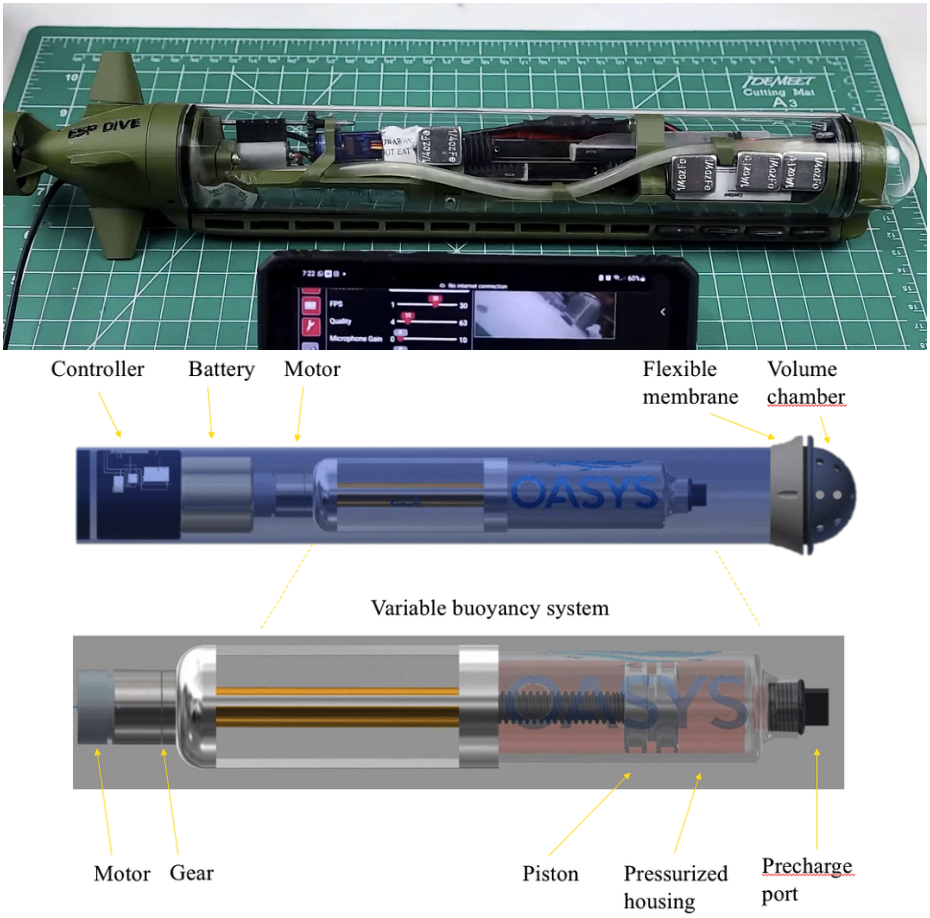
Design and Closed-Loop Control of an Active Variable Buoyancy System (VBS) for Next-Gen Amphibious Robots

Description

Most small underwater robots rely on constantly spinning propellers to push themselves down, which is noisy, energy-inefficient, and creates turbulence. We are taking a smarter approach. This project focuses on designing an Active Buoyancy Control Module. This module changes the robot's density on the fly—either by pumping water in/out (like a submarine's ballast tank) or mechanically changing the robot's volume (like a piston). The goal is to achieve Perfect Neutral Buoyancy, allowing the robot to hover silently at a target depth, perform delicate tasks, or conserve battery during long missions.



Background

The Challenge of the Deep Amphibious robots face a unique dilemma: they need to be light enough to walk on land but dense enough to submerge in water. Traditional robots usually sink like a stone or float like a cork, lacking the ability to stay at a specific depth (Z-axis).

The Solution: Static vs. Dynamic Control While drones use "dynamic lift" (propellers) to fly, efficient underwater vehicles use "static lift" (buoyancy).

Nature's Way: Fish use a swim bladder to regulate their volume.

Engineering Way: Gliders and submarines use Variable Buoyancy Systems (VBS). The Research Gap: Miniaturizing these systems for compact amphibious robots is difficult. We need a mechanism that is fast-acting, compact, and coupled with a smart feedback loop (using depth and velocity sensors) to compensate for disturbances in real-time.

Technische Universität München

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Lehrstuhl für Robotik, Künstliche Intelligenz und Echtzeitsysteme

Supervisor:
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Advisor:
Qian Huang M.Sc.

Type:
MA,SA,BA

Research area:
Computer Vision, Hardware Acceleration, Embedded System Design, SLAM

Programming language:
Verilog , C++ or Python

Requirements:
High self-motivation and passion for robots; At least six-month working time; (Optional) With experience on embedded system design.

Language:
English

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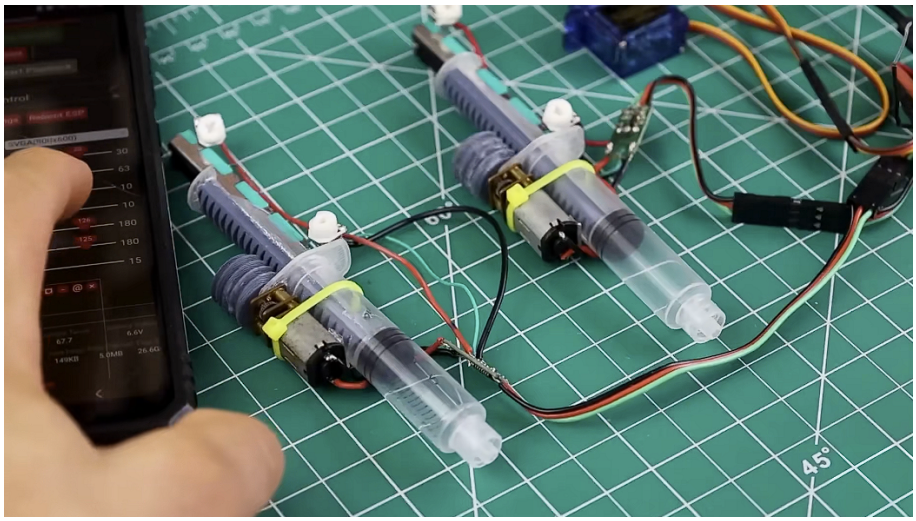

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Tasks

As a key member of this project, you will:

This is a complete Mechatronics project. You will touch every part of the robot's "nervous system":
Mechanism Design (The Body):
·Research different VBS methods (Piston-based vs. Pump-based vs. Syringe-based).
·Design a compact, waterproof buoyancy adjustment mechanism using CAD.
·Solve the engineering challenge of high-pressure sealing.
Sensing & Feedback (The Senses):
·Integrate high-precision Pressure Sensors (for depth) and Flow Sensors (for vertical velocity).
·Implement data filtering to remove sensor noise in the underwater environment.
Closed-Loop Control (The Brain):
·Develop a control algorithm (e.g., PID or LQR) on a microcontroller (STM32/Arduino).

The goal: Input a target depth (e.g., "Hover at 1.5 meters"), and the mechanism automatically adjusts to hold that position.

What You Will Gain

System Engineering: You will build a complete system, not just a component.
Control Theory in Practice: See your PID code turn into physical movement—watching your robot magically "freeze" mid-water is an incredible feeling.
Waterproofing & Sealing: Learn the rare and highly valued skill of designing electronics for underwater environments (IP68 standards).
Interdisciplinary Skills: Merge Mechanical Design (SolidWorks) with Embedded Control (C/C++).

Mentorship & Support

Does "Closed-Loop Control" or "Waterproof Sealing" sound intimidating? It shouldn't be.
We don't expect you to be an expert diver or a control theorist.
We value curiosity and engineering intuition.
Your mentor has extensive experience in mechatronic systems and will provide:
Guidance on selecting the right waterproofing components (O-rings, seals).
Tutorials on control logic and sensor integration.
Full support during the debugging phase (when things inevitably don't work the first time!).
All you need is the passion to build a robot that can conquer the water.

For further discussion on specific tasks, welcome to direct contact me via email.