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作品編號　100045

參展科別　工程學

作品名稱　AGRIBOT – ROBOTIC SOLUTION TO FOOD SUSTAINABILITY

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INTRODUCTION AND BACKGROUND RESEARCH

Food sustainability is key to human survival. Robotic solutions have started playing large roles in automating farming tasks in order to assist with crop yield and the efficiency of production. Due to the unreliability of and lack of manual labour in many parts of the world, Agribots are playing bigger roles. One of the biggest advantages of Agribots is that they can operate 24/7, 365 days a year without payment.

Agribots are being used more often in dairy farms to milk cows while others are used to shear sheep. Agribots are fast becoming very important to farmers by gathering valuable data; milking cows; automating animal feed; measuring the right amount of pest control, detecting weeds and pests, harvesting and ploughing with unmanned tractors.[1]

In many parts of the world farm labour is scarce and difficult to come by. In South Africa for example farm labourers endure gruesome attacks. These attacks on farmers result in the closure of the farm for an extended period of time resulting in the loss of large quantities of crops. Food sustainability is dire in Africa and many parts of the world. "Each day, 25,000 people, including more than 10,000 children, die from hunger and related causes. Some 854 million people worldwide are estimated to be undernourished, and high food prices may drive another 100 million into poverty and hunger.[2].

90 percent of the world's farms produce over 80 percent of the world's food. They also manage about 75 percent of farmland worldwide. Yet, paradoxically, these farmers are often poor and food insecure themselves.

Due to the increase in the world's population annually, there is a growing demand for food. This has led to increasing pressure on farmers to produce crops. In order to meet this demand, farming innovations are vital for the future of food and agriculture. Constant innovations in agriculture is thus needed to constantly feed a growing and increasing population.

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[1] White (2018) Three agribots transforming the farming industry: Available at: https://www.themanufacturer.com/articles/three-agribots-revolutionising-the-farming-industry/ Date accessed: 11 October 2019

[2] Holmes (2017) *Losing 25 000 a day to Hunger* Available at: https://www.un.org/en/chronicle/article/losing-25000-hunger-every-day Date accessed: 02 January 2021

Innovation in agriculture is also critical to help farmers use resources in better and more efficient ways. "Innovation is one of our best tools for creating a #ZeroHunger world."[3]

PROJECT PURPOSE AND ENGINEERING GOALS

The purpose of this project is:

- **To build** a working mechanical robot for the use of **retrieving data wirelessly, on farms,** using **precision movements** in sub optimal environments up to a **10km range using RF (Radio Frequency)** and **worldwide using GSM (Global System for Mobile Communication).**
- To submit the data to a user using communication APIs through SMS.
- **To learn** by applying the **principles of self-learning**, **limiting the use of ready-made solutions** and the integration of readily available components;[4]
- **To give back** by transferring the knowledge; skills and resources acquired to interested young students.
- The robot should be multi-purposed, motorised, have a 'Rocker Boggy' suspension and a Reach Arm.
- This robot should have unique **Sensors** and **APIs** (**Application Programming Interfaces**).
- Agribot could be used in a variety of fields such **Search and Rescue/ mining, Archaeology/ Caves, Agriculture and Architecture/Design.**[5]
- The body and wheels of Agribot will be fully designed by the developer; 3D printed; modular and tiered. The project will aim to integrate mechanics, electronics, design, software engineering, added sensors and APIs onto a single robot with limited conflict. This will be done by using available resources and components.
- The reach arm on Agribot is equipped with a Reach Arm which could gather soil, water and plant samples. The sensors would gather information such as gradients, terrain, weight, angles of velocity, soil humidity and the Pi camera would take photographs.
- The location and weather APIs could provide five day temperature forecast and send data via SMS.

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[3] FAO (2018) *Innovating for our Future of Food and Agriculture* Available at: http://www.fao.org/fao-stories/article/en/c/1170362/ Date accessed: 02 January 2021

[4] Michael (2014) *www.RobotScience.co.za is where teenagers age 14+ learn to build robots from electronic parts* Available at: http://roboscience.co.za/about/index.htm Date accessed: 30 May 2019

[5] Robotnor Created for advanced Robotics : Available at: https://robotnor.no/research/serpentine-robots-for-planetary-exploration-serpex/ : Date accessed: 12 April 2019

- The SDR (Software defined radio) would be able to pick up radio frequencies thereby enabling Agribot to locate certain markers.
- With Agribot's weight bearing capacity of 30kgs it could carry water, plant and soil samples.
- Agribot has 10km wireless range with RF (Radio Frequency) and could be used from anywhere in the world using GSM (Global System for Mobile Communication).
- The developer intends for the coding of Agribot to be so precise, that it could navigate to exact locations/ coordinates. The added GPS API also aids with this process.
- Agribot's data collection would be sent to an Arduino, which would be sent to the Raspberry Pi, and a Raspberry Pi would then to a computer, which would display the data through a program or store the information on the SD card and the Raspberry Pi. Additionally, with the use of API's, data gathered would be immediately sent to the user via SMS.
- Agribot is **environmentally friendly**. It is 3D printed from PLA, PETG and PTE filament which are all biodegradable. PLA is made from 80% corn-starch and so if the robot gets lost in any of the above environments it would decompose.
- The project aims to integrate mechanics, electronics, design, software engineering, added sensors and APIs onto a single robot with limited conflict. This was done by using available resources and components.

The developer prioritised his self-development on the wide range of knowledge and skills and development areas. To achieve this the developer had no technical support from school; had no technical support from his parents; restricted any usage of third-party solutions; self-learnt each area in order to design and produce every component on Agribot; worked independently and did his best to recycle and produce in a sustainable manner.

METHODS

Definitions

The definitions of the concepts to be used in this project plan are as follows:

Concept	Definition
Arduino[6]	Arduino is single-board with a microcontroller that interacts with other electrical components

[6] Android Authority (2015) *Writing your first Android App- Everything you need to know*: Available at: https://www.youtube.com/watch?v=mAJeK283j0I: Date accessed: 28 August 2019

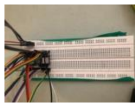
Raspberry Pi[7]	Raspberry Pi assists with programming in languages like Scratch and Python.
DC Motors	DC motors is a motor that takes electrical current (direct current and converts it into motion).
Soldering	Soldering is a process in which two or more items are joined together by melting soldering coil into the joint,
Additive Manufacturing	3D printing is referred to as additive manufacturing because it means that the manufacturing occurs by layers stacking on top of each other. For example, imagine if you are trying to build a sphere with sheets of paper. You would start off at the bottom of the sphere by cutting out a small circle on the paper. Then you would stack a slightly larger circle than the bottom layer. Thereafter, when you get to the required radius height of the circle then you would start decreasing the sizes of the circles that you stack. At a certain point you would reach the required diameter of the sphere. You would have then manufactured an object by using Additive Manufacturing. The same is used in 3D printing by substituting paper with high temperature, high viscosity PLA.
Coding	Coding is programming, where a programming language such as Python is used
Python[8]	Python is programming language.
HTML	Hypertext Markup Language is the standard markup language for documents designed to be displayed in a web browser.
Autodesk Fusion 360	Fusion 360 is a CAD (Computer Aided Design) software used to design 3D models
Prusa Slic3r	Slic3r is free software 3D slicing engine for 3D printers It converts .stl files into .gcode for the printer.
Prusa	Prusa is a 3D printer developer and retailer based in Prague
Multimeter	A multimeter measures voltage, current, and resistance

[7] Weaver (2018) *Controlling Stepper Motors using Python with a Raspberry Pi:* Available at: https://medium.com/@Keithweaver_/controlling-stepper-motors-using-python-with-a-raspberry-pi-b3fbd482f886*:* Date accessed: 20 June 2019

[8] *Operators and Expressions in Python – Real Python:* Available at: https://realpython.com/python-operators-expressions/*:* Date accessed: 23 June 2019

SDR	Software Defined Radio
Perfboard	Perfboard is a board that allows one to solder components onto it thus creating an electronic circuit.
Potentiometer	A potentiometer is a terminal resistor that forms an adjustable voltage divider based on a rotating spinner.
GUI	Graphical User Interface
UI	User Interface
API	Application Processing Interface
RF	Radio frequency
GSM	Global System for Mobile Communication

The following **materials** will be used to build Agribot:

2 kgs of filament (Part PLA, part PTE and part PETG) 	M4 Bolts 	M6 Bolts 
M3 Bolts 	Nuts 	Breadboard 
Breadboard Wires 	Arduino’s (Due, nano, 101 intel curie) 	18650 cells to form a battery (up cycled) 
Alligator Clips (recycled) 	Soldering Wire 	Raspberry Pi 3 b+ 
Sellotape 	Electrical Tape 	Zip Ties 
Steel Shaft	Pulleys	USB Hub

		
Wifi Module/ Router 	Flux 	Hot glue/ Glue sticks 
LED’s 	Bearings 	Buck Module 
DC Motors 	Servos 	LoRa Module 

Equipment

The following **equipment** will be used to build Agribot:

Laptop 	Allan keys – various sizes 	Soldering station 
Pliers 	Prusa i3MK2S & i3MK3S 3D printers 	
Screwdrivers various sizes (Phillips and Flat) 	Wire Strippers 	Scissors 

AC to DC Battery Charger system 	Multimeter 	LithoKala 18650 cell charger 
Knives 	XT60 Connectors 	Bosch cordless drill 

Components

The following components will be built onto Agribot:

	Ultrasonic Sensor[9] *To estimate the distance to an object in front of the robot by emitting an ultrasonic signal which bounces back to a sensor.*
	Temperature and humidity sensor *To measure temperature and humidity*[10]
	Gyrometer Sensor built into the Arduino *To measure rotational motion and angles of velocity relative to the earth's gravity (e.g. inclines and declines)*
	Accelerometer sensor built into the Arduino *To test for different forces (e.g. wind, gravity, vibrations/ earthquakes, rockslides, mudslides, volcano eruptions, vibrations from bombs, avalanches etc.)*
	Pi Camera
	RTL – SDR Kit *To test for radio waves, airband, security walkie talkies, bandwidth and radio frequencies*

[9] *Arduino Uno and HY-SRF05 ultrasonic sensor example - Arduino Learning* Available at:http://arduinolearning.com/code/arduino-uno-and-hy-srf05-ultrasonic-sensor-example.php Date accessed: 06 June 2019

[10] Raspberry Pi (2017) *DS18B20 Temperature sensor with Python (Raspberry Pi)*: Available at: https://bigl.es/ds18b20-temperature-sensor-with-python-raspberry-pi/: Date accessed: 01 September 2019

	Photoresistor *To change the resistance relative to the light input*
	Weighing Sensor *To change its resistance relative to the load applied*
	Weighing cell
	Infrared Sensors
	Soil moisture sensor
	GPS module

STEP BY STEP PROCEDURE

Agribot Robot Build

Item	Description	Process	Learning Objectives	Resources	Tools
1.	**Design of the robot**	Process: Design the body based around the suspension shape and dimension on fusion 360 and to enable this to factor in the robot overall design Consider different designs of robots and looked at the tank, normal car, spider and mars rovers inspired design options. Select the most adequate design Research various models. Design various cases around the electronics in a modular	Learn: Designing of robot on Fusion 360. Different types of tension. Weight distribution, sprocket system and its integration The design for electronic components and sensors to fit in a model using fusion 360. And improve knowledge and skill in designing 3D printing models by using different type tools: such as revolution tool, rotational tools for sketching and extruding. For sketching, the tools such as revolution, circle, squares,	Resources • 3D printing Nerd • Makers news • Thomas Sanladerer • How to make anything • Evan and Katelyn • Michael Reeves • Bobby Duke Arts	Tools • Ruler • Data sheets • Fusion 360

Item	Description	Process	Learning Objectives	Resources	Tools
		fashion Place these modules in the shape of the robot. Design all of these components in SDL files to enable printing on 3D printer Use Fusion 360 to design Research different types of wheels and suspension. Design the developer's own ideas on Fusion 360, scale down on the design and convert it to a 3D printing model on an SDL file. Test and change design if required	rectangles, arcs, mirror and line tools. For extruding the sketch – revolutions, cutting, intersecting, creating new body, filleting, rounding out edges and extruding normal faces of sketches. How to obtain dimensions of electronic components, bolts, 8mm shaft, bearings, tension between belt and pulleys, aerial holder, placement of Go Pro, compartment for batteries, placement for lights, holds for Raspberry Pi, Arduino, buck modules, stepper motors.		
2.	**3D Printing**	Process Extract the SDL files from Fusion 360 and import them to Prusa Slic3r software. This takes the SDL files and slices it in layers to allow for the 3D printer to perform the additive manufacturing. The Slic3r software uses a	Learn: How to set different temperatures, speed, for different filaments Considerations of how and when an object requires a skirt, brim How to determine whether an	Resources You tube channels • 3D printing nerd • Makers news • Thomas Sanladerer • How to make anything	Tools • Original Prusa i3 Mk2S Printer • Spatula • Glue stick • Pliers • Hobby Knife

Item	Description	Process	Learning Objectives	Resources	Tools
		modified file from Prusa to set the temperature of the hot-end, temperature of the heat bed, the speed of the print, estimates the time, estimates the quantity of material, the density of the filament, the estimated cost and arranges the object for printing on a virtual heat bed. The files are converted to G Code, which is transferred to an SD Card. The SD card is inserted to the 3D printer. Filament is loaded on the 3D printer. The temperature must be set to ensure that the layers must bind together. This prevents warping. When 3D printing the bed must be constantly cleaned with isoproterenol alcohol.	object need a high or low infill? How many perimeters does the object require? Does the printer need to recalibrate for starting a new print? Setting room temperature. The filament must be kept in low humidity environment to avoid damaging the extruder When to use sticky glue on the bed when using different type so filaments. The influence of speed of print to quality. The best software for the Prusa printer is the Prusa Slic3r as it has a good interface, is user friendly and provides useful data. When using cleaning the hotbed the selection of cleaning material such as isopropylarene alcohol or window cleaner is important as it affects the contact of different type of	• Evan and Katelyn • Electroboom • Prusa 3D by Joseph Prusa • Alex • CNC Kitchen • Colinfurze • Michael Reeves • William Osman • Peter Stripol • Prusa manuals	

Item	Description	Process	Learning Objectives	Resources	Tools
			filament		
3.	**Electronics**	Process Research Source and purchase components such as DC motors, APIs, sensors, connectors, wires, wire connectors, different types of wire, solder, soldering station, soldering helping hand, perf board, multi-meter, micro controllers (raspberry pi and Arduino) and bread and perf board. Assemble components on the bread board. Test the components on bread board with pin connectors. Check if electronic components work by testing the code and its functionality. Check if there are any shorts. Simplify wiring schematics.	Learn: How different electronic components work; How to wire. How circuits work How to work safely with electronics. How to measure voltage; amps and resistance. How micro-controllers communicate to the Arduino and Raspberry pi and other components electrically, How to connect batteries in different ways, How to measure how long a battery would last How to better configure batteries. How to calculate resistance in a circuit board by calculating amps.	Resources • EEV BLOG • Electro Boom • Colinfurze • Michael Reeves • William Osman • Peter Stripol • Great Scott!	Tools • Stepper driver, • Sensors, • Connectors, • Wire connectors, • Different types of wire, • Wire stripper, • Solder, • Soldering station, • Soldering helping hand, • Perf board, • Multi-meter, • Micro controllers (Raspberry Pi and Arduino) and • Bread board

Item	Description	Process	Learning Objectives	Resources	Tools
		Compact wires. Assemble all components on perf board using the schematic and solder all components in place. Check if any shorts on the perf board using a multi-meter. Connect to Raspberry pi and Arduino. Run the code to check for functionality.			
4.	**Physics**	Process Understand the speed of sound to derive the distance of the ultrasonic sensor. Understand and test the different honeycomb structures to develop the strength for designing objects. The use of mathematics for to understand how the sensors work and what they measure.	Learn: To create and use equations. To use equations to derive data product. The use of math to develop coding . The use of math to bring together the software and electronic components . About how fast sound travels? Sound beams.	Resources You Tube: • Veritasium • Physics Girl • Vsouce • Tested	Tools • Calculator • Internet research and obtain information

Item	Description	Process	Learning Objectives	Resources	Tools
			Sonar. Force from accelerometer. Gyro – how different objects act in a space. How can different objects and shapes be used to create a heavier load bearing capacity while constructing with design that is light, efficient and practical.		
5.	**Coding**	Process Research how to control stepper motors from a Raspberry Pi. Obtain a list of components. Consider which coding languages to be used based on what work was needed. Select code that has a GPIO library Understand C# and C++ and as such could use C. To learn new code and what is closer to the Raspberry Pi-	Learnt* How to write Python. How to write C#. How to write C++. How to write HTML. How to write PHP. How to write SQL. How to write Raspberry Pi terminal code. How to write Windows terminal code. How to write Java script.	Resources • Freecodecamp.org • circuit.io • Live overflow • Michael Reeves • Peter Stripol • The coding train • Code Bullet • Simone Giertz • Jabrils • Devon Crawford • Allen Pan – Sufficiently Advanced • AvE • William Osman • Jarvis Johnson • Alexis Gay	Tools • Websites • You Tube • Google • Computer • Atom and Visual studios Integrated Development Environment (IDE)

Item	Description	Process	Learning Objectives	Resources	Tools
		such as Python. Learn Python through different forums on the internet videos on the basics of python from freecodecamp.org Start using the different GPI codes on Python and outputting data from Raspberry Pi to the stepper driver boards. Use knowledge to connect the two step driver boards into one in order to control both at the same time using a common code. Start programming the sensors on the Arduino . Test using pre-existing code from circuit.io – If code is not effective based on the UI, to adapt the code to make own UI with own sensors .Re-write own code in various code languages. Code HTML website to display any HTML document. Connect the Arduino with Raspberry Pi using Python.	How different codes speak to each other in different ways . How computer code works on the most basic level. How to integrate math in equations for solutions to most problems *	• Carykh	

Item	Description	Process	Learning Objectives	Resources	Tools
		WrIte code with Atom and Visual studios Integrated Development Environment (IDE)			
6.	**Manufacturing**	Process: Parts from 3D printer cleaned with a knife and plyers . Select the bolts and nuts for the required parts. Set out the electronics and fasten with M3, M4 and M6 bolts. Use vice to insert the bearings in plastic. Use lathe and grinder to manufacture steel axles. Use handsaw to cut down on different bolts. Tighten and assemble	Learn: How to use equipment like lathe and grinder. How to design parts that work with certain manufactured materials such as bots, nuts bearings etc . How to tension different materials and components. Plastic deformation. Different kinds of materials that can be sued for different parts of the robot. How to use the nuts and bolts to make the robot modular. How to use a Vernier scale.	Resources : • I like to make stuff • Michael Reeves • William Osman • Collinfirze • Peter Stripol • Tested • Evan and Katelyn • Alec Steele	Tools • Lathe • Screw drivers • Allen Keys • Grinder • Different types of measuring tools such as Vernier scale • Knife • Plyers • Vice • Saw • Soldering Iron

THE DEVELOPMENT OF AGRIBOT

ITEM	AREA	RESULTS
1.	Design	• SPR was initially designed as a tank (SPR101). • Due to the limitations with this design (see first prototype) the developer redesigned SPR102 • SPR102 was designed around the electrical components making it a more compact and neat design. • The wheels of SPR102 were initially designed as broad wheels and later redesigned as thinner wheels due to the increased torque on thinner wheels. • Scietmeer3 had extra batteries and the body was built to accommodate the electrical components. • The wheels of Scietmeer3 were printed with TPE (flexible filament) to allow for more agility • Scietmeer4's body was designed to have a longer and wider wheelbase thus allowing more space for the sensors and components • The suspension was changed to a rocker boggy suspension. • The wheels were reprinted to be wider. • Scietmeer5's body and legs were reprinted to be stronger than Scietmeer4, a Reach arm and loading tray were added to the robot
2.	3D Printing	• The printing of SPR101 was affected by various limitations (See pg.25) • Printing SPR102 was much easier to print as the developer was on holiday and had the ability and time to keep a close eye on the printer during prints • The developer further experimented with using a combination of PLA and PETG filament to print and found that PLA was a more durable substance, however PETG was a lot stronger. • This means that PLA has some play in the material but PETG would snap under certain forces. • Scietmeer3's wheels were printed in PTE (flexible filament) • Scietmeer4 & 5's wheels were printed wider and in PTE. Each wheel took 17 hours to print. • The body was printed in a combination of PLA and PETG (which is stronger and harder than PLA)
3.	Electronics	• The developer realised his limitations with regards to Electronics as parts were burnt out due to his lack of knowledge

		• This part of the project was the most difficult and frustrating for the developer as he could not find direct answers to his questions on the internet. • He used trial and error with, for example, the Adafruit Hat and realised through the trial and error method that certain components would not be feasible to use. • The developer also burnt out a battery pack in the manufacture of Scietmeer5. • Burnt out components lead to additional costs and time needed to redo the electronics, yet on the positive side it is a huge learning curve.
4.	Mechanical	• The developer found that he had minimal problems with the Mechanical side of the project • He was able to understand and find a lot of relevant information on the internet. • Testing load balance and mass was relatively easy and he found that during the second, third, fourth and fifth prototypes the mechanical side of the project went extremely smoothly and easily.
5.	Coding	• The developer enjoyed coding all the prototypes with Python and C++. • He taught himself both coding languages including Javascript, HTML and Scratch and with some trial and error found that he was able to code the prototypes quite effectively and precisely using the code. • He used Python for the stepper and DC motors and he used C++ for the sensors. • He ran the code numerous times, check for errors. • He ran the robot to determine faults • He tested code for movement, precision, distance, sensors and APIs.
6.	Manufacturing	• During the manufacture of all the prototypes, the developer tested for the correct tension and had to redesign and reprint various parts to vary the distance between axle and motor to check which one worked the smoothest. • During the design of the prototypes the developer ensured that he measured out the electronic parts very precisely during the design process, the manufacturing process was relatively easy. • He realised that the time and accuracy taken during the design process enabled him to quickly and effectively manufacture and assemble the prototypes.

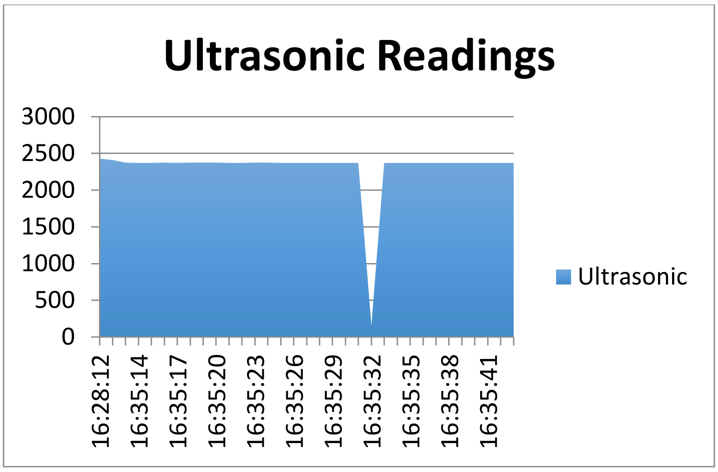
For more information on step-by-step and day-to-day results please refer to the Journal.

TESTING

ITEM	AREA	METHOD
1.	Design	Measure components and double checking on the Fusion 360 to determine of all components will fit
2.	3D Printing	Print out small squares with set dimensions and test tolerance of printer. Test different materials that could be used for compression, stress and other forces Test if different parts and shapes could stick to the heated-bed Visual inspection
3.	Electronics	Multimeter to test voltage and current, resistance and shorts Run electricity through it to check if all areas working.
4.	Mechanical	Test design, shape, weight, size, set out of all components, motor, axle design, load balance. Use the sliding finger technique to determine the centre of mass.
5.	Coding	Run the code numerous times, check for errors, run the robot, determine faults, test code to relate to movement, distance, sensors etc
6.	Manufacturing	To test for the correct tension, printed various parts to vary the distance between axle and motor. Check which one works the smoothest. Check axle and whether it smoothly fits on axle by running motor

TESTING AND RESULTS

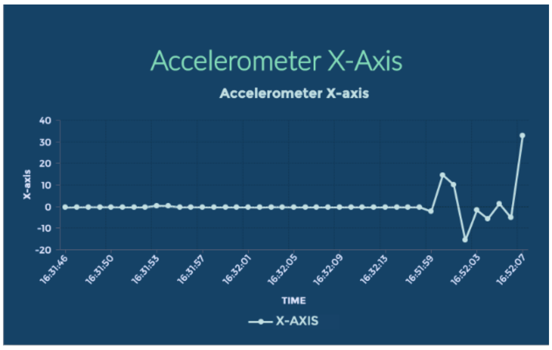
During the testing phase of Agribot, the following results were gathered:

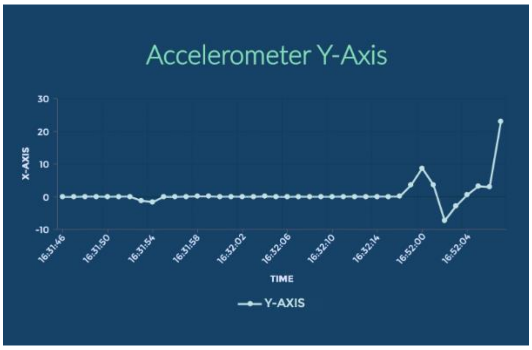


1. **Ultrasonic Readings**

   The Ultrasonic sensor sends out a pulse of sonar, which hits an object and bounces back whereby the ultrasonic sensor would retrieve the pulse of sonar. The ultrasonic sensor was placed on the top of the robot in order to retrieve data of the height of a cave.

   The reason the numbers are so high is that when the pulse of sound bounced off the roof of the cave, the roof was not parallel to the ultrasonic sensor causing the beam of sound to bounce around the cave walls thereby taking longer to come back to the ultrasonic sensor. The readings from the ultrasonic sensor were therefore not accurate. The developer would in the future like to try Infrared as an option to see if it would yield more accurate readings.

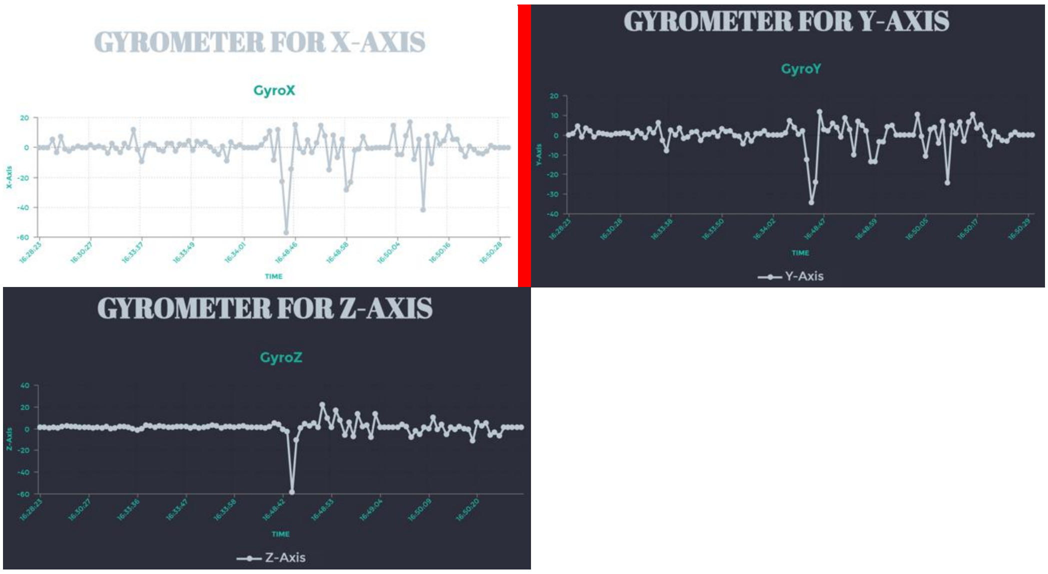




Cave readings

2. **Accelerometer Data**

   The accelerometer measured three axis, viz. X, Y and Z Axis. The graphs above represent time against G forces (acceleration and deceleration). The information gathered above could be used to detect natural disasters such as earthquakes, tremors, tsunamis, volcano eruptions, tectonic shifts, rock falls, mud slides, avalanches etc. The graphs above indicate that the accelerometer is gathering the data intended by the developer.



Cave readings

3. Gyrometer Data

The Gyrometer captured X, Y and Z Axis. The data in the above graphs are displayed as time against degrees per second. This information is useful to in understand the terrain of the cave. Additionally, it is helpful to providing data that would assist one to create a 3D model of the terrain of the cave. The gyrometer collected the data as intended.

	**Coding the Raspberry Pi 3b+** The code for the Raspberry Pi is written in CSS HTML Node JS (Express) The rest of the code on the Raspberry Pi is written in Python
	**Radio Frequency (RF) (LoRa Modules)** The developer built a communication hub which is coded in C++ which communicates with Agribot through LoRa modules. Due to the lockdown, the developer was only able to test the RF up to 100m. It worked perfectly and the developer is sure that given a larger open space the RF would be able to work well.

Pi Camera

The Raspberry Pi is connected to the Pi camera which is running open CV and allows for visual analysis i.e. facial recognition.

Arduini due/ nano / 101 intel curie

The Arduino communicates with the Robots arm and gives it movement commands

The Arduino is also connected to the relay and activates on input from sensors.


```
#include <SPI.h>
#include <LoRa.h>

int counter = 0;
int ledPin = 7;
void setup() {
  Serial.begin(9600);
  while (!Serial);

  Serial.println("LoRa Sender");

  if (!LoRa.begin(433E6)) {
    Serial.println("Starting LoRa failed!");
    while (1);
  }

  LoRa.setTxPower(20);

}

void loop() {
  Serial.print("Sending packet: ");
  Serial.println(counter);

  // send packet
  LoRa.beginPacket();
  LoRa.print("hello ");
  LoRa.print(counter);
  LoRa.endPacket();
  counter++:
```

Coding and accuracy of movement

Agribot is running a server on the Raspberry Pi

This server is a node express server and allows communication to the robot through APIs via the network to retrieve data.

This communicates with the Arduino.

The Arduino communicates to most of the sensors in order to retrieve data.

The code for the Arduino is written n C++

Reach Arm

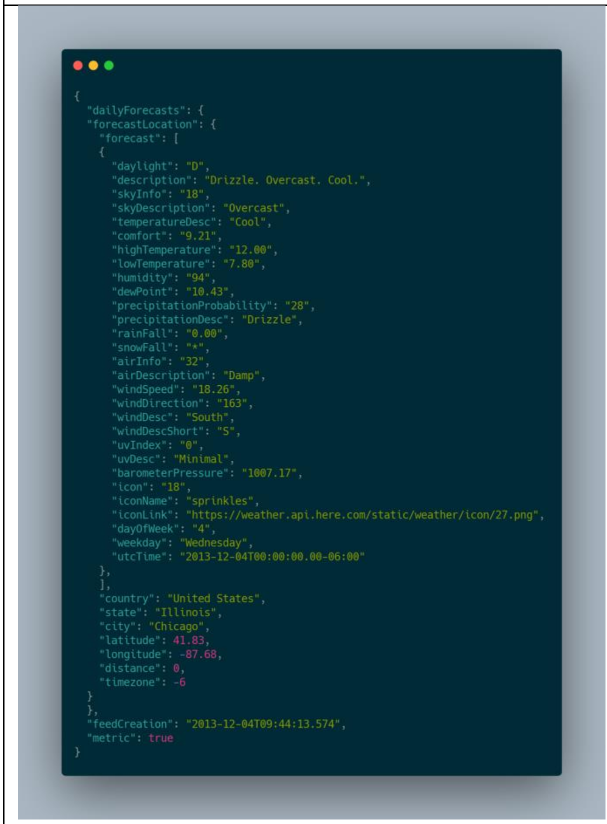
The Arduino communicates with the Robots arm and gives it movement commands.

The reach arm was able to carry weight of up to 100g during testing. During the continuous testing of the arm the shoulder servo broke.

The developer had trouble obtaining stronger servos for the shoulder joint of the arm during lockdown as these servos are procured from China.

Weigh Sensor

The weigh sensor was tested using a tin of tuna, baked beans and tinned fruit. The results of the sensor was 2grams off the weight displayed on the tins. The developer

<table>
<tr><td></td><td>believes that this discrepancy is negligible and thus indicates the validity and reliability of the sensor.</td></tr>
<tr><td>
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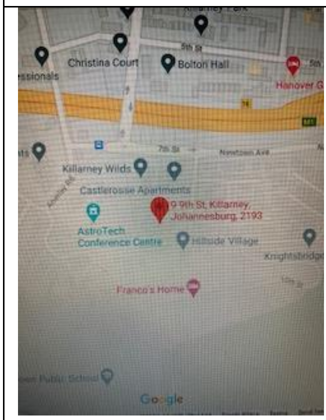
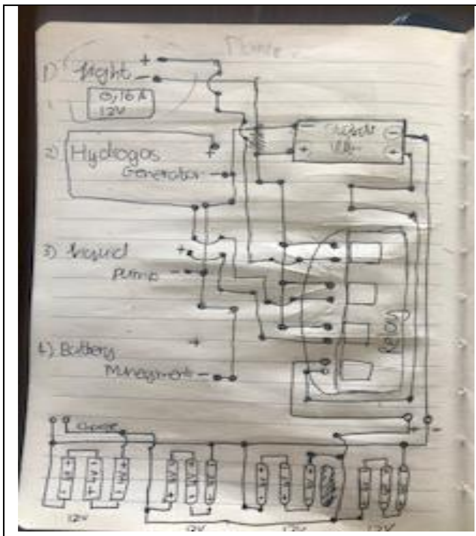
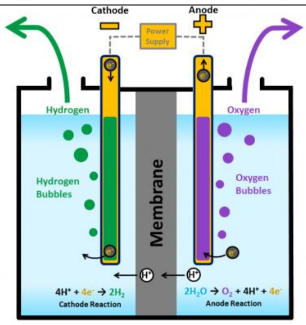
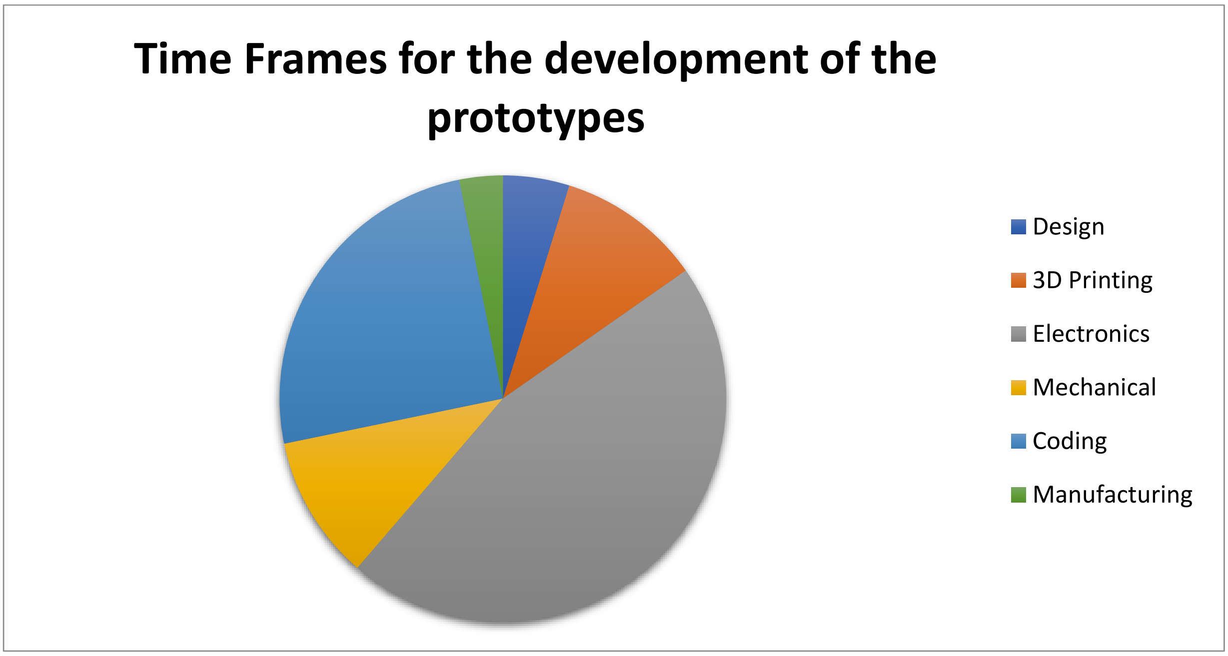
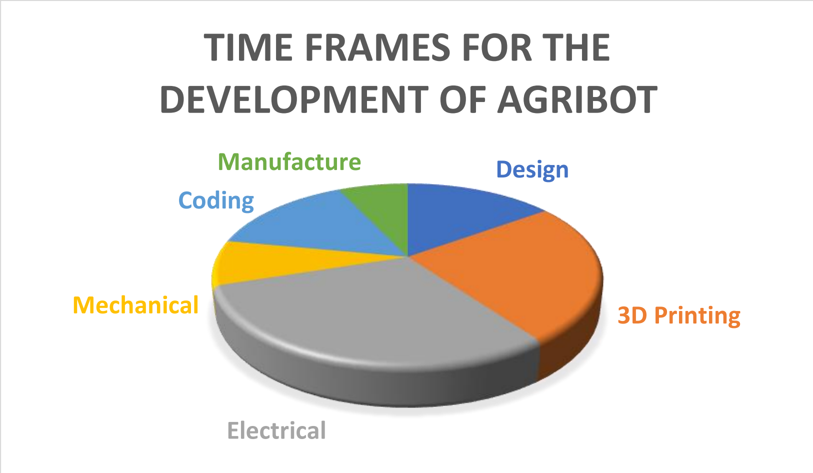
"forecast": [
{
"daylight": "D",
"description": "Drizzle. Overcast. Cool.",
"skyInfo": "18",
"skyDescription": "Overcast",
"temperatureDesc": "Cool",
"comfort": "9.21",
"highTemperature": "12.00",
"lowTemperature": "7.80",
"humidity": "94",
"dewPoint": "10.43",
"precipitationProbability": "28",
"precipitationDesc": "Drizzle",
"rainFall": "0.00",
"snowFall": "*",
"airInfo": "32",
"airDescription": "Damp",
"windSpeed": "18.26",
"windDirection": "163",
"windDesc": "South",
"windDescShort": "S",
"uvIndex": "0",
"uvDesc": "Minimal",
"barometerPressure": "1007.17",
"icon": "18",
"iconName": "sprinkles",
"iconLink": "https://weather.api.here.com/static/weather/icon/27.png",
"dayOfWeek": "4",
"weekday": "Wednesday",
"utcTime": "2013-12-04T00:00:00.00-06:00"
},
],
"country": "United States",
"state": "Illinois",
"city": "Chicago",
"latitude": 41.83,
"longitude": -87.68,
"distance": 0,
"timezone": -6
}
},
"feedCreation": "2013-12-04T09:44:13.574",
"metric": true
}</td><td>Weather API
The weather API worked perfectly and even provided a seven-day weather forecast, with sunshine, rainfall and minimum and maximum temperatures. This API is better than the one on the cell phones which only provide five-day weather forecasts.</td></tr>
<tr><td>
</td><td>Heremaps/ Googlemaps API
The developer tested the googlemaps API at various locations and obtained the exact degrees of latitude and longitude. The API also indicated the position of the robot on googlemaps including the address. This API works perfectly. As can be seen, the address of 9 9th Street Killarney was located.</td></tr>
</table>

	**18650 cells and batteries powering the Hydrogas generator, liquid pump** This wire diagram was sketched for the relay circuit. It shows how the Hydro-gas Generator, the liquid pump and the lights are controlled and powered. The batteries that are used to power these sensors were made by the developer from upcycled and bought 18650 cells.
 	**Rocker Boggy Suspension** The developer designed and 3D printed his own version of the Rocker Boggy suspension. He made them strong by printing out hollowed out legs in which he inserted 8mm stainless steel metal rods in the leg. This compensates for the weight of the robot and any additional weight that it could carry as well as ensuring that it would be able to traverse uneven terrains easily.
	**The Differential** The developer designed, developed and 3D printed the differential for Agribot. The differential converts a right rotation of motion to a left rotation of motion by inverting the rotation. The differential balances the robot. The differential was put into place as an auto-leveller that does not use any electronics. When one leg of the robot goes up the other one goes down and vice versa

	**Software Defined Radio (SDR)** The SDR was tested on many occasions and it picked up many radio frequencies including that of security radios, radio channels and on clear days vague airplane conversations with control towers. This sensor was successful.
	**Hydrogen Testing** The electrolysis machine induces a current in a liquid from an anode (+) and a cathode (-), this current thus splits molecules and in the case of water produces hydrogen gas, oxygen gas – and depending on your electrolyte chlorine (tap water)/a form of sodium.
	**Communication Box** The communication Box holds a LoRa module that is connected through SPI to the Arduino nano. The nano and the LoRa were both powered by a single 18650 running through a voltage regulator to convert 3~4v to a stable 3.3v.
	**Photoresistor** The photoresistor produces a resistance proportional to the light. This resistance is read by an Arduino and detects a change, for that change it with send a digital high to a relay that will turn on the lights.
	**GPS Module** The GPS Module connects to the raspberry pi 3b+ through serial and then communicates to a python program that records the data given out (latitude, longitude, pitch, etc.), this is pushed into a node.js express API that then speaks to a weather API and then gives weather forecast.

	**Infrared Sensors** This sensor tells the Arduino and Raspberry pi if an object is in front of the robot. The robot will try to move away from the object and carry on its path.
	**Soil Moisture Sensors** This sensor will give a percentage of moisture proportional to the moisture inside the soil, this data can be sent to the raspberry pi so that it can be store what soil moisture the soil is in an area thus show what plants you can plant there





- The electrical components took the most time to implement due to the different voltages needed for the different components. The developer did not have any prior knowledge of the way electrical components fit together. He learnt everything from the internet and Youtube videos. During the learning process, the developer burnt out component and wiring, which was extremely frustrating and upsetting for him, however this was the only way for him to learn to wire the robot. Additionally, the developer spent hundreds of hours researching and sourcing the best and most cost effective components from around the globe for Agribot.
- The 3D printing took the second most time because the wheels were printed using PTE (flexible) filament. The print took 17hours per wheel and the first four wheels failed between 7 and 12 hours during the print.
- The design of Agribot took many hours because of the research that went into the Reach Arm, the Rocker Boggy Suspension and the self-balancing body of the robot.
- The coding process was time consuming because the developer first had to learn a few coding languages, then code the robot, then tested, re-coded re-tested and repeated the process until he was satisfied that the movements were fluid and perfect.

COSTING

Description	**Cost**
3kg of PETG, PLA and TPE filament	R600.00
Estimated print cost	R1 000.00
M3 Bolts	R39.80
M4 Bolts	R59.40

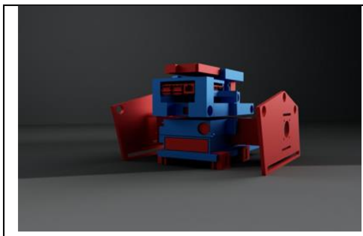
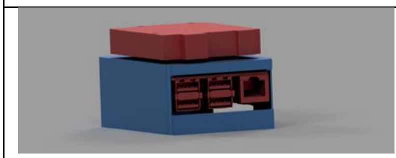
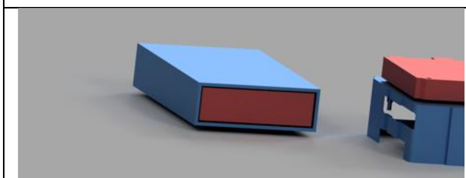
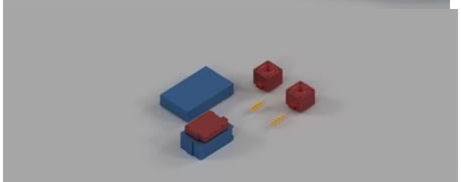
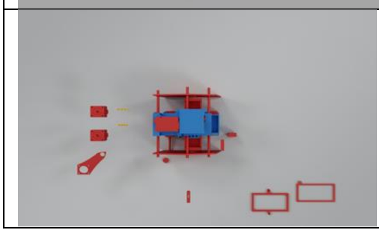
M6 Bolts	R79.60
Nuts	R19.90
Breadboard	R117.33
Breadboard Wires	R33.91
Arduino Genuino 101 intel curie board with built in Gyrometer and Accelerometer	R275.00
18650 cells to form a battery (up cycled)	Free (upcycled)
Alligator Clips	Recycled (Free)
Soldering Wire	R55.90
Raspberry Pi 3 b+	R560.86
Cellotape	R20.00
Electrical Tape	R17.95
Zip Ties	R10.00
Steel Shafts	R100.00
Pulleys	R159.00
Belts	R120.00
USB Hub	Free (Borrowed)
Wifi Module/ Router	Free (Borrowed)
Flux	Free (came with soldering wire)
Hot glue	R26.51
LEDs	R49.55
Temperature and humidity sensor	R109.04
Pi Camera	R175.00
RTL – SDR Kit	R420.00
Ultrasonic Sensor	R44.60
Stepper Motors	R679.60
Bearings	R79.60
Buck module	R56.52
6X DC Motors	R1 134.00
5X Servos	R720.00
LoRa Module	R149.99
Photoresistor	R1.15
Weighing Sensor	R30.00

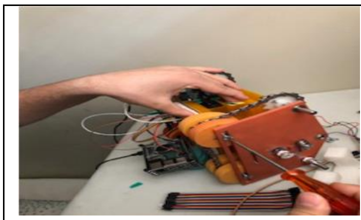
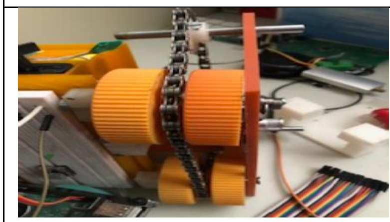
Weighing Cell	R69.00
5X Infrared Sensors	R245.00
Soil moisture sensor	R25.00
GPS module	R186.05
	R7 469.26

THE PREVIOUS PROTOTYPES

PROTOTYPE 1

SCIETMEER PRECISION ROBOT (SPR101)

	SPR101's wheels were based on a double bicycle chain on each side of the robot, thus making up two bicycle chains in total, which would have been driven by a single sprocket driver and at the base of the robot's chain was a pulley on each axel. The base axel sprockets were substituted for pulleys with a bicycle sprocket in its middle, this was to ensure that the chain does not jump the pulleys.
	The blue section is the case around the Raspberry Pi. The red piece on top of the blue is a casing for the electrical boards
 	The blue section here is the casing around the battery, and the yellow pieces are the M4 bolts
	Aerial view of the preliminary thinking and designs on Fusion 360.

	The parts on SPR 101 had to be adjusted by re-designing and re-printing some of the parts to ensure that they fit correctly and to ensure that the chain does not skip and also to ensure that the motors were able to handle to pressure of these PLA filament home-made pulleys.
	The most difficult assembly was that of the chain, because a chain breaker had to be used to break the bicycle chain and then reconnect the two ends to make it the correct size chain for the robot. Figuring out the places that the sprockets should go in, and the alignment of the motor to the main drive by getting the stepper motor pulley and belt tensioned accurately was also quite difficult.

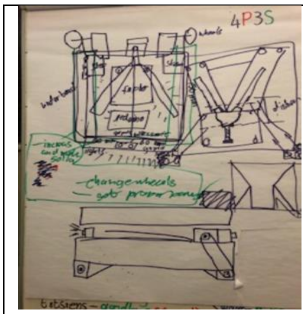
PROTOTYPE 2

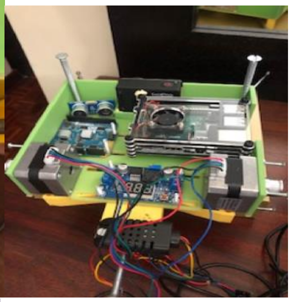
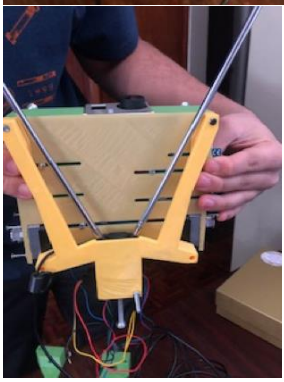
SCIETMEER PRECISION ROBOT (SPR 102)

Due to the limitations presented by SPR101 including the following, the developer decided to redesign, re-print and re manufacture the current prototype SPR102:

- The mass of SPR101 was too heavy for the motors to handle
- The design of the chain system was too complicated for the developer to perfect with the time constraints
- SPR 101 was bulky in design.
- SPR101 had sharp edges that could easily get hooked onto rocks and netting.
- The electrical components did not have proper places for them to fit on SPR101

The developer decided to use stepper motors instead of a chain driven motor

	The preliminary design thoughts were roughly sketched out first. The developer designed SPR 102 on Fusion 360. SPR 102 was designed around the electrical components thus making it a very compact robot. Once the design was done, the developer was able to 3D print SPR 102.

  	The print went well over the first day and the developer was able to start the assembly of the parts[11] with ease because the measurement of all the electronics that were to be fitted onto SPR102 had been made provision for during the design. This also ensured that the parts fitted well together. *Saving your work from the python console* Available at: http://blog.e-shell.org/174 Date accessed: 18 June 2019
	Part E is the axel to hold the wheels
 	Initially the developer designed and printed a wider wheel for SPR 102. After a testing process of the movement with this wheel the developer conducted further research in order to understand the type of wheel that would exert more torque. Research indicated that a thinner wheel exerted more torque that a wider wheel which led the developer to redesign the wheels.

[11] *pi 2 - How to connect Raspberry Pi to 3 stepper motors - Raspberry Pi Stack Exchange* Available at: https://raspberrypi.stackexchange.com/questions/57667/how-to-connect-raspberry-pi-to-3-stepper-motors Date accessed: 20 June 2019

PROTOTYPE 3

SCIETMEER PRECISION ROBOT (SPR 103)

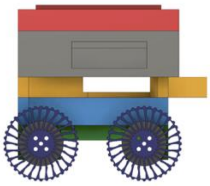
Due to the limitations presented by SPR102, the developer decided to redesign, re-print and re manufacture the prototype Scietmeer3: Precision Robot and Mobile Science Lab.

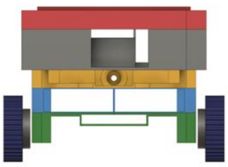
The developer decided that even though SPR 102 moved and worked well he was keen to refine the prototype in order to ensure that all the electrical components fit more neatly onto the body. He furthermore felt the need to print wheels for the robot using flexible filament so that Scietmeer3 would be able to easily manoeuvre on rough terrains such as a cave. Additionally, he added a cover to the top of Scietmeer3's body so as to protect the electrical components from the elements.

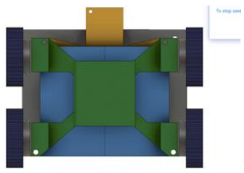
Scietmeer3's design was very similar to that of SPR102, however it was designed, printed and built to fit the electrical components, the sensors, the batteries, an extra battery and the battery bank snugly and more comfortably. The wiring was also neatened up a lot on Scietmeer3.

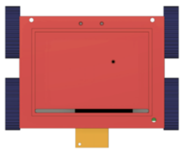
The wheels were redesigned and reprinted in a flexible filament. This new design made the robot more agile on rough terrain.

The following pictures depict the design of Scietmeer3 on Fusion360


Side view


Front view


Bottom view


Top view

PROTOTYPE 4

SCIETMEER PRECISION ROBOT (SPR 104)

Due to the developer's continuous research, he decided to upgrade the prototype and as such set out to develop and design Scietmeer4: Precision Robot and Mobile Science Lab.

Scietmeer4 was a completely new robot with a wheelbase and suspension. The 'Rocker Boggy'[12] suspension was adopted (referenced to the Mars Rover Curiosity) as this would mean more

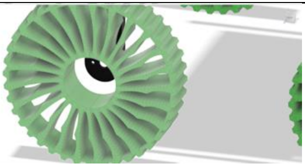
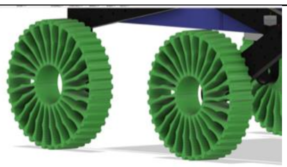
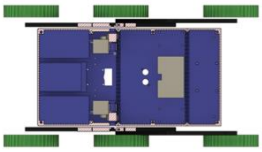
[12] Rocking Dave (2017) Why do *Mars Rovers have 6 wheels attached in this weird way?*: Available at: https://steemit.com/space/@rocking-dave/why-do-nasa-mars-rovers-have-6-wheels-attached-in-this-weird-way: Date accessed: 14 September 2019

flexibility in terms of movement. This suspension would allow Scietmeer4 to climb stairs, thus enabling agility on rough and rocky terrains.[13]

Once again, the body of the Robot was widened and lengthened to be able to neatly and comfortably fit all components such as batteries, Arduino, Raspberry Pi, Wiring, Sensors etc.

An SMS API was implemented onto Scietmeer4

The developer designed the wheels from scratch.

	Three dimensional view of the wheel[14]
	The wheels were printed in a flexible filament (TPE). Each wheel took 17 hours to print. These wheels are broader and have a greater infill than that of Scietmeer4, due to the size of the Robot's body
	Scietmeer4 was equipped with a 'Rocker Boggy' suspension and six wheels. This would allow for more agility over rough terrain.
	Bottom view of Scietmeer 4

PROTOTYPE 5

SCIETMEER PRECISION ROBOT (SPR 105)

During the testing phase of Scietmeer4 at a Hackathon a careless onlooker broke the leg of Scietmeer4 thereby causing damage.

[13] Bhardwaj (2015) *Design analysis of Rocker Bogie Suspension System and Access the possibility to implement in Front Loading Vehicles:* Available at: https://www.researchgate.net/publication/330854620_Design_analysis_of_Rocker_Bogie_Suspension_System_and_Access_the_possibility_to_implement_in_Front_Loading_Vehicles: Date accessed: 05 September 2019

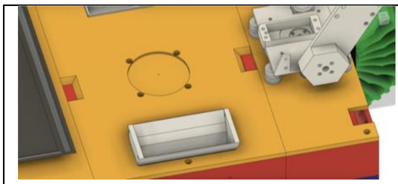
[14] Wheels 24 (2019) *No more punctures: Michelin GM goes reveals airless tyres for passenger cars:* Available at: https://www.wheels24.co.za/News/Gear_and_Tech/no-more-punctures-michelin-gm-goes-reveals-airless-tyres-for-passenger-cars-20190613*:* Date accessed: 03 August 2019

The developer managed to patch up the leg for the presentation and judging process, however this got him thinking about strengthening the legs of Scietmeer. Apart from this he decided to further enhance Scietmeer 5 with the following additions:

- The redesign of sturdier *stronger legs* printed in PETG filament, which is stronger than PLA
- *Additional batteries* for longer usage of the robot
- A *Reach Arm* for gathering samples
- A *loading plate* to drop samples onto, so that multiple samples could be collected from one place
- *Hydrolysis* testing
- LoRa modules to enable a *10km wireless range*
- *GSM* to enable the robot to be used from anywhere in the world
- *GPS API* to be able to provide locations and for the robot to be able to navigate to exact locations

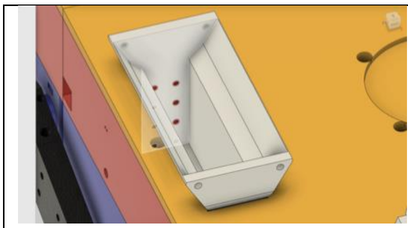
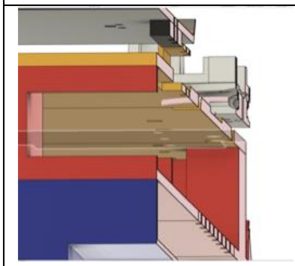
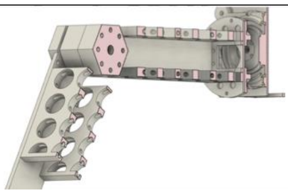
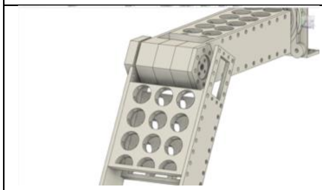
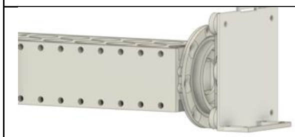
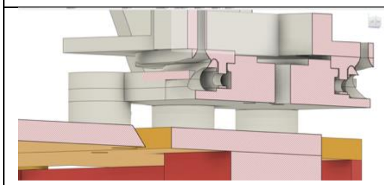
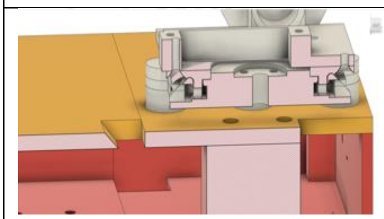
Reprinting and adding on additional components and batteries meant that the electrical components on Scietmeer5 had to be completely rewired.

In addition to the SMS API, the developer added on the API which enables location services. This would allow Scietmeer5 to transmit exact locations to the user or be sent to an exact location by the user e.g. farmer in agricultural situations, to assist with exact locations for search and rescue and in archaeological sites.

	The white trough in the picture is the part that will conduct hydrolysis testing[15]. M4 bolts acts as electrodes to the hydrolysis sensor[16]

[15] Make it big *DIY Hydrogen Generator* Available at: https://www.instructables.com/id/DIY-hydrogen-generator/ Date accessed: 01 March 2016

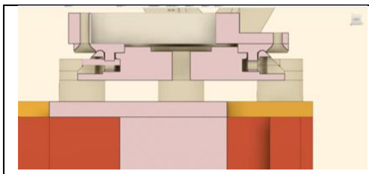
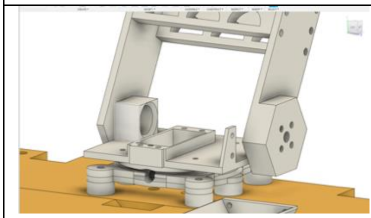
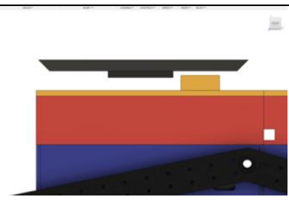
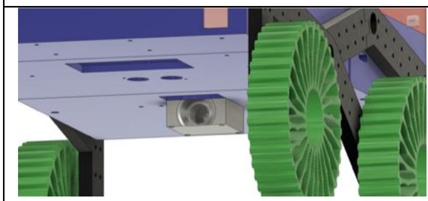
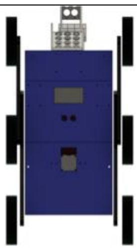
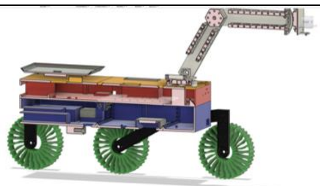
[16] The king of Random (2015) *How to Convert Water Into Fuel by Building a DIY Oxyhydrogen Generator* Available at: https://www.instructables.com/id/How-to-Convert-Water-into-Fuel-by-Building-a-DIY-O/ Date accessed: 01 March 2016

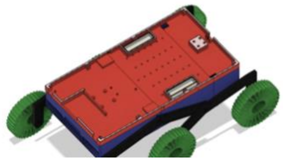
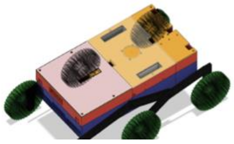
	A closer look at the hydrolysis testing trough
	A cross section of Scietmeer5 cut in half.
	Reach Arm. The elbow allows for 360 degree movement.[17]
	Front view of the reach arm and elbow[18]
	Wrist bearing on the Reach Arm[19]
	A closer look at the bearing for the base of the Reach Arm.
	A cross section of the base bearing

[17] Kang (2016) *6 DoF robot arm test;* Available at: https://www.youtube.com/watch?v=uBP4FCDORtQ *:* Date accessed: 12 October 2019

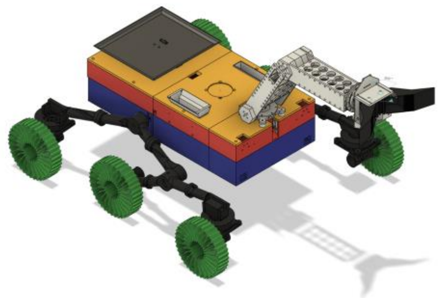
[18] Geminy studio (2016) Robot Arm - Arduino & 3D Printer project Available at: https://www.youtube.com/watch?v=QOcm2gTX_8U Date accessed: 17 November 2019

[19] Beck (2015) Arduino / Teensy 6 DOF / Axis Robotic Arm Inverse Kinematics: Available at: https://www.youtube.com/watch?v=AGHwW5TSNCY: Date accessed: 01 September 2019

	Side view of the cross section of the base bearing
	The base bearing of the Reach Arm connected to the body of Scietmeer5.
	The loading tray, which will be used for the collection of samples
	The side view of the loading tray and where the load cell will fit in the yellow part.
	A view of the bottom of Scietmeer5. The box at the bottom hold the SDR (Software Defines Radio).
	Bottom view of Scietmeer5
	Side view of the tiers of the body of Scietmeer5
	Front view of the inside of Scietmeer5.

	Top view of Scietmeer5 during development
	Top layer of the robot
	Back view of Scietmeer5
	Side view of Scietmeer5

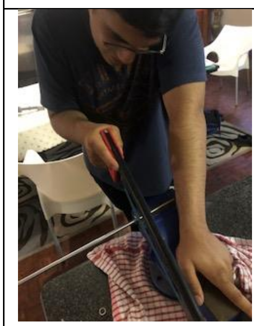
CURRENT PROTOTYPE: AGRIBOT



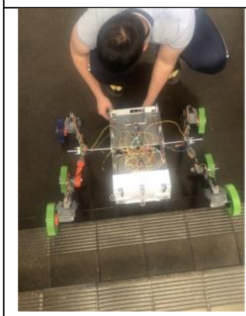
The developer changed the legs of the Rocker Boggy design to compensate for a lack of stability and support. This new leg design allows for better precision and easier turning movements. The new leg design ensures that the legs are sturdier and stronger.

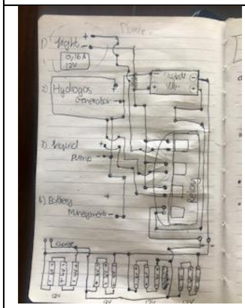
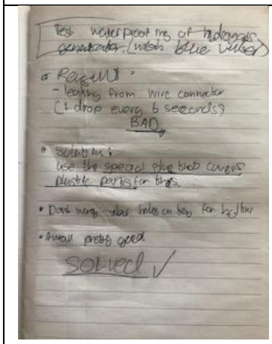
The developer researched existing designs on Nasa's 'Curiosity" Rover.[20] He then created his own design using Autodesk Autocad Fusion360.

[20] *Mars engineering curiosity:* Available at: https://www.lpi.usra.edu/education/explore/LifeOnMars/activities/pdfs/CuriosityToolsSchematic.pdf: Date accessed: 14 February 2020

  	These pictures show the initial sketch and design of the legs.[21]
  	The developer 3D printed the hollowed out legs in which he inserted 8mm stainless steel metal rods to create a stronger leg that could also compensate for the weight of the robot and any additional weight that it could carry samples and aid in search and rescue operations etc.
	The above pictures show the developer cutting the 8mm stainless steel rods, using handsaw and a bench-press, to size to be inserted into the 3D printed legs. He held the rods in place with a bench press while he used a hand saw to cut them.

[21] Nasa Science (2009) *From legs to wheels: Available at:* *https://mars.nasa.gov/resources/24247/from-legs-to-wheels/* *Date accessed: 14 February 2020*

	The differential was sketched first before it was designed on Autocad Autodesk Fusion 360.
	This is where the legs connect to the differential rod. The differential was put into place as an auto-leveller that does not use any electronics. When one leg goes up the other one goes down and vice versa.
	The developer is assembling the turning mechanism on the legs. There are four turning mechanisms on the robot.
	This is the preliminary testing of Agribot's ability to ascend and descend stairs.
 	Scietmeer5 and Agribot was fitted with a pincer that would be able to collect soil and water samples. The pincer was designed with a scoop to make the collection of water samples easy. The ends of the pincer have ridges on them to assist with the grip of samples so that they do not slip when they are being placed on the weigh scale. The pincer is attached to the arm of Scietmeer. This arm was designed and 3D printed by the

	developer. The arm has a shoulder joint that rotates 360 degrees, an elbow joint that moves up and down and a wrist joint that also rotates 360 degrees.
	Wire diagram for the relay circuit.[22] It shows how the Hydro-gas Generator, the liquid pump and the lights are controlled and powered.
	This picture shows the testing of the Hydrolysis generator. The testing showed successful results.

ERRORS AND LIMITATIONS

- *Time limitations:* The project was time intensive as the developer needed to self-learn and apply every aspect of the process, design, electronics, coding, mechanical, software engineering and assembly of the robot. This was exacerbated as the developer was 14 years old at the time, has a full school and religious study during the day and needed to do all work at nights, on the weekends and during the holidays.
- *Accessibility of parts:* The developer acquired specialised components such as the Adafruit Hat and Arduino hat for SPR101; the SDR (Software Defined Radio); the LoRa module (Long Range module), which is available from Amazon and Bangood in China. These parts were difficult to find locally and if they were available locally they were more expensive than importing them.

[22] *CircuitMaker workspace Activation:* Available at: https://shell.circuitmaker.com/activate/EE6B1310-4FEB-4940-9E7F-6677F1453C69?mkt_tok=eyJpljoiWVdVM01qSTFOelF5TkRBeilsInQiOiJxeHF0bTlyamRpY1ZidlBkQjRzdHhYNU5CZ0tpYXV6aGdwRXk1SzlORTR1YUw0aDVTUTVuK3k4dUNHQkZ0K3FDM1ZqZ3daNStxRkdGdDJOTmVoYVp4WHhkTVdVMVdTThadzdOdjVxUm1lUVZvRXE1Nm9VdlhKYWRGa0FSMjdKWiJ9 Date accessed: 21 June 2019

- *Covid-19:* Due to the Covid-19 pandemic and lockdown, any burnt out electronic parts as well as simple bolts and nuts were almost impossible to obtain. This was due to the closure of and inaccessibility of many stores as well as the inability to order any parts from China or through Amazon. The developer had to redesign certain parts in order to make do with whatever he had available
- *Burnt out electrical parts:* Electrical engineering errors and faults led to burning out of components and parts during the learning process. This would however on the positive side result in practical and valuable lessons
- *Limited access to mentors / professionals:* None or very limited access to a mentor that understood the full scope of the prototypes. Main sources of information was the internet, YouTube and trial and error to get different parts of the design, the coding, the electrical components and the mechanical components to work.
- *Cost of parts:* The developer was 15 years old at the time; he does not have an independent income and has no sponsor. The developer depended on his own pocket money, available devices in the home, his parents, recycling, and borrowing of tools and parts.
- *3D Printer Problems:* The 3D printer resulted in failures due to the heat bed, the PINDA (Prusa Induction Auto Levelling Probe) faults and the fluctuation of outside temperatures. Any failures to the 3D printer resulted in long delays; expenses and components that had to be shipped in from Prague.
- *Filament Humidity and Temperature:* The filament is stored in the developer's bedroom in an apartment. The slightest amount of humidity caused the filament to destroy itself. The filament needed to be dried out by putting it into zip lock bags The ideal temperature for filament is between -20 degrees Celsius and +30 degrees Celsius and the filament humidity range has to be below 50% humidity.
- *Filament Problem 1:* The prints needed to take place at night and took long periods of time to complete. Filament levels can be underestimated and there is no filament sensor on the printer. This resulted in failed and costly prints.
- *Filament Problem 2:* A knot in the filament would lead to the Bowden tube clogging inside the hot-end. This required the developer to use a "cold pull technique". This entails inserting a piece of filament, then setting the nozzle temperature to 215 degrees Celsius and then letting the temperature cool down to around 170 degrees Celsius and then pulling the filament out from the bottom of the nozzle with force. This increased the time, frustrations and costs.

- *Filament Problem 3:* The nozzle blocked up with filament. This required the developer to push an acupuncture needle up the bottom of the nozzle and then use the “cold pull technique” to pull out the blocked filament.
- *Printer Fails:* Due to load shedding and sudden power cuts the print failed. Prints needed to be timed out of load shedding schedules. However unplanned power cuts led to failed prints

CONCLUSION

From the above investigations, it was verified that a home-made robot does not have to be expensive to build. It can be built using mainly recycled, up-cycled, borrowed and biodegradable materials.

Agribot was fitted with a range of sensors and APIs which after much testing yielded positive results. There were minor discrepancies on some of the sensors, however they did provide the information that was intended.

Agribot is coded in Python and Arduino (C++). The developer is an exceptional coder for his age and has won many awards in this field. Therefore the coding for the movement of Agribot is precise and exact. The coding process was also used to collect data through the sensors via the Arduino and this process was also accurate.

The electronics of connecting all the sensors onto Agribot was extremely difficult. The developer went through a trial and error process in this area. With persistence he obtained success.

Since the developer has been successful in 3D printing and 3D design the design and 3D printing of Agribot is was so precise that the parts fit accurately together making the assembly of Agribot easy.

Although the developer has had challenges with the weight bearing and shoulder servo on the reach arm of Agribot, he views this as a challenge and as soon as parts are more accessible he aims to tackle this challenge with renewed energy.

The developer researched and learned about electrical and mechanical engineering as well as increased his knowledge on software engineering, the project of building six prototypes took approximately eighteen months to design, develop, build and code. It is important to note that the developer devoted all his weekends, holidays and spare time and many sleepless nights to this project.

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【評語】100045

This work is aimed to build up an Agribot system for the multipurpose in the agriculture field, essentially a self-driving vehicle with a robotic arm and environmental sensing. Very detailed engineering works were carried out. It may be more helpful if the design can be divided into modules or integration of changeable modules. Besides, many functions are set for this project. For example, what function of Hydrogen Testing is in this study? These have to be justified clearly for practical uses in the report.