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BYOE: SeaKatz 2.0 – Vision and Pneumatic Claw for Underwater Robot with VR Simulation

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Introduction

Over the years, humans have conquered more outer spaces than our oceans, overcoming many challenges [1]. Underwater robots have been present for decades and used for multiple purposes. A few applications include researching deep sea marine life, disaster prevention, search and rescue underwater [2, 3], etc. An efficient underwater vehicle can perform the tasks that humans can't do due to the pressure of the ocean. This BYOE paper chronicles a decisive journey in the realm of robotics - an Underwater Remotely Operated Vehicle (ROV) equipped with an onboard camera and an innovative pneumatic claw system. As we delve into these experiences, we share the skills honed, the profound discoveries made, and the challenges overcome. This work is a continuation of a previously published work in the 2020 ASEE Annual Symposium [4], but with vision, pneumatic claw, and added V.R. simulation for the users. Our implemented prototype can withstand water pressure of about 5 feet deep, detect a visual aspect of the bed of the water using a camera, and grasp it using a pneumatic claw. Some skills honed through this prototyping include but are not limited to – mechanical engineering, electronics and control, software development, engineering design, hydraulics and pneumatics, and problem solving. The V.R. application was created to provide a safe and immersive learning environment for users to practice controlling the robot and completing underwater tasks. The V.R. application targets students, researchers, and professionals who need to learn how to use underwater robots. The application can be used in a variety of settings, including classrooms, training laboratories, and research facilities. Some features included are interactive controls, guided tutorials, and progress tracking. The software and tools needed for this V.R. part are Unity game engine, environmental and character assets, AI voice generators, Oculus Quest 1 Headset, Blender, and Polycam 3D Scanner.

Knowledge Context and Skills Honed

a. Mechanical Engineering:
   - Designing the ROV's structure and hull to withstand the crushing pressures of the deep.
   - Meticulously selecting materials for buoyancy, durability, and weight distribution.
   - Ingeniously integrating propulsion mechanisms and control surfaces for agile maneuverability.

b. Electronics and Control Systems:
   - Crafting an electronic control system to manage motor functions and help seamless communication.
   - Mastering the intricacies of the ROV's circuitry for precise, real-time control.
   - Implementing a comprehensive suite of safety features and fail-safes tailored for the challenging underwater environment.

c. Software Development:
   - Provisioning an intuitive user interface for remote operation, simplifying complex tasks.
   - Seamlessly integrating camera and sensor data into the control software, enhancing situational awareness.

d. Hydraulics and Pneumatics:

- Designing and fabricating a 3-D printed pneumatic claw system, bringing precision object manipulation to life.
- Mastering the delicate balance of ROV buoyancy and stability through precise control of air and water levels.
- Navigating the principles of pressure regulation and control within the demanding underwater environment.

e. Problem Solving:
- Navigating complex technical challenges as they appeared during development, applying creative problem-solving strategies.
- Adapting to unforeseen obstacles and setbacks with resilience and agility.

<u>Materials Used</u>

The materials used for the robot prototype involved:

- Small 12V Air Compressor
- Air Tubing (10 meters)
- Polyethylene Foam (16x12)
- Small 12V Battery
- Wire Connectors
- 100-Piece Terminal Kit
- 1/4-inch Coupler Plug
- Pneumatic Cylinder
- Male Fittings (10 Pack)
- 1/2-inch PVC Pipe
- GoFish Wireless Underwater Camera
- Expandable Wire Mesh Sleeve
- Lead Acid 12V 5Ah Battery
- Commercial Electric - Assorted Cable Ties (650-Pack)
- Air Fittings (22 pieces)
- Pneumatic Hand Valve
- Assorted Cable Ties
- Commercial Electric - 3/4 in. x 30 ft. Commercial Carded Electrical Tape, Black
- Everbilt - 1/4 in. I.D. x 3/8 in. O.D. x 20 ft. Clear Vinyl Tubing
- Husky - 1/4 in. I/M Coupler Plug with Increased Air Flow (6-Piece)

Table 1 shows the Bill of Materials (BoM). With the above-mentioned materials, the team developed a fully functional underwater ROV with following features:
- An onboard camera system primed for capturing high-definition video and stunning imagery.
- A pneumatic claw system which skillfully manipulates objects resting on the ocean floor.
- Unparalleled precision in maneuverability and control across diverse underwater conditions.
- The ability to collect visual and physical data and precisely execute intricate underwater tasks.

Table 1: Bill of Materials for Underwater ROV

Item Description	Item #	Price per Item	Quantity	Total Amount
Small Air Compressor 12volt	ASIN: B00WUU03QO	$104.39	1	$104.39
Pnuematic Cylinder	ASIN: B0881HGYLT	$16.99	1	$16.99
Air Fittings (22 pieces)	ASIN: B08L4MRWWW	$21.99	1	$21.99
Air Tubing (10 meters)	ASIN: B08B8F5P23	$20.99	1	$20.99
Male Fittings (10 Pack)	ASIN: B07VBPMC2Q	$14.99	1	$14.99
Pnuematic Hand Valve	ASIN: B07Z67G4DR	$18.99	1	$18.99
GoFish Wireless Underwater Camera	ASIN: B0792FYDXF	$199.99	1	$199.99
Small 12V Battery	ASIN: B079ZCJYP3	$15.99	1	$15.99
Wire Connectors	ASIN: B07V35375X	$16.91	1	$16.91
Expandable Wire Mesh Sleeve	ASIN: B00BM97WP4	$39.98	1	$39.98
1/2 inch PVC Pipe (3 pack)	ASIN: B085B4W15B	$21.99	1	$21.99
PVC Couplings (42 pieces)	ASIN: B097B4XGJQ	$25.99	1	$25.99
Zip Tie Assortment	ASIN: B0777LWBD9	$13.99	1	$13.99
Polyethylene Foam (16x12)	ASIN: B07N6JPYK4	$18.99	1	$18.99
		FINAL TOTAL		$552.17

<u>Project Demonstration</u>

Demonstration of SeaKatz in action can be found using the following links:

1. https://youtube.com/shorts/yQRJE2krgq8
2. https://youtube.com/shorts/igAgCbwWzug
3. https://youtube.com/shorts/19D2WWNIhuE
4. https://youtube.com/shorts/V9Hfm9GV-V8

V.R. Simulation Environment

The V.R. application was created to provide a safe and immersive learning environment for students, researchers, and professionals to practice controlling the robot and completing underwater tasks. The application can be used in various settings, including classrooms, training laboratories, and research facilities. If accepted, the authors plan to show the V.R. Demonstration onsite. Figure 1 below shows a screenshot from the V.R. environment.

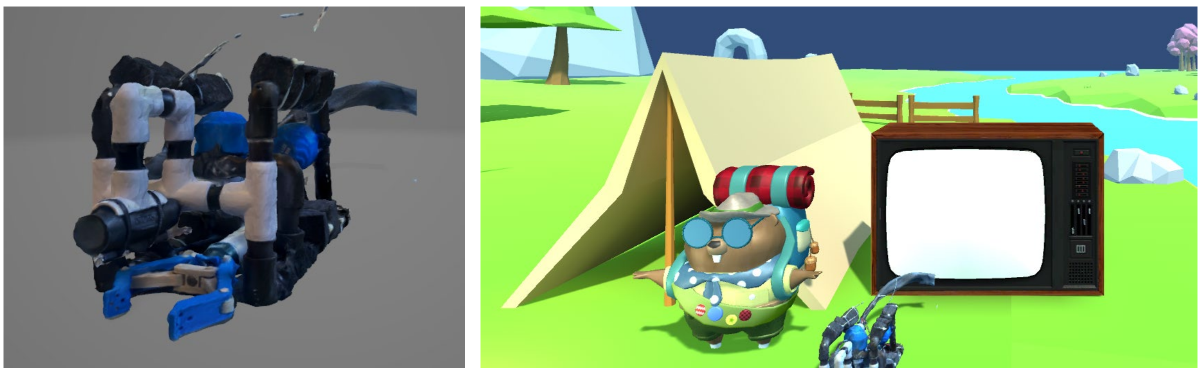

Figure 1: Screenshots from the implemented V.R. environment

a. Features

Interactive Controls: The application provides a user-friendly interface that allows users to manipulate and control the underwater robot using motion controllers, closely emulating the actions required in a real-world setting.

Guided Tutorials: The application offers a series of step-by-step tutorials and missions to help users learn and master the various functions of the underwater robot.

Progress Tracking: Users can monitor their progress and track their performance in each mission, promoting a sense of achievement and motivation.

b. Software and Tools: Unity game engine, Environmental and Character Assets
c. AI Voice Generators: Oculus Quest 1 Headset, Blender, Polycam 3D Scanner
d.Development Process: Modeling and texturing the underwater environment and robot, Programming the robot's controls and physics, Creating the training missions, Testing and debugging the application, Developing the user interface
e. Creating the 3D Model of the Robot: The first step in the development process was to create a 3D model of an underwater robot. We initially used Blender, a popular 3D modeling application, but it was found that the results were not realistic enough. After some research, we found Polycam 3D Scanner, an application that can turn pictures into 3D models. We used Polycam to create a basic model of the robot and then used Blender to fix some holes and add additional details.
f. Creating the Environment and Characters: The project incorporated free online resources in the public domain for environmental elements and character models. We felt it would

be natural for a character to teach the user how to operate the robot. After finding a suitable character and matching environment, we used a free AI voice generator to create a voice that matched the character.

g. Writing the Tutorials: We first wrote out how the tutorials should go, and as we kept adding more elements to the application. For example, in some parts of the tutorial, it became evident that the user would need a closer look to understand. So, we incorporated a small TV that would play animations of what the users needed to do or what the user needed to press.

h. Organizing the Code: To keep our code organized and manageable, we created “classes” to manage the voice elements and keep track of the order of events. For example, we created a class called “VoiceManager” that handles all voice playback and recording. We also created a class called “EventManager” that keeps track of the order in which events should occur in the tutorials.

Conclusion

The V.R. application for underwater robot training is a valuable tool that can be used to teach users how to control the robot and complete underwater tasks in a safe and immersive learning environment. The application is easy to use and effective, and it has been well-received by users. The implemented prototype worked fine with minor hiccups, like the sensor camera and app not communicating at times. In future, we plan to have the automated path planning versus the manual control of the ROV to collect debris from the water surface.

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References

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[4] Iftekhar Ibne Basith, and Emanuel Sanchez, “SeaKatz – an Underwater Robot”, in the ASEE Annual Conference and Exposition at Montreal, QC, Canada, June 22-26, 2020.

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