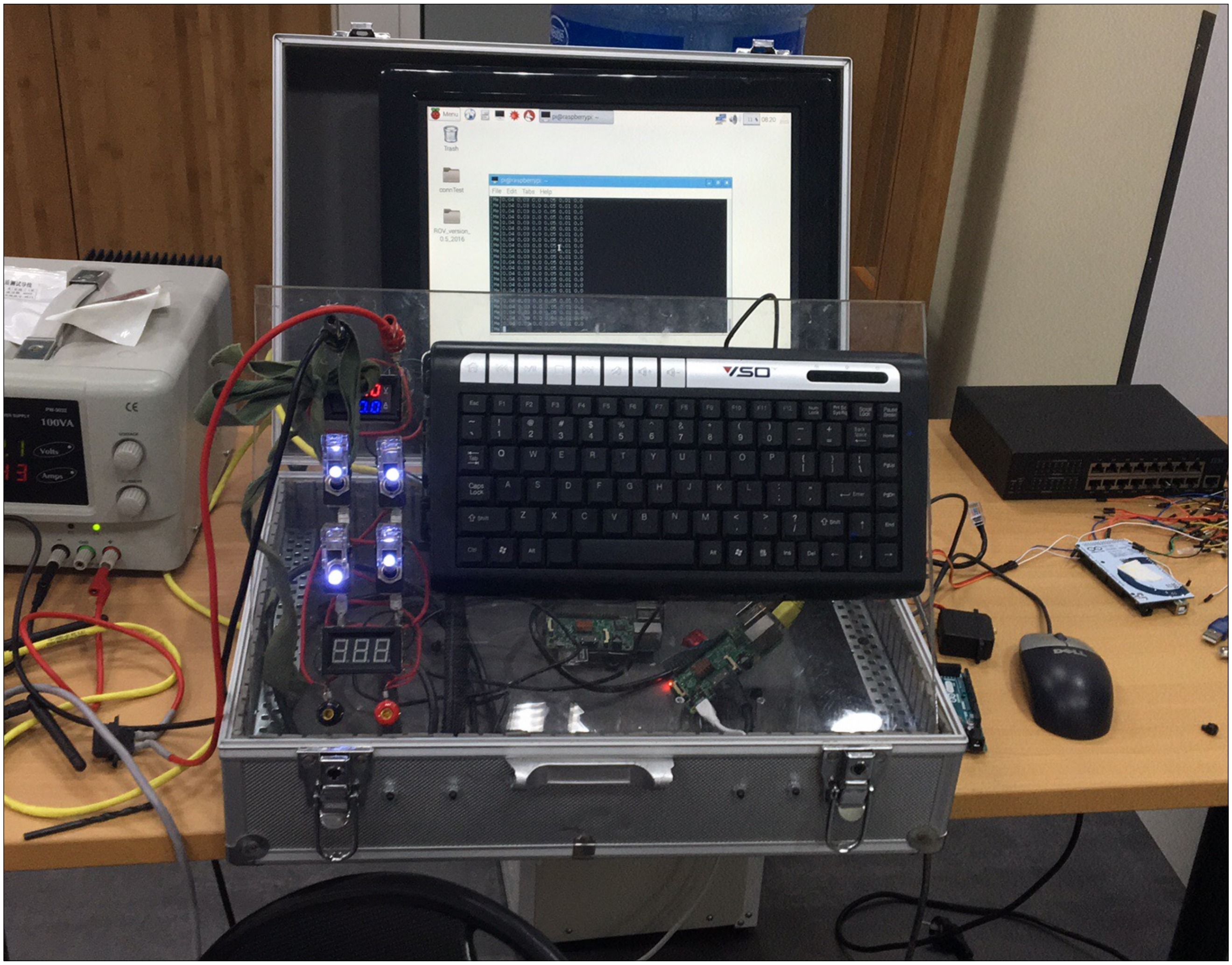

Project Wormhole

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ABSTRACT

Catalyst is a company based in Shanghai, China dedicated to provide underwater robotics technology, products, and solutions with international competitiveness. Since August 2016, its team has been working on the Project Wormhole to develop a Remotely Operated Vehicle (ROV) to be used to ensure and maintain the health, safety, commerce, and entertainment of the Port of Long Beach as well as its waterfront. The service includes

FINANCE

Catalyst is a team

Description	Quantity	Unit Price	Cost
Xbox Controller	1	CN¥ 280	CN¥ 280
Web Camera	4	CN¥ 180	CN¥ 720
Raspberry Pi 3	1	CN¥ 240	CN¥ 240
			CN¥ 0
Total			**CN¥ 1,240**

SAFETY

Catalyst's safety philosophy is to ensure the protection and safety of all members and facilities. At the beginning of the construction, company members received instructions from mentors on how to use tools and other equipment in a manner that ensures their own safety and that of others around them. They were also periodically reminded as time went on in order to really imbue a culture of safety within the workspace.

All members were required to work in pairs when using certain tools or equipment were used like the soldering iron, cutting iron and the drill. The purpose of this is so that team members are not only able to help each other keep the piece they are working on steady, but they can also help each other in case of an emergency. Members are also not allowed to operate power tools without adult supervision in order to minimize the likelihood of an accident. We also require members to wear safety googles when using any hazardous equipment such as a power drill or an angle grinder. In addition to that, whenever testing the ROV, the power source is always asked to be moved away from the pool to minimize likelihood of accident.

Catalyst also requires certain safety precautions to ensure proper setup and prevent emergencies. These include: keeping all foods and drinks away from electronics; ventilating the area when working with epoxy, solder, or silicon-based adhesive; making sure the power is connected correctly; tying long hair back; ensuring that wires and cords are properly put away to prevent tripping; and advising others in the room when certain equipments will be used. The workspace is also cleared of any obstacles to prevent the tool or its wire from being snagged on something and potentially causing an accident.

Wormhole has been designed with safety features as well to ensure that all operators and the surrounding environment are protected. All wires have been waterproofed and electrical cases have been sealed shut to prevent leakage and damages. The chassis itself is also used as a protective measure for the entire robot so that all things within are safe. Thanks to the 90- degree connectors at its vertices, the chassis does not pose any external threat in transit. Any module that juts out of the ROV is removed while in transit as well.

Checklist during construction	Checked
Long hair tied back	
Gloves worn if handling adhesives	
Power sources moved away from the pool	
Area properly ventilated	
Safety goggles on	
Adult supervision present if using power tools	
Area is free of tripping hazards (wires, PVC pipes, etc.)	
Buddy system activated if using power tools	
Parts to be drilled/sawed are properly secured	
Power tool not carried by its cord	
Area properly ventilated	

Checklist before ROV is deployed	Checked
All modules and wires are securely fasted to the ROV	
All wires are contained within the frame	
Tether is properly plugged in	
All motors are working	
All cameras are working	
ROV securely connected to the power source	
Fuse is not broken	
All boxes are closed, sealed, and water proved	

Checklist during operation of the ROV	Checked
ROV handled by the one and only designated person	
At least one person is watching the ROV	
Only the pilot is handling the ROV maneuvering	
Only one person is operating the claw	
Control center is not crowded	

SYSTEM INTERCONNECTION DIAGRAM

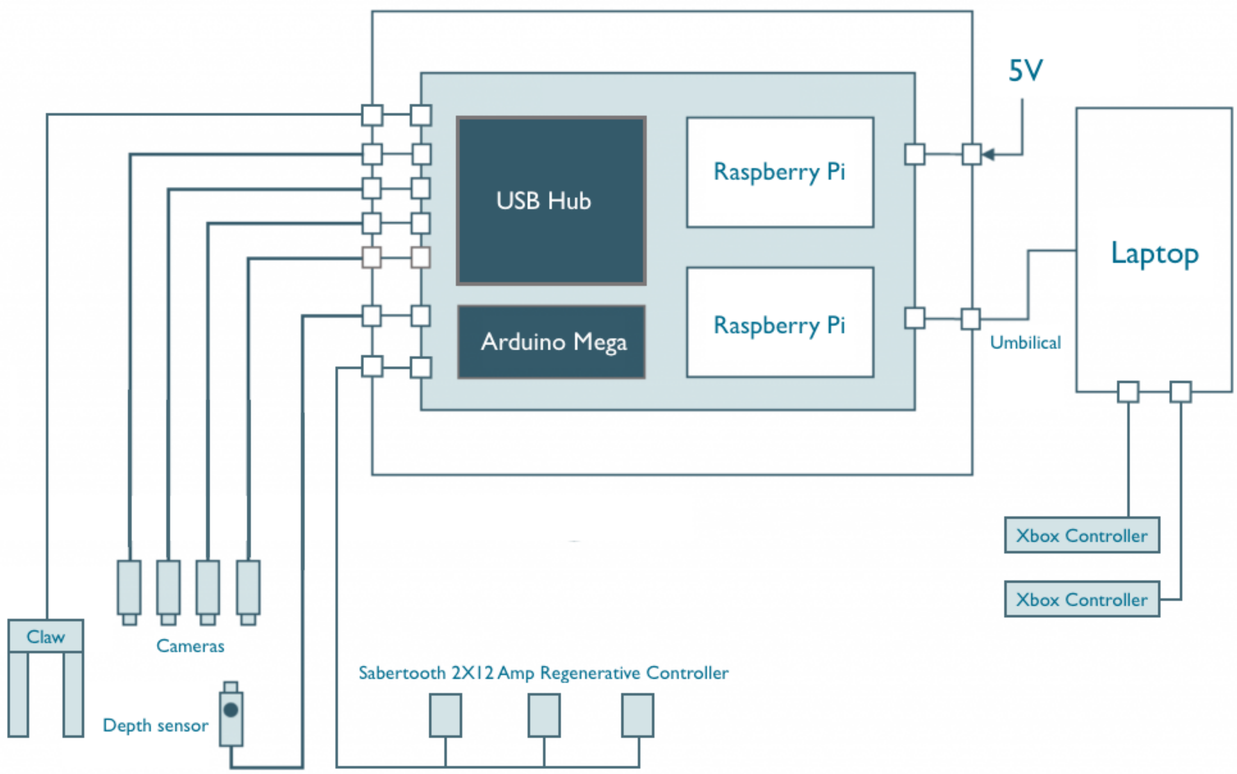

Figure 1. System interconnection diagram

DESIGN RATIONALE

The 2017 MATE ROV Competition is the third competition the Catalyst ROV team will participate in, and this year, we have updated the designs used last year. We learned that our robot needed to be smaller, smarter and more reliable.

Chassis

The chassis was the first feature taking into account when the team started the designing process. We learned from the robot last year that the size of the ROV can be compressed much more. The chassis this year is built around the central tube. Initially, the team followed the cuboid design from last year. However, it minimizes the freedom in arranging the thrusters, so the team switched to a design that connects two laser-cut boards on both sides, between which the central tube, thrusters, and cameras may be attached to the conjunctions that hold together the chassis. In this way, the ROV allows more freedom for the thrusters and camera, therefore giving the pilot a better view around the robot. It still simulates a cuboid because being based in Shanghai means that company Catalyst is required to transport the ROV to and from the competition. Therefore a cuboid makes it easy to transport from Shanghai (where the company Catalyst is based in) to Hong Kong (where the competition takes place).

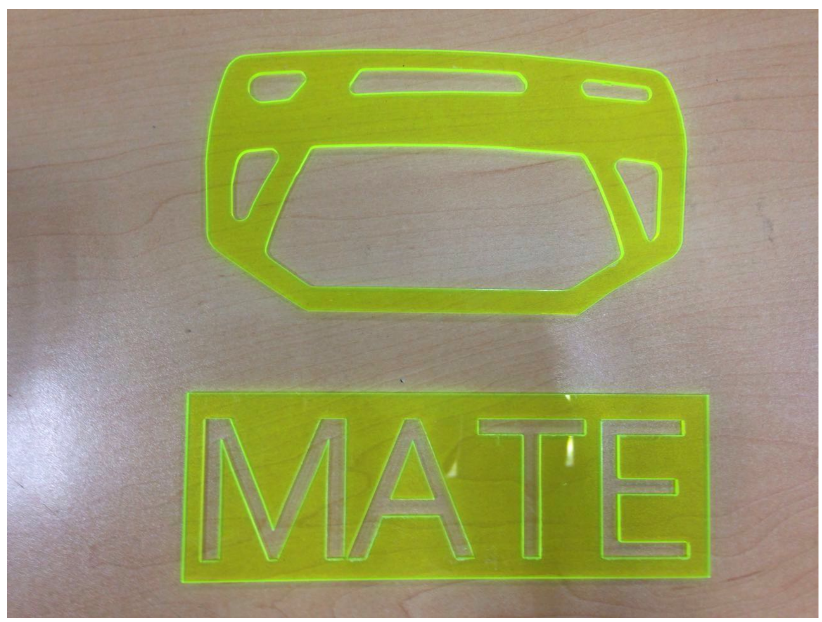

Figure 2. Side board of the chassis.

Manipulator

Although we intended to have a modular claw system, we scrapped that idea in favor of a new manipulator that was effective at a wide range of tasks, instead of targeting one task at a time. We wanted to create a claw that was versatile enough to perform all the tasks necessary for the competition.

Typically, an ROV has a simple claw or tool at the end of the vehicle, but we had issues with controlling the claw solely by the thrusters on the ROV. In order to be more precise, we designed a 4 axis robotic arm that could easily grab and pick up any object, even when the ROV isn't fully stationary. This also allowed us to control for human error while driving the ROV, and while controlling the arm. If either was malfunctioning or imprecise, we could adjust for it with the other. This is superior to a fixed claw due to its flexibility and adjustability. To make it easy to control, we built a similar model that we can control with our hands, and the one underwater will mimic its movements. The design we had is effective, but difficult when it comes to controlling directly via the servos, so this gives the driver a very intuitive way of controlling the arm.

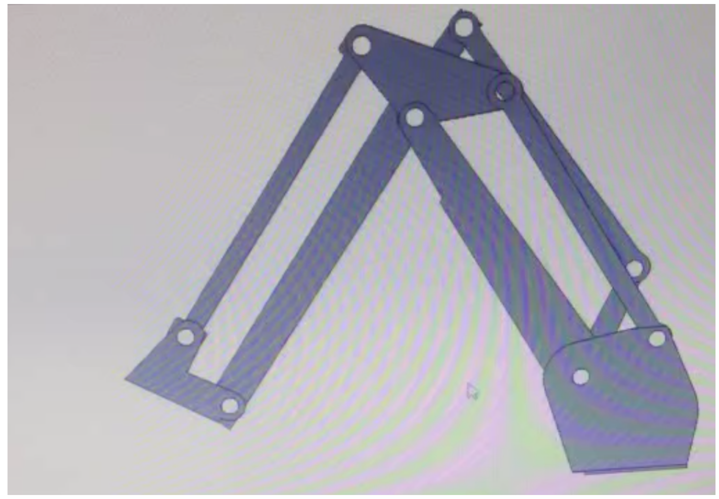

Figure 3. 3D design of the manipulator

The design for the claw itself was used because it is strong and simple. The design can be easily made with a 3D printer, and directly attached onto a servo. Foam pads were also stuck to the inner surface of the claws to give the manipulator more grip when it is handling objects underwater.

Propulsion

We used the four SeaBotix thrusters donated to us, with: two thrusters at the back for forward, backward, and yaw control; one thruster in the center mounted vertically for depth control; and one thruster also in the center mounted laterally to control our side-to-side movement. We mounted the thrusters like this because our ROV will be able to move along all three axes, allowing our ROV to move dynamically underwater. Thanks to such a generous donation, we were able to use such high-performance thrusters while saving around 10,000 RMB (~$1535).

Figure 4. Thrusters

Tools

Because the Wormhole is using a manipulator, there is little need for extra tools such as hooks and plates. However, there were some extra sponsors that we attached to the ROV to complete missions and give more information about the ROV's surroundings. We added depth and temperature sensors, a gyproscope, a magnetometer, and an accelerometer. The gyroscope, magnetometer, and accelerometer are purely used to give the driver more information about the ROV's current state. This is crucial because it helps the driver orient the ROV. The depth and temperature sensors also relay extra information about the ROV, but they also help the ROV accomplish mission tasks such as measuring the temperature of a vent or analyzing the thickness of the ice layer.

Software

The programs operating Catalyst this year will be running on Raspberry Pis, an Arduino Mega, and a gyroscope with an Arduino bootloader. Our software contains a socket server hosted by any one of the Pis and broadcasted on lan through a router. Any client running the software will be able to access communications across the server once connected to router, which includes multiple platforms including OS X, Windows, and Linux, so any computer can be used for control or debugging. The code running Raspberry Pi on the surface will process data from two controllers that are plugged into that Raspberry Pi and send the controller information in a packet to the server. The packet will include multiple data values for buttons, joysticks, and a hat switch that will be separated by delimiters. On the server Raspberry Pi, the data received from the client with the controller information will then be forwarded through a serial port to the Arduino Mega. The reason that we decided to run the server in Python is because Python has a well established library that makes using game controllers easy and setting up the server is not difficult as well. The program on the Arduino Mega is quite extensive and will serve multiple purposes. To parse the data sent by the Raspberry Pi server with the game controller information, the Arduino Mega will separate the information using the delimiters and write all of the data to the respective motors and servos. To deal with the sensors that are plugged into the Arduino Mega, the code running on the Mega will receive the data and put it into a string with delimiters. We separated the data with delimiters because it makes parsing the data into its respective parts much easier so the information is easily known. This string will then be sent to the Raspberry Pi that is on the ROV. This same file also receives data serially from a gyroscope with an Arduino bootloader. An HTTP server will host our camera streaming as well as sensor data. We will also attempt to use stereovision for depth perception vision to make driving and control simpler.

Cameras

This year, Catalyst purchased four new web cameras because the old ones could not be recycled. Originally, the team was thinking about using a tube-shape camera that is similar to an endoscope. It was water-prove, small, and affordable. However, when the team tested it on the Raspberry Pi, it turned out to be laggy and used up over 90% of the RAM. Therefore, the team reverted to the original plan to water prove cheap web camera that sends back digital files to the Raspberry Pi to the server for display on the monitor screen through streaming. This camera will be mounted on the top front of the ROV to give the driver a view of what is in front of the ROV and what the driver needs to look out for. The second camera will be right up against the manipulator so the employee controlling the manipulator will have a sense of how the claw is going to pick the object up and relay that information to the driver. The third camera will be mounted on the top of the ROV facing down, so that the driver can see what he or she needs to look out for and be careful not to result in any undesired collision. Finally, the fourth camera will have a wide-angle lens and will be attached to the tether that is trailing the ROV to give the team a 3rd person view of the ROV. This will allow the team to better control the ROV as it makes clear what is around the ROV. Therefore the pilot can make adjustments accordingly. All cameras are mounted either with zip ties to allow a removable yet stable mount.

Water-tight Electronics Boxes

These boxes were used to house the onboard electronics such as the two Raspberry Pi's that receive images from the camera and communicate with the Arduino Mega to drive the motors as well as the manipulator. This box allows the team to easily run wires in and out of the boxes to connect the electronics to the modules and be able to modify the contents of the boxes if need be. All the boxes are sealed with epoxy and silicon-based adhesive to make sure the box is completely safe from water. Last year, in order to secure the position of the cameras within the boxes, the team used the silicon-based adhesive inside of the boxes as well for camera boxes. However, it turned out that silicon, due to its network covalent bonding and other structures of the material, actually created small gaps that would absorb water and consequently deliver water to flood the camera eventually. Therefore, this year, the team decided to use epoxy entirely to prevent water invasion.

Tether

The tether connected with the ROV consists of a ten meter gigabit ethernet cable. The team made sure that the tether is long so that the control team can operate the ROV from a further distance, and so that the pilot can maneuver it around obstacles without being tangled. The Catalyst team have also added a connector to the robot to allow for easier transportation. The team did not have a waterproof ethernet connector, but the Catalyst were able to solder the individual wires to pins of a waterproof 8 pin microphone connector, so the tether can be disconnected when needed.

CHALLENGES

The main technical challenge that the team faced was trying to ensure that the camera stays out of water and that the size of the robot stays as small as possible. Last year, the team used PVC tube as frame. However, it contains much empty unused space within the frame and the drilled tubes were hardly reusable. Therefore, this year, the team decided to use acrylic boards as the chassis, which is easily drilled and reusable.

Besides technical challenges, the team was also looking for a pool that can be used to test the ROV. Last year, there wasn't such chance and therefore the water-prove problem for camera was not caught. However, this year, the team managed to find a water tank large enough to accommodate the ROV and therefore, most of the water related testing could be done.

FUTURE IMPROVEMENTS

While the ROV seems to operate well this year, there is always room for improvement. First of all, we did not have to make the ROV frame so large, as we have a lot of empty space still inside of the robot. This would allow us to make a more compact ROV capable of being transported easily. It can also help us cut down on costs as we are saving PVC. Secondly, while we are using pool noodles this year for buoyancy, they are not the most ideal, especially in deeper waters. This is because the pressure from the water will affect how much air is trapped inside of the pool noodles. In the future, we wish make a ballast to dynamically modify our buoyancy. This will allow us to create a precise neutrally buoyant robot so that we can more accurately move our robot along all three axes. Third, we wish to create a symmetric manipulator.

ACKNOWLEDGEMENTS

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