ROCO318: "Walking with Robot Dinosaurs"

Abstract:

The purpose of this report is to show the design and manufacturing process, using 3D printing, to produce a walking robot.
This report will include problems and issues that occurred and how they were resolved.
As well as how and why the final four-legged robot design was chosen. It will also present the different testing methods, and prototypes that were developed to build the final product.

Walking robots are an important topic to discuss, research, and develop due to new advancements within this technology that will soon be common and have many possible purposes.

The aim of this project is learning how to effectively design a robot, and how to efficiently test a design using simulations. Another key aspect is utilising the knowledge from the simulations to learn from each failure to produce the most efficient method possible.

A possible application for the design could be a child's toy. The overall design of the robot is based on a dinosaur which appeals to younger children and could be used as an interactive toy or an educational tool when teaching children about engineering and robotics.

Research:

Before working on any designing, my partner and I decided that we would do individual research and then collate our research.

For the research I have investigated real world examples of different kinds of 2-legged and 4-legged walking and moving techniques (Fig.1).

Figure 1: Examples of research on real-world example of walking methods

Doing this research allowed me to get a clearer idea of how my robot could move and what could be the best way to implement locomotion for the robot.

For 4-legged examples, I looked at a cat, a triceratops, and a crab. For 2-legged examples, I looked at a chicken and the movement of birds.

For each of these examples I would circle each point of movement and how they connect. Plus, I commented on where servos could possibly be placed, balance considerations and how the robot would contain all the components like the Arduino Nano.

After completing the first steps of my research, I decided to focus on the triceratops and further my research into how they walked (Fig.2) and how their limbs were designed.

During my research I found "…palaeontologists have been able to determine that the hind limbs of *Triceratops* were larger than the forelimbs… (Scannella, 2021)". Meaning that my design needs to look and walk like a triceratops, ensuring that the back limbs are larger than the front limbs.

Furthermore, I investigated existing robotic examples like the Boston Dynamics' Spot robot (Anon., n.d.). I have decided to focus a section of my research on this example because the Spot robot is a quadruped like the triceratops design that has been chosen for the initial design.

Looking at the downsides of using the Spot robot as inspiration is that it only has two degrees of movement. Whereas our robot needs three degrees of movement. More so the Spot robot also has much thinner legs and feet that are static in relation to the libs. For our robot, the legs would be thicker, and the feet would have servo actuation/ control.

After doing this research my partner and I presented to each other and discussed the research we had done. When discussing the research, we realised that we were both interested in the dinosaur design. Acknowledging this the final decision between us was made to execute the dinosaur design.

Design:

Once the decision was made to base the design on a dinosaur, we started to individually work on an initial design. For my design I wanted to base it on a triceratops. This meant I wanted my design to include a wide, rectangular body with the back limbs being longer than the front limbs so the front of the body would be slightly angled downwards.

I started with some rough sketches of how the legs and feet would look (Fig.2), then I progressed to using Fusion 360 to design a 3D model of the design.

My design (Fig.2) for the legs is very simple and consists of movement at the hip, the knee, and the foot. I wanted to keep this design simple and make it easy to test and manufacture because I don't want to have issues with assembling or trying to get the robot to walk.
The design comprises of a part 1 that connects to a servo on the body and has a servo attached to the other end.

Part 2 is connected to the servo on the end of part 1 and has another servo attached to the end of it which will be connected to the final part, the foot. The two back limbs would be bent forward, and the two front limbs would be bent backwards to mimic the way triceratopses had their limbs positioned.

Once we had finished designing our individual design, we explained them to each other and we then worked on how we could combine the two designs together. My partner decided to base their design on a tyrannosaurus rex, so their design consisted of two legs (Fig.3).

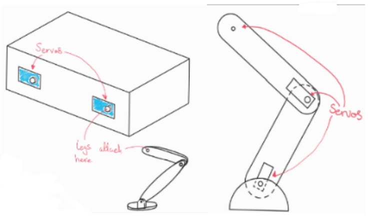

Figure 3: Another initial design sketch for the leg and body

When discussing how we would combine our design we decided that we would design a quadruped robot using my overall idea for the body and use my partners leg designs (Fig.4).

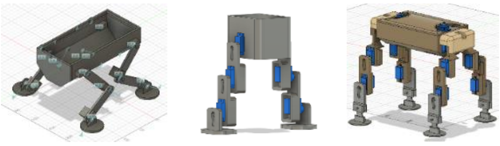

Figure 4: (From left to right) My design, my partner's design, and our final combined design.

One of the reasons why we decided on a four-legged robot was because balance would be less of an issue in comparison to a two-legged robot.

In the PDR, we presented our individual designs and explained the reason behind are design choices. We also received some feedback from the PDR including advice on making the feet free moving so that they weren't controlled with the servo. As well as, moving the hip joint so it moves outwards instead of front to back. We took this feedback onboard and implemented changes to develop the new design.

To manufacture the design, 3D printing will be the main process as we have access to a home 3D printer. Allowing us to easily and quickly manufacture our parts and have no wait time for the lab to print them. Another reason we decided to use a 3D printer is because they are relatively cheap to use, and we could manufacture prototypes, test them and if it wasn't up to spec a redesign and print can be executed quickly.

Different variations of a foot design were constructed; some of the feet had a circular base and others had a more rectangular base.

To test the design, we used the stress and safety tool in Fusion 360 (Fig.5) which allowed us to see which design would be the best to handle the force and weight that could be applied to them.

Doing these tests made us change the design of the front feet to have a round base and the back feet to have a rectangular base (Fig.6).

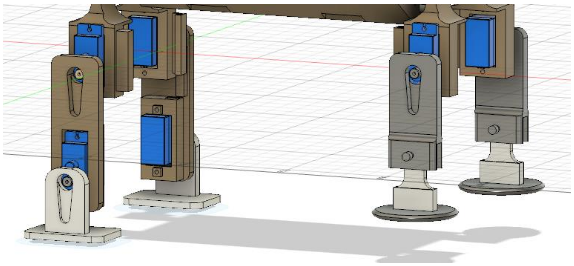

Figure 6: Updated design after the stress testing

Implementation:

When it came to implementing our design, we realised that the original planned size for the body might be too big. We struggled to visualise how big the body would look in Fusion 360 so before we 3D printed the body, we decided to make a model of it out of paper (Fig.7). We used paper instead of 3D printing because we didn't want to waste materials on a part we might not use. When we made the paper model, we realised that the body was unnecessarily big so we decided to make it small enough so that all the components could fit inside.

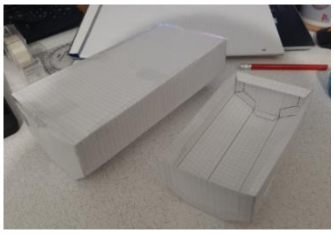

Figure 7: (Left) The original, bigger design and size of body. (Right) The newer, smaller design.

Once we had adjusted the dimensions of the body and had 3D printed the new design, we could start assembling our model (Fig.8). Assembling all the parts was relatively easy, we didn't run into any major issues. However, some of the limbs were a bit loose which could be caused by 3D printing warping. To fix this issue we used washers between the leg and the servo, and this gave the limbs more stability. We placed them on all the legs except from the free moving feet.

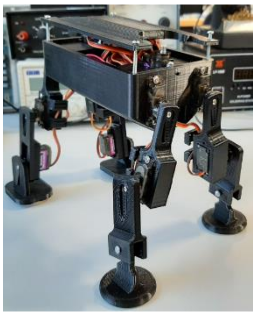

Figure 8: Full assembled robot

Once everything was assembled, we started to design code to control servos for allowing the triceratops to walk.

To do this we found a library (Fahad, 2021) that would allow us to easily program multiple motors. We first tested the template code on just one servo just to ensure that it works and to understand how it works.

The code works by using a range from 10 - 450, the range of movement, and would move the servo horn from the minimum value to the maximum value.

We experimented with this code for a while to see if we could use it to make our robot walk but we struggled to do this because each of the servo horns weren't attached at the same angle. To fix this issue we had to use the map function which allowed us to map the 10 – 450 to 0° - 180° (Fig.9).

```
//initialise all joints to 90 - start position
libconversion = map(90,0,180,10,450);
HCPCA9685.Servo(0, libconversion);
HCPCA9685.Servo(12, libconversion);
HCPCA9685.Servo(1, libconversion);
HCPCA9685.Servo(13, libconversion);
HCPCA9685.Servo(14, libconversion);
HCPCA9685.Servo(4, libconversion);
HCPCA9685.Servo(5, libconversion);
HCPCA9685.Servo(8, libconversion);
HCPCA9685.Servo(9, libconversion);
HCPCA9685.Servo(10, libconversion);
HCPCA9685.Servo(2, libconversion); //HEAD
HCPCA9685.Servo(3, libconversion); //TAIL
delay(200);
```

Figure 9: Code for setting all the servos to 90°

The first thing we did after realising this, was to set all the servos to 90° (Fig.9), which would set the robot to have straight legs. When we did this, it moved all the servos to 90° and we then removed and reattached all the servo horns so that they were at 90°.

Once we had done this it allowed us to accurately set the different parts of the legs to different angles so we could get the robot walking (Fig.10).

When our robot is walking it isn't the smoothest of movement but when two of the opposite legs are lifted off the ground it can balance itself on the two remaining legs.

Sometimes when the robot is walking, the free moving feet on the front won't always land on the flat base of the foot but will go on the side instead (Fig.11) which could cause the robot to fall over. The feet were doing this because of the force and movement from the leg being moved would cause the foot to uncontrollably swing.

However, every time we tested the robot it has managed to not fall over and to carry on walking even with one of the feet not securely on the floor.

Future work:

If we had more time on our robot, we would work on making the walking smoother and less "robotic". We would also work on having mechanism that would make sure the free moving feet on the front were more reliable and less likely to not land on the base of the foot.

If we had more money to use on our robot and the whole process, we would use a higher quality of material so that the surface of the parts was smoother and better quality.

I would also invest in better servo motors. This would help with making the movement smoother and less unstable. With better servos we also wouldn't have to worry about the weight of the robot as much because they would be able to handle the weight of the robot better.

If we were to make another version of our robot, I think we would make it look more like a triceratops. We could do this by making the limbs less square and more rounded like triceratops (Fig.12). We could even work out how to cover the robot in a type of material that would give it a more reptilian look.

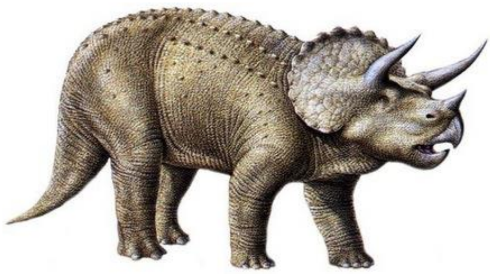

Figure 12: An image of a triceratops where you can see the shorter front legs and the rounded feet and limbs (Bing, n.d.)

Conclusion:

At the beginning of this I stated that we wanted to learn how to effectively design a robot and use simulations and tests to make the design as efficient as possible. I believe that everything I have presented in this report proves that we have achieved these goals.

The key takeaways I learnt from the last three months is that research is an important step before starting any initial designing. The research allows you to have a clearer idea of how to start building a design and how to effectively design a walking robot.
Another key takeaway we have learnt from this project is that your first design will most likely not be your final design and that to have a working, final product you must thoroughly test everything. This allows you to efficiently adapt and evolve your design so that it works correctly.

Our design stands out from others as we have used real-world inspirations to base our design on and thus have successfully adapted the initial design effectively by using simulations and prototypes.

References:

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Scannella, J. B., 2021. *Triceratops.* [Online]
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Appendix:

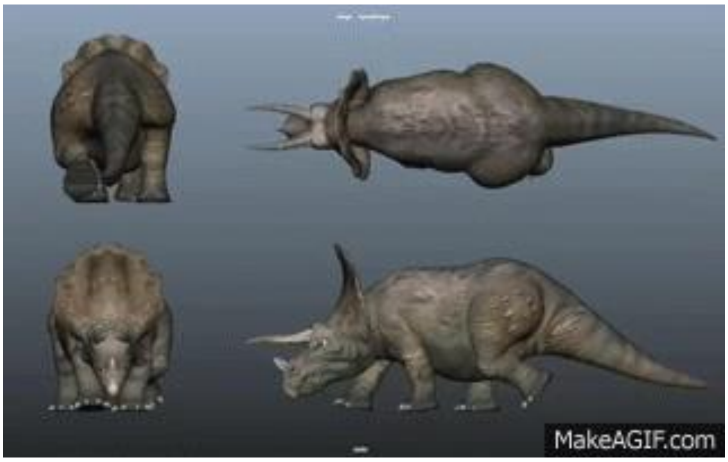

Figure 2: A gif showing how we think a triceratops would have walked. (Anon., n.d.)

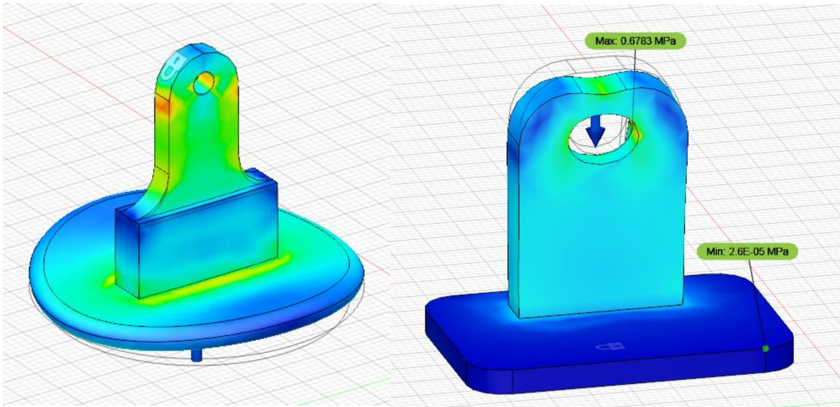

Figure 5: (Left to Right) Stress test on the free moving front foot. Stress test on the servo controlled back foot.

```
//**********************************************************
//FRONT LEFT AND BACK RIGHT LEGS
//**********************************************************

  //hips out
  libconversion = map(100,0,180,10,450);
  HCPCA9685.Servo(0, libconversion); //hip
  libconversion = map(80,0,180,10,450);
  HCPCA9685.Servo(12, libconversion); //hip
  delay(200);

  //knees
  libconversion = map(50,0,180,10,450);
  HCPCA9685.Servo(13, libconversion);
  libconversion = map(140,0,180,10,450);
  HCPCA9685.Servo(1, libconversion);
  delay(200);

  //foot
  libconversion = map(125,0,180,10,450);
  HCPCA9685.Servo(14, libconversion);
  delay(200);

  //hips back
  libconversion = map(90,0,180,10,450);
  HCPCA9685.Servo(0, libconversion);
  libconversion = map(80,0,180,10,450);
  HCPCA9685.Servo(12, libconversion);
  delay(200);
```

Figure 10: Section of code showing different servos set to different angles

Figure 11: (Circled) The free moving foot landing on its side.

Links:

Video of the robot walking:

https://youtu.be/zfQhzPn64kY

GitHub link:

https://github.com/alKettle/ROCO318_COURSEWORK_1061841.git