Ben-Gurion University of the Negev

Faculty of Engineering Science

School of Electrical and Computer Engineering

Dept. of Electrical Engineering

Finals Year Engineering Project

PDR

"Design and Implementation of a Hovering Autonomous Underwater Vehicle (HAUV)"

Project ID	p-2024-038
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Sponsors	-
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"Design and Implementation of a Hovering Autonomous Underwater Vehicle (HAUV)"

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Abstract:

In underwater operations, a prevalent challenge is the need to scan and analyze objects submerged in aquatic environments. Often, the deployment of human divers for such tasks is fraught with difficulties. Divers face substantial constraints including limited dive time due to oxygen supply, depth limitations for safety reasons, and the extensive planning required for each mission. Additionally, the complexity of navigating and identifying specific objects in vast, often murky underwater environments compounds these challenges. To address these issues effectively, my project proposes an innovative engineering solution: the development of a compact Hovering Autonomous Underwater Vehicle (HAUV).

The HAUV is designed with the practical needs of underwater exploration and object retrieval in mind. It is compact and agile, enabling efficient navigation in diverse underwater terrains. Equipped to perform scan routines autonomously, the HAUV serves as an advanced tool for pre-diving operations, locating and marking objects of interest. This significantly streamlines the process for divers, enhancing their operational efficiency and safety. Moreover, with an eye on future expansion, the HAUV is engineered to be adaptable for additional functionalities, such as the integration of remote-operated arms. These arms could undertake various tasks, including clearing obstacles and placing visual aids like balloons or flashlights, to assist divers.

This project, thus, represents not only an academic endeavor but a practical contribution to the field of ROV technology, aimed at overcoming the specific challenges of underwater object identification and retrieval.

Key words: HAUV, Autonomous Underwater Vehicle, Underwater Exploration, Robotics, Underwater Surveillance, Autonomy, Real-time communication.

תקציר

בפעולות תת-מימיות, אתגר נפוץ הוא הצורך לסרוק ולנתח עצמים הנמצאים בסביבה תת-ימית.

לעתים קרובות, פריסת צוללנים אנושיים למשימות אלו כרוכה בקשיים רבים.

צוללנים מתמודדים עם מגבלות משמעותיות, לרבות זמן צלילה מוגבל עקב אספקת חמצן, מגבלות עומק מסיבות בטיחות, והתכנון הנרחב הנדרש לכל משימה. בנוסף, מורכבות הניווט וזיהוי חפצים ספציפיים בסביבות תת-מימיות עצומות ומעורפלות לעתים קרובות מחריפות את האתגרים הללו. כדי להתמודד עם בעיות אלו ביעילות, הפרויקט שלי מציע פתרון הנדסי מתקדם:

פיתוח של רכב תת-מימי אוטונומי מרחף (HAUV).

ה-HAUV מתוכנן תוך התחשבות בצרכים המעשיים של חקר תת-מימי ואיתור חפצים. הוא קומפקטי וזריז, ומאפשר ניווט יעיל בשטחים תת-מימיים מגוונים. מצויד לבצע שגרות סריקה באופן אוטונומי, ה-HAUV משמש ככלי מתקדם לביצוע פעולות לפני צלילה, לאיתור וסימון של חפצים בעלי עניין. זה מייעל באופן משמעותי את התהליך עבור צוללנים, ומשפר את היעילות והבטיחות התפעולית שלהם. יתרה מכך, עם ראיה לעתיד, ה-HAUV מתוכנן להיות ניתן להתאמה לפונקציונליות נוספת, כגון שילוב זרועות תפעול מרחוק. זרועות אלה יכולות לבצע משימות שונות, כולל ניקוי מכשולים והצבת עזרים חזותיים כמו בלונים או פנסים, כדי לסייע לצוללים.

פרויקט זה, אם כן, מייצג לא רק מאמץ אקדמי אלא תרומה מעשית לתחום טכנולוגיית ה-ROV, שמטרתה להתגבר על האתגרים הספציפיים של זיהוי וניתוח חפצים תת-מימיים בסביבה מורכבת.

Project goals:

The overarching objective of this project is the development and implementation of a compact Hovering Autonomous Underwater Vehicle (HAUV) designed for enhanced underwater exploration and object retrieval. The HAUV aims to streamline pre-diving operations and provide support for divers through advanced autonomous navigation and object marking capabilities. Key goals include:

1. Integration of Autonomous Navigation Systems:
Implementing an advanced guidance system enabling the HAUV to autonomously navigate through diverse underwater terrains. This includes the use of sensors for precise movement and location tracking.

2. Sensor Communication and Data Transmission:
Establishing robust communication links with all onboard sensors (such as DVL, cameras and IMU) to ensure the reliable transmission of high-quality data to a remote operator. This real-time data flow is crucial for identifying and marking underwater objects in real time.

3. Development of Object Marking Mechanisms:
Designing and integrating mechanisms to mark located objects effectively, such as deploying balloons or flashlights, to aid divers in their operations.

4. Collaboration with Mechanical Engineering Team: Working closely with a mechanical engineering team to optimize the placement and integration of propulsion systems (motors) and sensors, ensuring efficient and stable operation of the HAUV.

5. Software Development and Integration:
Crafting software (in Python and C) to integrate all system components, ensuring seamless communication and functionality. The software will be based on ROS2 for effective module communication and integration.

Measure of success:

The project will be deemed successful under the following conditions:

1. Effective Autonomous Navigation and Data Transmission:

The HAUV should be able to autonomously navigate to predetermined locations and transmit clear data from its sensors, including images, to a remote operator.

2. Accurate Object Identification and Marking:

The HAUV should successfully identify and mark underwater objects, enhancing the efficiency and safety of diving operations.

3. Operational Range and Data Bandwidth:

At a depth range of up to 300 meters, the HAUV should transmit high-bandwidth data, and at extended ranges of approximately 2 kilometers from a ground station, it should maintain low-bandwidth data transmission capabilities.

Specifications:

"Design and Implementation of a Hovering Autonomous Underwater Vehicle (HAUV)"

Platform Description: The HAUV is a compact, remotely operated underwater vehicle designed for enhanced underwater exploration and object marking. It is equipped with advanced navigation systems and a suite of sensors to perform its functions effectively.

Navigation and Control: Movement of the HAUV will be controlled by sophisticated guidance algorithms, which utilize a combination of remote-control inputs and autonomous navigation capabilities. This system will use target waypoints and real-time positioning data, integrating inputs from onboard sensors such as GPS, IMU (Inertial Measurement Unit), and Doppler sensors for precise movement.

Main Control Unit: The central processing unit, likely an UP-board computer or a specialized real-time board, will handle the integration and communication between various components of the HAUV. This unit will operate on the ROS2 system to manage sensor data processing, motor control, and other essential functions.

Camera System: Two high-quality cameras will be mounted on the HAUV to provide comprehensive underwater video footage from different angles, enhancing the operator's visual assessment capabilities.

Sensors: The HAUV will be equipped with a range of sensors, including depth sensors, pressure sensors, and environmental sensors, to monitor various aspects of the underwater environment. These sensors will provide critical data for navigation, object identification, and operational safety.

Propulsion and Maneuvering: The vehicle will be propelled and maneuvered using jet motors and an array of servos, ensuring agile and stable movement in underwater environments.

Data Transmission System: A static station located above water will receive wired data from the HAUV. This station will then relay the data to the remote operator via RF communication, ensuring real-time data transmission and operational control.

Additional Features: The HAUV is designed with future expandability in mind, allowing for the potential integration of additional functionalities such as object marking mechanisms and remote-operated arms.

Physical specifications:

1. General Description:

Type: Small to Medium-sized ROV

Purpose: Underwater exploration, surveying, monitoring, and light manipulation tasks

2. Physical Specifications:

Size: Approximately 500mm x 400mm x 300mm (LxWxH)

Weight: 10-15 kg in air

Buoyancy: 500g to 1 kg net positive

Endurance: Up to 3.5 hours with standard payload

Temperature Range: 0-30°C

Structure: High-strength, corrosion-resistant materials suitable for marine environments

Payload Capacity: 1.5 kg

3. Propulsion and Mobility:

Motors: 4-6 high-efficiency brushless thrusters for propulsion and maneuverability

Motors Max Input Power: 350W per motor.

Motors Max Propulsive Power: 200W per motor.

Motors Total Weight: 5kg for both motors.

Speed: Up to 4 knots (2~3 m/s)

Maneuverability: 6 degrees of freedom (surge, sway, heave, roll, pitch, yaw)

4. Power System:

Battery: Two rechargeable Lithium-ion or Lithium-polymer battery

Capacity: [XX] Wh, providing up to [X] hours of operation

Voltage: 30V nominal.

Power Consumption: Average [XX] W, with peak at [XX] W

5. Operational Depth:

Maximum Depth Rating: [XX] meters

Pressure Hull: Designed to withstand pressures at maximum depth.

6. Onboard Computer:

Model: UP Board series (or equivalent).

Processor: Intel® ATOM™ x7-E3950 64-bit Quad-Core up to 2.0GHz.

Memory: 8GB DDR3L RAM.

Storage: 128GB eMMC.

Connectivity: 4x USB3.0, UART, I2C.

7. Cameras:

Cameras: High-definition, low-light camera with adjustable tilt and optional zoom

Front Camera: For navigation and obstacle detection.

Front camera tilt range: +/- 90-degree camera tilt (180 total range)

Front camera tilt servo: [XX]

Rear Camera: For recording underwater operations and providing a rear view.

Resolution: 2MP.

Frame Rate: 15FPS at Full HD.

Lights: High-intensity LED lights with adjustable brightness

Environmental Sensors: Temperature, depth, and possibly salinity sensors

6. Sensors and Instruments:

Depth Sensor: Accurate up to 200m.

Pressure Sensor: For hull integrity monitoring.

IMU: For orientation and motion tracking.

Doppler Velocity Log (DVL): For precise underwater velocity measurement.

7. Navigation and Control:

Navigation System: Inertial Measurement Unit (IMU) with compass, depth sensor, and optional Doppler Velocity Log (DVL)

Control System: User-friendly interface for navigation, data collection, and vehicle diagnostics - Qground control software

Software: for user interface, ROS2 with python for inter-communication between modules.

8. Communication:

Primary Communication - Tether: Wired link to surface station, providing data transfer, and live video feed

Surface Station: RF communication with remote operator.

RF Module: XX - Up to [XX]kbps @ [XX] MHz for long-range, low-bandwidth communication.

9. Payload and Attachments:

Payload Capacity: Up to [X] kg for additional instruments or tools

Tooling: Interchangeable manipulator arms, sampling devices, and measurement tools

10. Additional Features:

Modularity: Easily replaceable parts and scalable design for various missions

Customization: Options for additional sensors, tools, and software based on user requirements
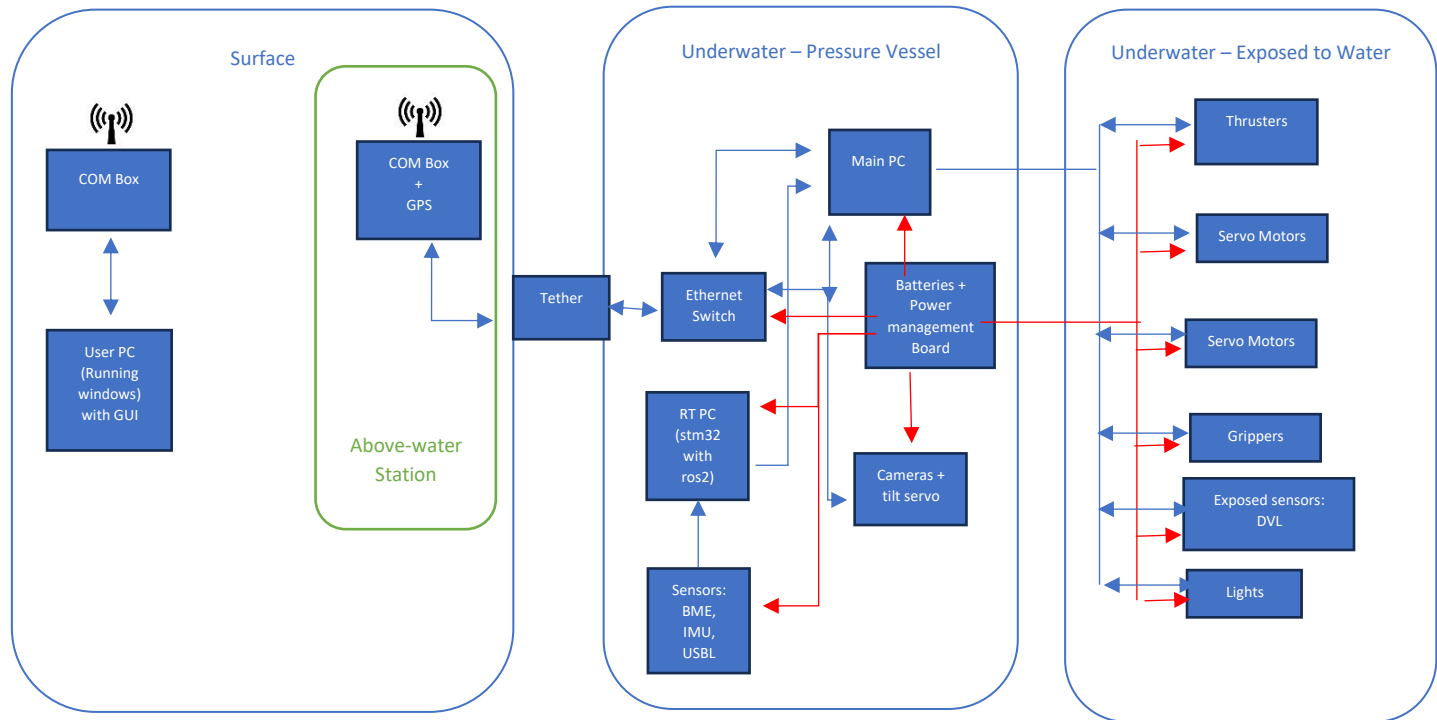
11. Safety and Maintenance:

Fail-safes: Auto-return, leak detection, and emergency shut-off systems.

Maintenance: Designed for easy field maintenance and part replacement

<u>Expandability:</u>

Designed for future integration of remote-operated arms and additional sensor modules.

Design proposal:

Equipment Proposal:

	Option 1	Details	Option 2	Details	Option 3	Details
MCU	STM32F769NI	link	32F746GDISCOVERY	link	STM32H757I-EVAL	link
Motors	T200 – Blue Robotics	link	SeaBotix Thruster BTD150	link	SUBLUE Navbow Underwater Scooter Motor	link
Cameras	Camera Tilt System – Blue Robotics (no ethernet)	link	Underwater IP cameras - Subcom services	link		
IMU						
USBL	Deeptrecker	link	Invocean	link		
Pressure Sensor	Bar100 – Blue robotics	link	Bar30 – Blue robotics	link	Rovmaker	link
Temp/humid Sensor	Blue robotics	link	BlueRov	link		
A2D Module						
Lights			Underwater lights – Subcom services	link		

literature review

Project constraints:

Project assumptions:

Project testing proposal:

Schedule and work plan:

Budget evaluation:

Human resources and salaries

Equipment

Total budget:

Reference:

המלצת ציון (ע"י מנחה אקדמי) לדו"ח מכין

<u>אם יש צורך, לכל סטודנט/ית בנפרד</u>

מספר הפרוייקט: ‏_____-_____‏P-20

שם הפרוייקט:

שם המנחה החיצוני:

שם המנחה מהמחלקה:

שם הסטודנט/ית: ת.ז.:

%		חלש 55-64	בינוני 65-74	טוב 75-84	ט"מ 85-94	מצוין 95-100	
15	הבנת הנושא הצורך וסביבת היישום						
15	חיפוש מקורות והבנת עבודות דומות						
15	שלמות דף מפרט (הצעת מחקר)						
15	הצעת תכנון ותכנון הבדיקות הסופיות						
10	גילוי יוזמה וחריצות						
20	פתרון בעיות, מקוריות ותרומה אישית (מעבר למילוי ההנחיות)						
10	הערכת תקציב, לו"ז וחלוקת עבודה, ציון מקורות ושלמות כללית						

הערכת רמת הקושי של הפרוייקט: קל מאוד / קל / בינוני / קשה / קשה מאוד

הערות: