DISCOVERY ROBOTICS

Grove Academy

Dundee, Scotland

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ABSTRACT

Discovery Robotics is a group made up of 6 pupils from Grove Academy in Dundee, Scotland. The team was formed in 2021 and design and construction began in the early summer. The Team focussed on renewability, precision and innovation in order to structure the design with an aim to utilise the craft for green energy applications, assisting to maintain sustainable sea life and the Arctic and Antarctic landscapes.

Over the past year we have created a versatile ROV ,Captain Scott, that can be used in many different ways such as analysing and interacting with its surroundings and conducting research to improve the environment. These aspects are very important to us as we believe these capabilities will be of most value to our potential customers.

(Discovery Robotics team at a pool test)

COMPANY PROFILE

Discovery Robotics is a pre-incorporated company founded in August 2021 by a group of six pupils from Grove Academy, Dundee. The company concentrates on sustainability aspects and has designed a prototype ROV that when further developed would be suitable for arctic exploration. We aim to create an ROV that is able to be sold or leased for commercial use. We are an ambitious group of individuals who each have different responsibilities corresponding to their role in the company. The group is split into two departments in order to maximise progress and balance the workload.

Personnel

Jacob Sharpe - The CEO, responsible for overseeing the entire operation and also working closely with the AutoCAD design.

Jonathan Main - The Vice CEO, a dedicated team member who is responsible for the construction of the ROV control box, designing the vehicle code and pilot of Captain Scott.

Sam Terroni - The Head of Electronics, is very hardworking and is responsible for the construction of the grabber and has written its servo-control code as part of his role.

Kyle Reid - The Head Structural Engineer is responsible for the construction and framework of the ROV craft and has taken up the poolside role of tether management.

Arran Leiper - The Chief Safety Officer is responsible for the safety of the whole operation by making safety protocols for the team in the construction workshop area and at poolside, he is also

Fraser Robson - The Production Engineer is responsible for the construction of component parts and the building of ROV, as well as being co-pilot of Captain Scott.

(The Discovery Robotics team)

Scheduling

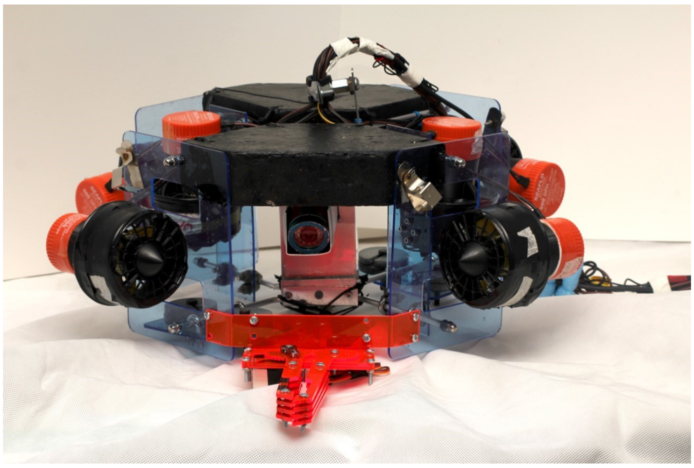
The team met four times a week in line with our school timetable, holding a short briefing before each work session to plan the day's tasks. This schedule routine was adhered to over the entire school year from August 2021 to April 2022.

The team had access to a classroom and computers 4 times a week as well as a workshop and tools to construct parts for the ROV. The team were also were allocated an hour of pool time each week from November to December 2021, going up to 2 hours a week from January 2022.

The team was divided into two sub-teams to ensure that the project had a balanced progress for each activity. This helped significantly with efficiency, the project progression ,minimising time for the craft developers to wait for the design/electronics team to finish a task and vice versa.

Time	Task
0-5 minutes	Entire team arrive, set up
5-15 minutes	Team briefing on tasks for the day (discuss ideas)
15-20 minutes	Assign tasks corresponding to individual roles and split into sub teams.
20-60 minutes	Attempt given tasks.
60-70 minutes	Regroup as a team and discuss progress and issues with tasks.
70-75 minutes	Reassign roles and give new tasks if required.
75-95 minutes	Reattempt tasks and fix any new problems discovered.
95-100 minutes	Tidy up and report the day's progress to CEO.

Assembled ROV



(Captain Scott assembled and pool ready)

DESIGN RATIONALE

Initial Design Process

The team's initial design was around a diamond shape originally which subsequently refined and adapted to become an asymmetric hexagonal shape after significant team discussions.

During very early meetings the team agreed that there would be no onboard electronics due to the possible dangers of leakage, disabling the ROV. The design of the poolside control box and its connector panels followed with the construction of the harness tether to connect the box to the ROV craft.

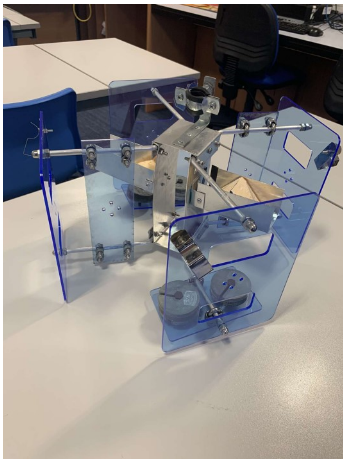
(The new design for umbilical bracket)

Material

After a careful initial analysis of available materials, the decision was made to use continuous cast acrylic as the material for the framework as the material was strong and flexible enough to withstand pressure stresses caused by the power of the ROV thrusters.

The sides of the craft were designed using AutoCAD software and subsequent made by laser cutting them from pieces of acrylic.

Structural Design

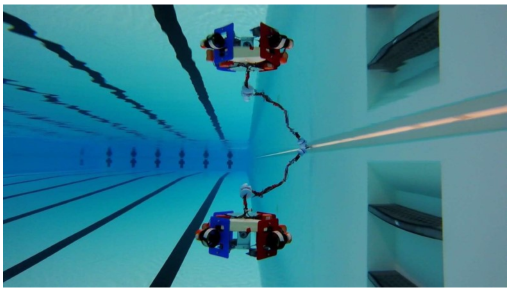


(Frame of Captain Scott)

The design a basic ROV structure continued by using four aluminium rods as the spine. The design of a small aluminium box followed and made, in order to fasten a bracket to connect the umbilical control cables to the ROV craft from the control box. When this was fabricated, several members of the team raised their concerns about the strength of this bracket and after a team discussion this led to a new design being created. This new design, altered the shape of the aluminium rods leaving no cross-section, allowing for a new spine to be constructed and thus a flat surface created to which the bracket could be fastened securely.

Thrusters

The six thrusters are made from yacht bilge pumps incorporating a nozzle and an in-house designed and manufactured 3D printed adaptor joining the nozzle to each thruster. This design was chosen as it was tried and tested to be successful in previous years by other previous ROV companies from our school. The thruster position design was centred around their being an optimum position of the thrusters on the frame, resulting in four thrusters on the outside of the framework, controlling the horizontal movement of the ROV craft, and two on the inside controlling the vertical movement.



(Initial pool testing)

Drag

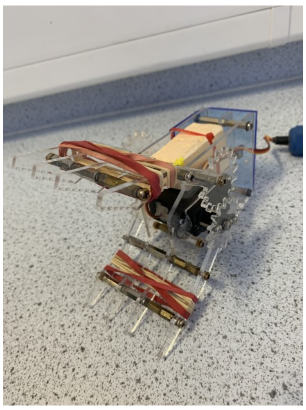
After a pool test an observation was raised by the team that the huge surface area on either face of the two laser cut sides created a lot of drag, effecting the directional speed and sensitivity of the ROV. This problem was tackled by the team deciding to change from 2 long sides to four smaller sides allowing more water to flow through the ROV making it lighter and more streamlined in the water.

Cameras

The use of two underwater “fishing” cameras were fixed to brackets providing the main vision on the craft with a smaller fishing camera positioned to be used to monitor the grabber operation. These cameras have been used in previous ROV craft designs in competitions and had proven reliability.

Grabber

The grabber was out-sourced and has parts added to adapt the operation and attach to the ROV securely. The grabber has been tried and tested in various pool tests and has 4 layers of arms to give strength and structural integrity making it easier to operate. The grabber is now able to open vertically or horizontally as the positioning is interchangeable at the operator’s discretion.



(Out sourced Grabber)

Innovation

The team designed and made four adaptable and versatile camera brackets positioned on the craft to allow the small camera to be moved between the. The brackets were made out of stainless steel drawing board clips which had a mounting hole drilled through the top to attach each to the ROV with a fixing bolt. This was a low-cost item as the clips were found in the school's technical department and were no longer in use thus saving the team valuable funds to be used in other project areas. The team used AutoCad software design and a laser cutter tool in the design and manufacture for the fabricated ROV bodywork. This design for manufacture method was extremely helpful as it permitted the creation of parts having precise measurements and tight tolerances required for the completely symmetrical components and it opened up possibilities for incorporating new design features to the ROV. This technique also reduced the costs of manufacture as it abled in-house design and fabrication thus eliminating the costs associated with outsourcing a subcontractor.

The Discovery engineers also created two camera holders out of sheet aluminium, this was a more reliable and structurally sound way of securing the cameras than cable ties or electrical tape. The aluminium was bent twice at 90 degree angles to hold the camera in place.

Problem Solving

The team held weekly feedback meetings to discuss ideas and thoughts on proposed new ideas where all concerned discussed their pros and cons. The team then voted on each proposal and a general consensus was agreed. At times, compromises had to be made where there were disagreements with the majority team decision.

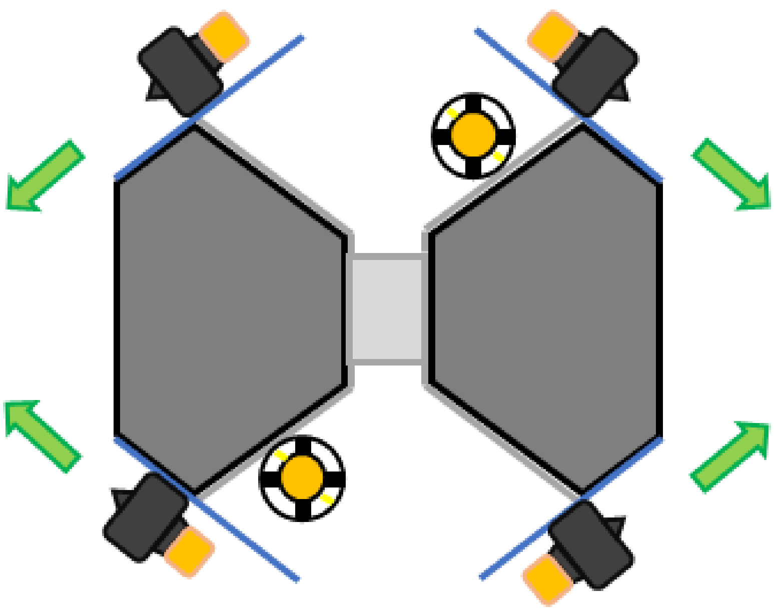
The team encountered problems all throughout the project and had to come up with feasible solutions to problems in a relatively short space of time. An example of this was when a camera came adrift from the ROV in the initial testing period as the first fixing method used could not withhold the drag forces of the water upon the camera.

Systems Approach

The ROV itself is made up of many different systems that need to cooperate smoothly if the machine is to function as best it can. This was considered from the very start of production as well as all the way through. For the best performance, the ROV needed a solid frame to build from so this was considered first. When focussing on this it was important that all members of the team were aware of how the frame was built so that it would be easy to build out from it efficiently. The frame, consisting of four aluminium rods connecting four acrylic panels joined by aluminium plates at the centre, gives the ROV strong foundations to incorporate the other parts of the ROV. This is including the grabber and hook placed at opposite ends of the ROV to give balance in the water and appropriate tooling for different tasks. The frame was also specially designed to allow for six thrusters, four on the outer body with two inside the main plating. This gives the ROV easy manoeuvrability through the water.

There are three cameras in use with two of them being fixed at opposite ends of the ROV. The third camera can be moved to four strategically placed locations on the outside plating to give the pilot as much sight as needed especially when in use of the grabber or hook. This was an elegant way to ensure the maximum efficiency of all parts of the ROV.

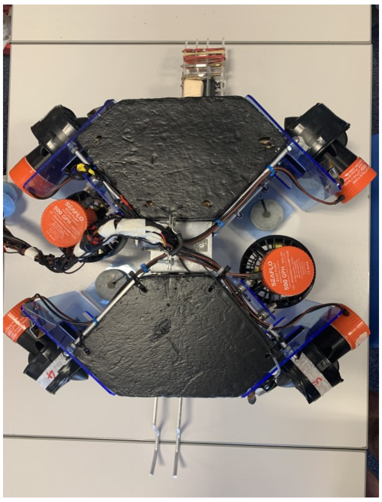
Every system on the ROV is centrally controlled through the



(Shape diagram of Captain Scott)

Vehicle Structure

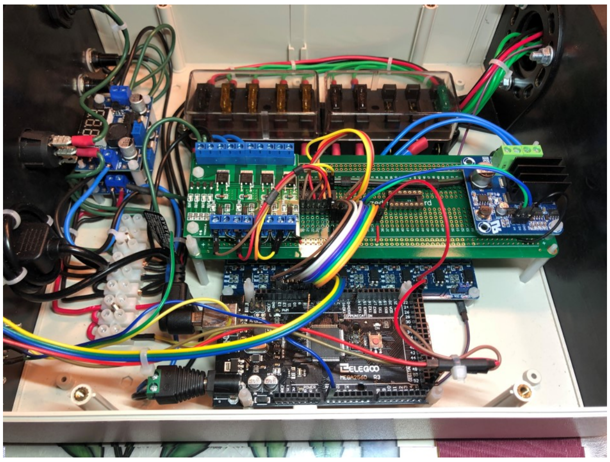
The team were given a budget of £300 that was kindly donated by the competition's sponsors Robert Gordon University. The budget was used appropriately to make progress with, Captain Scott, however some drawbacks had to be made in order to stay within budget.
The team built their own grabber to minimise cost as the price of a pre-built one was very expensive. The team 3D printed thruster guards saving money outsourcing them, with money also saved on reusing old wiring for the umbilical. The team decided is was necessary to spend some of the budget on a control box as it would take up too much valuable time to build one from scratch, this proved successful as the box is sturdy and large enough to accommodate the entire control system.
The vehicle dimensions are 540 mm diagonal diameter from thruster to thruster. The basic 400 mmx400 mm structural design agreed in the initial design stages, remained throughout the development project. It was considered this size of footprint would permit space for further tooling used to optimise the design of the ROV's capabilities while maintaining the streamline in the design as far as possible. The team decided on four-sided approach moving away from the original two-sided design to allow for more waterflow through the vehicle in order to reduce drag. This allowed Captain Scott to have more accurate movement in the water as the reaction time from the controller operation to craft was significantly reduced.



(Overview of Captain Scott)

The vehicle weighs approximately 5.71 kilograms, this makes the ROV sturdy and easier to control in the water. This weight was not excessive as much tooling had been added including the weights used in the ballast system. The ROV is currently still under 15 kg in weight in order to achieve the maximum points for ROV weight in air.

Control Box



(Control System)

The Control Box features an Arduino Mega2560 micro-controller board with two methods of outputting power to the ROV, as it contains both an eight-way relay board and a solid-state switching board which both bring different attributes to the box but allowing for a backup option should one or the other fail.

The Box is powered from a 12V battery and has two dc-dc convertors inside - one 12V to 9V and the other 12V to 5V - to distribute the required voltages throughout (ie 9V to the Arduino, 5V to the power grabber servo). When used with the Arduino, the relay board worked on an active low output, however the solid-state worked on an active high output. In order to comply with both switching boards, the work around this was to design the code to suit both boards. An additional invertor was added to the motherboard of the solid state board to minimise the Arduino control output configuration. For the vertical drives (up and down motors), to achieve multidirectional movement, an H-Bridge was required to be configured using relays on the relay board and a solid state H-Bridge module was used with the solid-state board.

The operators controller selected was a SNES controller which was chosen due to the number of input buttons and its familiar layout and style allowing for easier adaptability when controlling the ROV initially. The controller picked for the Grabber was a potentiometer which allowed for variable operation of the servo-controlled grabber to complete the tasks in the competition.

ROV Code

Due to being novices at coding, an Arduino Mega 2560 microcontroller was selected as it was easy to use with a wide variety of open source code available to assist with the initial software platform.

The code for the ROV is written in "C/C++" and features a wide variety of commands and instructions. The code was developed over the course of the year starting off with an open source base code which was further developed, with it taking 18 iterations of software development to arrive at the final version of the code used in the complex dual controlled system unit driving the ROV.

The code for the ROV was developed by Jonathan Main and the code for the servo-controlled grabber assembly was written by Sam Terroni with the two pieces of code being combined for use in the Arduino in the competition.

The code allows for multidirectional travel of the ROV with the ability to change the 'front' of the ROV depending on the task at hand and required tooling while allowing for the grabber to work simultaneously. This aspect of the code permits easier steering and manoeuvring of the craft in the water .

```
unsigned int buttonsPressed;
void loop() {
MAIN:delay(25);

  digitalWrite(pin1, HIGH);
  digitalWrite(pin2, HIGH);
  digitalWrite(pin3, HIGH);
  digitalWrite(pin4, HIGH);
  digitalWrite(pin5, HIGH);
  digitalWrite(pin6, HIGH);
  digitalWrite(pin7, HIGH);
  digitalWrite(pin8, HIGH);

  val = analogRead(potpin);
  val = map(val, 0, 1023, 79, 135);
  myservo.write(val);
  delay(15);

buttonsPressed = getSNESbuttons(CLOCK, STROBE, DATA);
```

(Screenshots of part of the ROV's Control Unit Arduino Code)

```
if (buttonsPressed & SNES_B){
goto FORWARD;

}

if (buttonsPressed & SNES_X){
goto BACKWARD;
goto MAIN;
}

return;

FORWARD: if (buttonsPressed & SNES_DOWN) {
  digitalWrite(pin1, LOW);
  digitalWrite(pin2, LOW);

}
if (buttonsPressed & SNES_UP) {
  digitalWrite(pin3, LOW);
  digitalWrite(pin4, LOW);

}
if (buttonsPressed & SNES_SELECT) {
  digitalWrite(pin1, LOW);
```

Tether

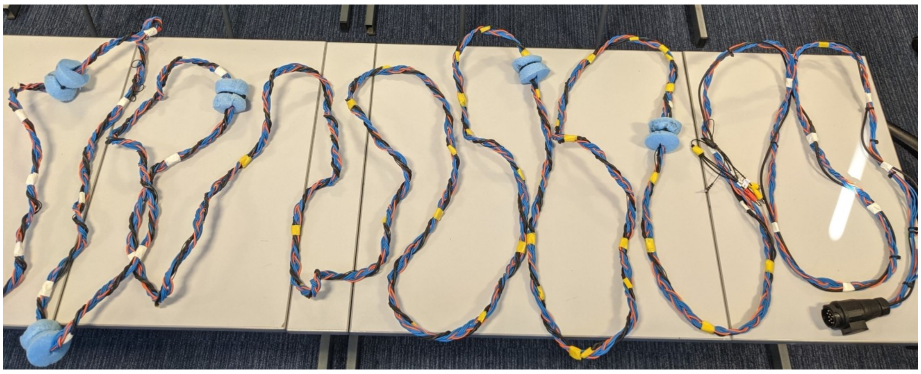
The ROV is equipped with a tether consisting of 12 cables plaited together so that there is less chance of it getting tangled in the thrusters when flying the ROV. Including three camera cables, two ground wires (one for the thrusters and one for the servo), six live wires one for each thruster (12v) and one 5-volt wire for the servo. The tether is 15 meters in length which allows the ROV to move with ease in the pool and has a total weight of approximately 3.37 kg. On the tether there are evenly spaced floatation devices so that the tether is neutrally buoyant and does not drag along the floor as this could affect how the ROV operates.

The tether is securely connected to the control box and the ROV when in the pool and when at pool side it is coiled up and out the way so that it is safe for anyone walking in the vicinity.

On poolside Kyle Reid is responsible for tether management, this responsibility entails being in direct communication with the pilot and sticking to the safety regulations set by the Chief Safety Officer.

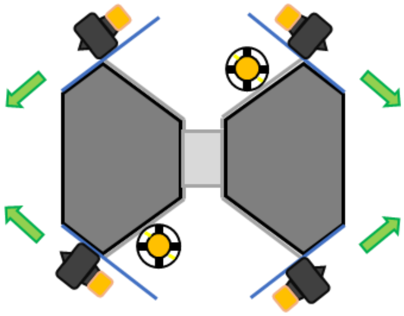
When in the pool the right amount of tether in the pool is pivotal, so there is no strain on the ROV, and any excess is neatly coiled up at the side so that there are no hazards for any team members.

Chief Safety Officer, Arran Leiper, ensures the Discovery team adheres to his poolside safety protocol. This ensures that the team and any other poolside officials are safe without harming the ROV, this means that each team member must stay with their assigned station and not step over the umbilical or any wiring as well as the various ROV safety procedures.



(Captain Scott's Tether)

Propulsion



(Vector thrusting layout)

The team used 6 yacht bilge pumps with nozzles and in-house designed 3D printed adaptors. With four thrusters around the exterior of the bodywork that controls the horizontal movement of the ROV. Using four thrusters for horizontal movement gives good balance to the ROV as they are positioned evenly around the diamond shape of the ROV maximizing the vector thrusting to optimise directional force. The two thrusters that control vertical direction are on the interior of the bodywork attached by in-house designed plates. The two thrusters are symmetrically placed on either side of the ROV to balance the weight on vertical force of the two thrusters. The thrusters work together to balance the vertical force with one thruster pushing forward and the other in reverse and vice versa to move up and down optimally and balanced.

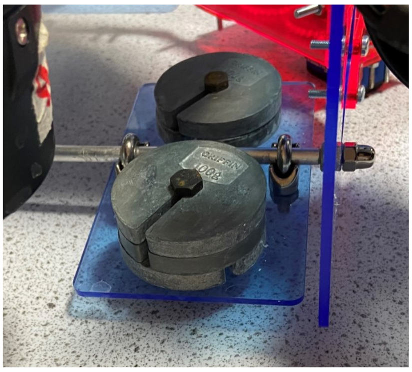
The team designed guards for the front and back of the thrusters to ensure the safety of the operation not allowing wires to be caught in the thrusters. After various team discussions and pool testing it was decided that only two thrusters will be used for each movement of the ROV, this makes the ROV move more smoothly in the water and save power. Using these thrusters saved us the additional cost of new thrusters as they are property of the school, this was the deciding factor for the team to choose these thrusters.

(Thruster used on ROV)

Buoyancy and Ballast

The ROV's buoyancy system consists of two large carbon fibre floats that fit symmetrically on either side of the ROV between the spine and outer bodywork. The two floats counteract the weight of the ROV and tooling, making the ROV positively buoyant. This was a huge problem for the team as the buoyancy massively effected the accuracy and precise movement of the ROV.

In order to overcome this challenge the design team come up with a simple ballast system where a laser cut plate was fastened securely using U-clamps to both of the lower aluminium rods connecting the spine to the framework. 100 gram weights were then bolted onto the plates allowing the team to add and remove weight depending on tooling used. The team strategically fastened the plates to the bottom of the ROV to maximise the ROV's balance with the buoyancy being found at the top of the ROV, the plates were placed on opposite sides of the ROV to ensure one side wasn't heavier than the other.



(Ballast System)

Cameras and Monitors

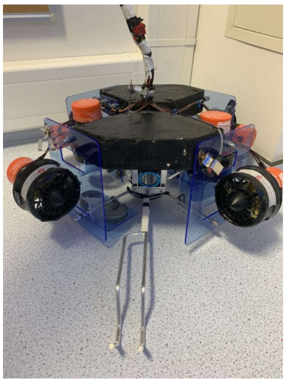
When the monitors were first used by the team, a number of issues were observed and subsequently fixed. The wires from the monitor to the battery were defective and had to be removed with a new wires being soldered on to the input plug.
The third, smaller monitor had a number of issues that needed addressing, The internal battery that was originally inside the monitor had been removed meaning the screen required a constant power source and so this also needed a new power lead. After searching for a lead that met all the requirements, a 5V to 9V step up power lead was selected with a new plug soldered onto the wire. The monitors are wired to the main power supply and, resultantly, the three screens are now fully operational and are up to a good safe-working standard.
The two main cameras have been attached to the central spine of the ROV using metal trays to hold the cameras in place and at an appropriate angle for full view in the pool. The third camera is being used at four identical positions on the outside of the ROV. This position may be changed at the poolside in a matter of seconds. This allows the pilot to have a second angle on tasks and the subsequent tooling to complete the tasks more efficiently.

(Monitor box)

Payload and Tools

Hook

Initially, the hook was designed as a temporary placeholder whilst work was being done on the grabber. Meaning it could be used to position the cameras and as practice for the pilot to manoeuvre the ROV in the water. During the practice, the hook proved to be useful alternative to the grabber and when the tasks were released, instances where it could be better suited than a grabber. This combined with a balance issue meant that the hook is incorporated into the final design on the opposite side to the grabber.



(Hook on ROV)

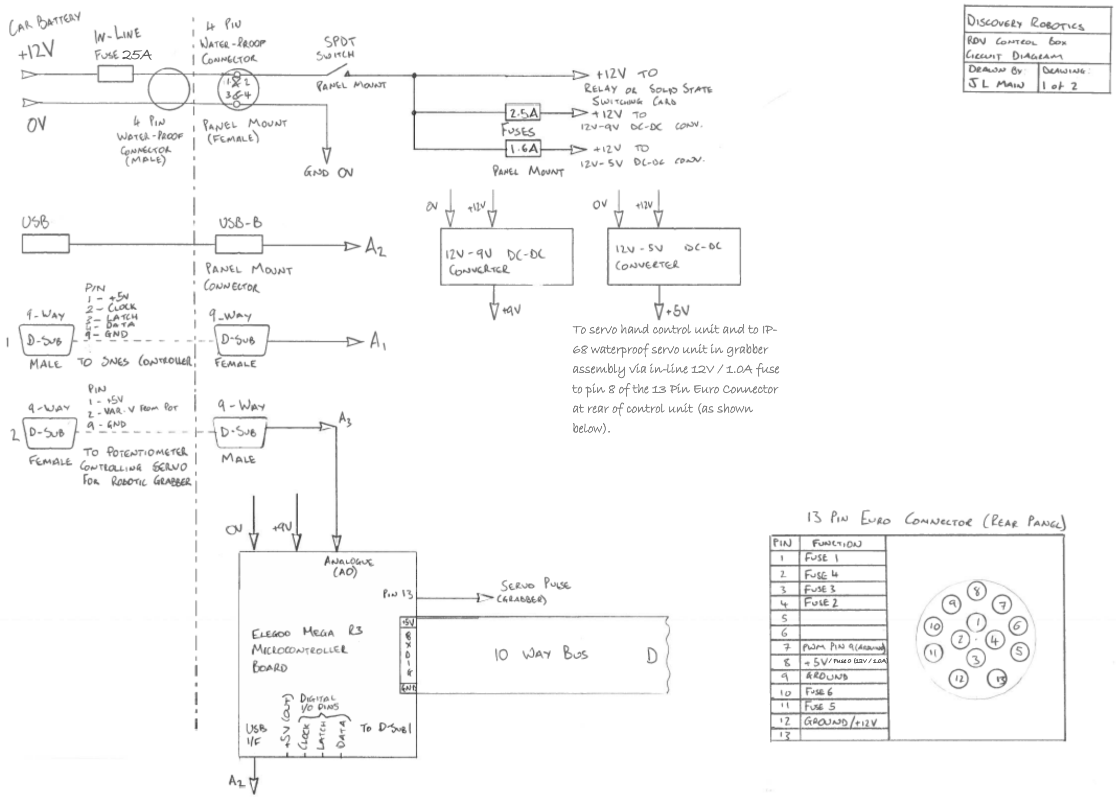
The hook used on the ROV is made of two aluminium rods. One of length approximately 525 mm and the other of approximately 500mm. These were bent five and three time respectively to form the shape of the hook. They are attached together with the longer rod bent perpendicular to the ROV the bent back parallel to the other rod after approximately 25mm to form the gap between the rods. This was done so that the two rods would be linked to make it easier to attach to the base of the ROV but also easy to detach when working on the ROV. This also meant that instead of attaching two separate rods we could attach the two rods as one thicker rod and avoid issues with the alignment of the bars.

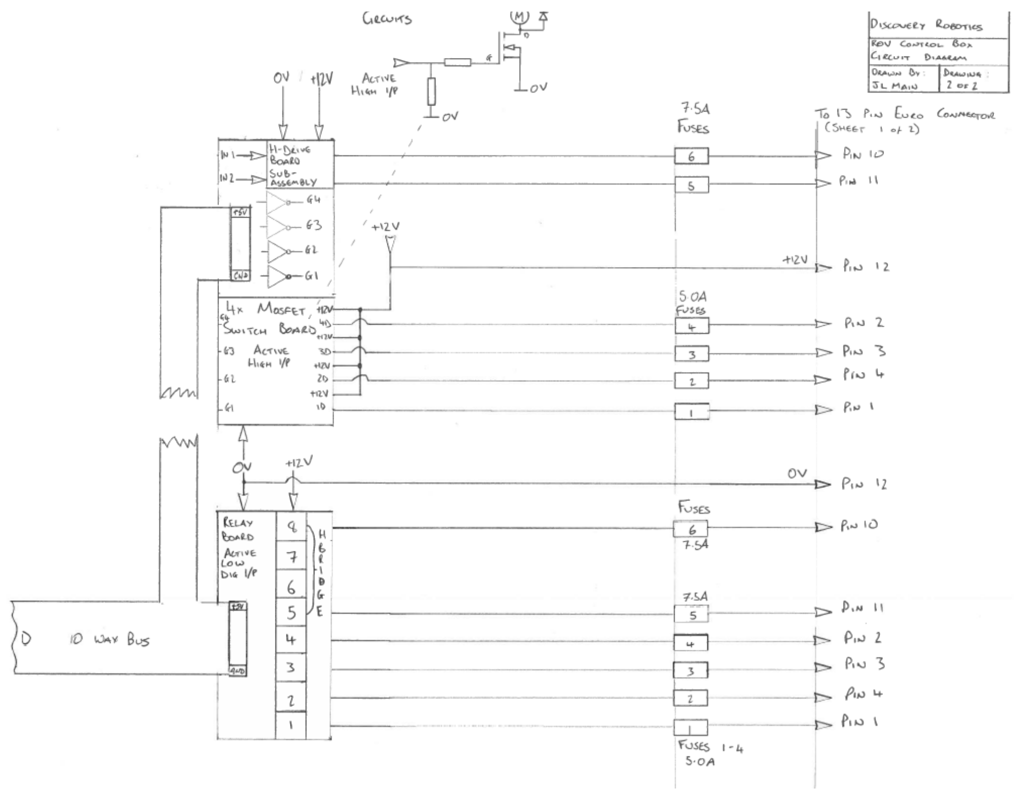
To form the section of the hook that will hold the objects, both bars had the same process. This process was an initial bend of 55°, 140 mm from one end. 55mm away from the bend, towards the end of the rod, the rod is bent again to make it parallel to the initial rod leaving a slope. 40mm away from the end of the rod, there is a final bend that takes the end of the rod to the same level as the longer section of rod. This creates a resting spot for anything the hook needs to pick up and ensures that it holds in place on the hook.

Grabber

The grabber on the ROV is designed and built by Discovery Robotics after grabbers and claws that were outsourced were too small and unsuitable for use. The gripper was designed on Inventor and later cut out using a laser cutter. The material used for the grabber is acrylic and was assembled using bolts. The gripper opens to a 285mm diameter and has a reach of 155mm. It is in the centre of the ROV and is attached to the side plates. The grabber is powered by a Servo motor and is controlled using a potentiometer. The potentiometer and Servo are coded through Arduino. The team also have an outsourced grabber that can be used in place of the in-house built one should any problems arise.

System Integration Diagram





Safety

Every employee at Discovery Robotics understands the importance of safety procedures when working in a workshop and with electronics. The safety procedures are a large part of the briefings at the beginning of each day. The safety briefings were conducted by the Chief Safety Officer, Arran Leiper ,who generally oversaw each task conducted by every employee to ensure maximum safety. Arran also assumed responsibility for ensuring the workplace is a 'COVID safe' environment during the pandemic. This was done by following guidelines as set out by the Scottish Government.
At the beginning of this project, before construction began, work was done to lay out the ground rules of safety. This included the wearing of goggles and making sure that each team member knew how to use each tool or machine safely and properly. These protocols have kept workplace accidents to a minimum.
One of the hardest yet most important parts of the safety procedures was dealing with electrical components which are a major part of a marine based machine. This was done by installing the control system in an ABS type plastic box separated via an umbilical from the ROV ensuring minimum risk of the electrical and electronic circuits coming into contact with water. This solution does have drawbacks however such as having several wires interconnecting the ROV and its control system. The Chief safety officer always checked all the way along each wire searching for any openings in the wiring. This was essential when preventing the possibility of the team members obtaining any electric shocks and damage to the vital control system. The team also designed thruster guards, that were 3D printed in-house, to prevent any wires being tangled in the blades.

(Thruster with rear guard attached)

Safety Procedures

- Safety briefings prior to each task referring to rules set since day 1.
- Oversight conducted by Chief safety officer during tasks.
- Following of government COVID guidelines – masks, social distancing, cleaning of work surfaces and tools pre and post use etc.
- Before activation of ROV, checking fuses, safe distance of employees and tether from spinning motors.
- Ensuring all electronic components are clear of water at all times.
- Ensuring any and all personal protection equipment is readily available.
- Checking all wires are safe to be used.
- Controller was wired so that two buttons must be pressed to activate thrusters.

(Arran and Fraser using the lathe)

Build vs Buy

Control Box

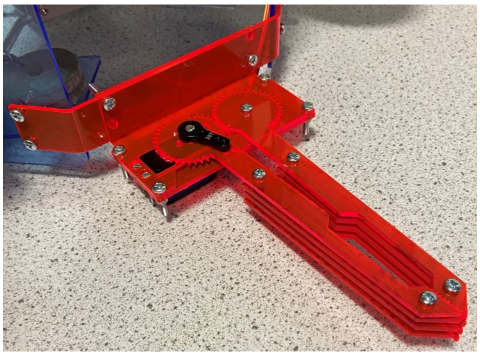
The team spent £31 on an ABS box to house our control system. The team decided this was the best course of action as the box was robust easily adaptable as we laser cut and drilled sides of the box to meet our needs. The team felt this was better than building our own box as wouldn't be a good use of our time and resources with such a busy schedule.

(Control Box)

Acrylic Sides

The team designed 4 acrylic sides to the ROV as the body work on AutoCad software that were cut out on a laser cutter. This was more advantageous than outsourced acrylic sides as we were able to modify the design to fit our ROV at any time of the project.

Grabber



(In-house built grabber)

The team opted to build our on grabber, Head of Electronics, Sam Terroni, designed a grabber system on AutoCad software that was cut out onto cast acrylic. The team then wired up a servo and attached it to the laser cut claw that was securely fastened by a bracket to the front of the ROV.
The in-house designed and manufactured grabber helped complete the tasks to the ROV's maximum capabilities, as the team were able to decide on our own dimensions, grabber movement and placement.
After various water tests, the team concluded that an out-sourced bought online grabber was more suitable to the competition tasks. The out-sourced grabber is more versatile as we designed an in-house built bracket to adapt the grabber's capabilities, this bracket allowed for the grabber to open and close horizontally and vertically.
The grabber has 4 layers of teeth made from acrylic that increases grip and contact surface when picking up objects, with the teeth creating friction with any given object. The team waterproofed the servo using epoxy to stop any water damaging the motor, the servo was then wired up and floats attached to counteract the added weight of the servo.

Controller

The team chose to buy a SNES controller to manoeuvre Captain Scott. The decision to buy a controller was made as it would be too time consuming and unreliable to manufacture one, the controller is easy to use and the pilot has previous experience using it on a games console. The controller features a 9-way D-Sub connector (M) to allow for easy connection with the connector (F) on the control unit.

SNES Controller with D-Sub (M)

New vs Used

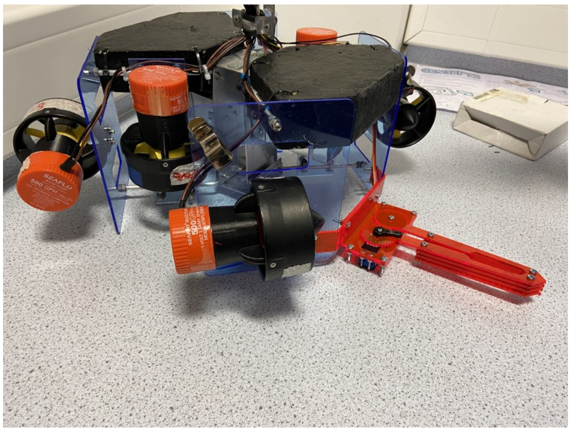
Reused/ Inherited Items

- 6 Bilge Pumps
- 2 Big Fishing Cameras + Monitors
- 1 Small Fishing Camera + Monitor
- Tether + Floats
- 2 Variable DC-DC Converters
- Camera Box
- Tether Bracket

New/ In-House Built Items

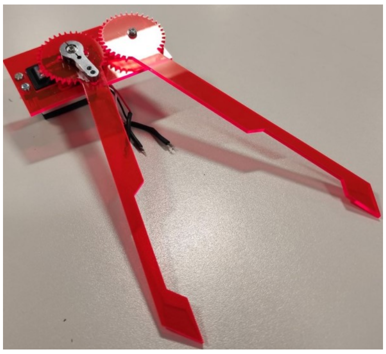
- Hook
- Thruster Guards
- ROV Side Plates
- Bilge Pump Adapter
- Camera Brackets
- Grabber

At the start of the project the team decided on items that they would reuse from previous ROV competitions within the school. The team made decisions based on what made the most financial sense as well as performance in previous competitions, the time taken to make new versions was also taken into account when using inherited items. Items inherited by Discovery Robotics were adapted to fit Captain Scott, alterations were made to the thrusters, tether and camera box to improve the performance of these items. The Discovery Robotics team the understand the importance of reusing components given the current global climate crisis, this has prompted the team to act by repairing and reusing existing components and adapting them for their own use. This idea was imperative to the company when using non-perishable plastic, where the team limited the use to new pieces of plastic as much as possible, taking the companies pledge to be responsible with their use of plastic seriously.



(Overview of Captain Scott)

Testing



(Grabber prototype)

The team conducted testing on new components of the ROV before they were added, the thrusters were tested before they were attached to the ROV making sure each thruster operated correctly. As a result a fault was found in one of the six thrusters where the blade was sticking to the side of the guard, this was fixed by readjusting the position of the adaptor.

The team tested the controller layout various times, the team created a base controller layout that was tested in the pool. The team decided that the layout did not allow optimum operation of the ROV, this led to the layout changing again and another round of pool testing completed, which proved much more successful.

The team tested the in-house designed grabber various times creating multiple prototypes to see pros and cons of different designs. The team then decided on a four-layered arm and textured ends to increase friction and thereby grip.

The team created several prototypes of hooks to find one best suited to the tasks required of the ROV. The first prototype proved unsuccessful as it gave little grip and control, this led to a two pronged approach on the second prototype which had the same issue. The final prototype consisted of three bends in the two aluminium rods which gave more control when handling the ROV.

Troubleshooting

The team had to troubleshoot the control box several times when the grabber was attached, the servo stuttered when connected to the supply from the box. This led to the team having to use a voltmeter over each connection in the box to find the fault, a voltage drop was then found across the ambilocal. The team fixed the fault by adding a new wire to the ambilocal.

During pool tests several thrusters stopped working in the water, the team had to think quickly and find the problem. It was clear there was an issue with the supply after a voltmeter reading over the battery confirmed this. The solved the problem by charging the car battery and resoldering loose wiring connections.

Budget

The team was given an initial budget of £300 kindly donated by Robert Gordon University to be put towards the development of the ROV. Using Microsoft Excel, the team were able to accurately track and log the expenses to make sure not to over spend, with the total expenditure amounting to £190.00.

The team had to make decisions based on the financial implications and ROV operation finding this balance proved to be difficult, but the team managed to stay comfortably within budget. This also made the team design many more of their own components than anticipated which helped as they were designed and manufactured to specifically meet the needs of Captain Scott unlike outsourced products.

Cost Accounting

Bought Items

Date	Product	Cost	Budget Remaining
25/08/2021	ELEGOO MEGA R3 Controller Board	£13.99	£286.01
08/09/2021	2x Aluminium Rod Bars	£6.00	£280.01
10/09/2021	1x Aluminium Rod Bars	£3.00	£277.01
22/09/2021	RS PRO White ABS Instrument Case, 291 x 264 x 111mm	£31.67	£245.34
01/10/2021	Varius Products for Control Box	£42.28	£203.06
30/10/2021	SNES Controllers	£15.99	£187.07
30/10/2021	Various Screws	£14.99	£172.08
06/12/2021	H-Bridge Controller Board	£22.12	£149.96
06/12/2021	2x Solid State MOSFET Boards	£11.98	£137.98
20/01/2022	5V to 9V Power Cable	£5.99	£131.99
20/01/2022	Potentiometer Set	£9.99	£122.00
14/03/2022	Waterproof Plug Socket	£12.00	£110.00
Total Spent		£190.00	

Inherited Items

- 6 Bilge Pumps - 6 x £17 (Approx.)
- 2 Big Fishing Cameras + Monitors - 2 x £230 (Approx.)
- 1 Small Fishing Camera + Monitor - 1 x £180 (Approx.)
- Tether + Floats - £20 (Approx.)
- 2 Variable DC-DC Convert-ers - £8.99 (Current Value)
- Camera Box - £20 (Approx.)
- Tether Bracket - £2 (Approx.)

Total Inherited Cost - 792.99

<u>Total Overall Cost</u> - £982.99

Acknowledgements

The Discovery team linked up with Shanghai Nanhui Senior High School in China. The team held an online conference with the existing ROV team from the school. The teams had a visual walkthrough of both ROV's where they described the control system and overall design of the vehicle. This was very helpful and gave the team ideas on how to make improvements as well as increase our networking resources.
Discovery Robotics would also like to thank MATE, Robert Gordon University, NCR and Grove Academy for the opportunity to take part in the Ranger class ROV competition 2022.

Sponsors

We would also like to thank our sponsors for their continued help and support in helping finance the team's trip to California, we have been supported by the Lang Foundation, NCR, Robert Gordon University, Core Fire Protection and Robert Gordon University this year.