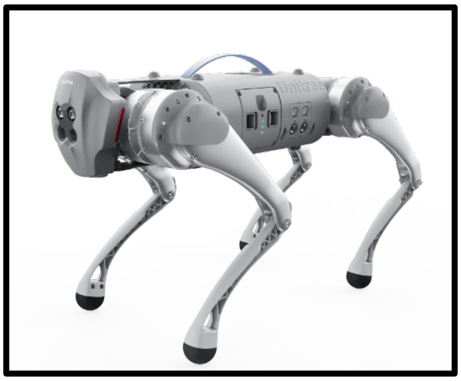

*Figure 8 - Unitree Go1*

The most important thing is to be able to understand from the ground up how a robot is operating. Once you can break things down like this, you can apply technologies in unique and unexpected ways to achieve a goal, far more than the sum of the parts.

## ***Example: Petoi Bittle***

*Figure 9 - Nybble and Bittle by Petoi: https://www.petoi.com/*

The Bittle is the evolution of his openCat project and the Nybble robot which started as a hobby project to make a miniature robotic cat. It features 4x 2 d.o.f legs consisting of “9g” servos and an IMU on-board for feedback. After multiple successful crowdfunding campaigns, his team of 3 have raised £1,428,466 and they now sell the robot for around £300.

With the components in this kit, you can build a more advanced robot with more degrees of freedom. You could even carry on this project through to your final year project and/or master’s project. You could then crowdfund your robot and create a fantastic educational platform for makers around the world raising millions of pounds in the process.

Why stop there? Quadruped robots are very popular as they are “easy” to design, build and program as they are inherently stable. Bipedal robots have yet to have the same break through into the makers world as they are far more challenging. Each leg requires more degrees of freedom, and the balancing and walking gaits are more difficult to generate. Competitions such as “Robo-One” and “RoboCup” are great examples of bipedal robots being designed and built by makers and students.

*Figure 10 - Two Robots Competing in ROBO-ONE*

## ***Lab Session Breakdown:***

Due to the number of students enrolled on this module, Lab sessions will be broken down into two timetabled slots alternating between groups each week. There will be one long session running from 2pm – 5pm on Thursdays and one shorter session running from 9am – 11am on Fridays.

Please remember which timetabled group you are in as we may not be able to facilitate extra capacity if you arrive for the wrong session.

| ***Date*** | **Long session** | **Short session** |
|---|---|---|
| *30/09 - WK1* | G1 – No Lab: Find Working Pair | G2 – No Lab: Find Working Pair |
| *7/10 - WK2* | G2 – CAD: Fusion 360 & Kit Release | G1 - CAD: Fusion 360 & Kit Release |
| *14/10 - WK3* | G1 – No Lab | G2 – No Lab |
| *21/10 - WK4* | G2 – CAD: Motion and Joints | G1 - CAD: Motion and Joints |
| *28/10 - WK5* | G1 – Group Design Review - PDR | G2 – Group Design Review - PDR |
| *4/11 - WK6* | G2 - CAD: Tolerances and Prototyping | G1 - CAD: Tolerances and Prototyping |
| *11/11 - WK7* | G1 – Prototyping Design Iterations | G2 – Prototyping Design Iterations |
| *18/11 - WK8* | G2 – Group Design Review - CDR | G1 - Group Design Review - CDR |
| *25/11 - WK9* | G1 – Programming & Simulation | G2 - Programming & Simulation |
| *2/12 - WK10* | G2 – Programming & Simulations | G1 – Programming & Simulations |
| *9/12 - WK11* | G1 – Programming & Testing | G2 – Programming & Testing |
| *16/12 - WK12* | G2 – Showcase/Presentations | G1 – Showcase/Presentations |

Week1: There will be no lab session, however this time can be used to find a lab partner as the end of the first lab, you will receive your kits.

Week5: It will be expected that both lab partners will have completed their own designs. These designs will then be reviewed via a simplified preliminary design review with each group. This will be performed with each group individually with the members of staff.

Week8: It will be expected that each lab pair will have cooperatively completed their final group design and a critical design review will be performed. Each pair will be expected to present to the whole class with the opportunity for questions and further feedback from staff and students.

Week12: This will be your final presentation where you can explain and describe your design and the process you underwent to achieve that, including the results. This will be to the whole class with other academics invited to attend. A miniature showcase of everyone's robots.

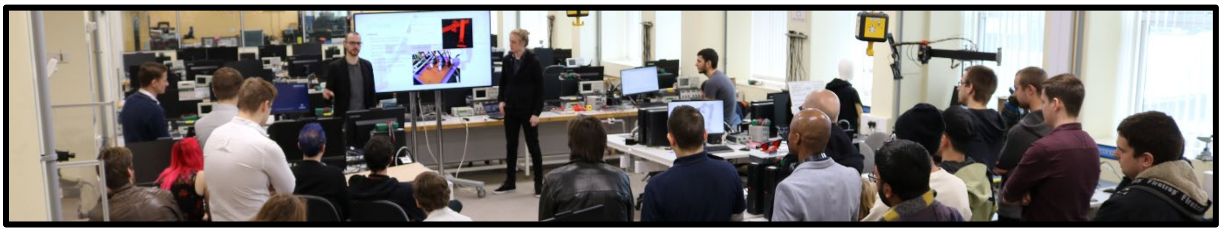

*Figure 11 - Showcase and Presentations in December*