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SEARCH AND RESCUE AUTONOMOUS VESSEL

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Abstract:Search and rescue operations in maritime environments are critical for saving lives and ensuring the safety of individuals in distress. The advancement of autonomous technologies has led to the development of Search and Rescue Autonomous Vessels (SRAVs), which have the potential to revolutionize the efficiency and effectiveness of such operations. This paper presents an example of the design, capabilities, and challenges associated with SRAVs. The integration of various sensors, communication systems, and artificial intelligence algorithms allows these vessels to navigate autonomously, detect and identify distress signals, locate survivors, and provide immediate assistance. Also, there are presented results from testing the SRAV and future development perspective.
Key words: AI, autonomous vessel, distress, GMDSS, search and rescue.

1. INTRODUCTION

As maritime activities continue to expand across the globe, the need for efficient and reliable search and rescue operations has become paramount. From distress signals emanating from remote corners of the ocean to emergencies unfolding in the midst of bustling shipping lanes, the GMDSS serves as the lifeline connecting those in distress with the rescuers who stand ready to provide aid. Within this framework, Search and Rescue Vessels play a pivotal role in bridging the gap between the call for help and the delivery of assistance.

The main purpose of the proposed system is represented by the continuous search of Romania's interest zone for any possible naval accidents which resulted with victims, in order to save them efficiently and with a short reaction time. This system is developed as a way of eliminating human error and in addition it becomes benefic for the saviors, because this system can be operated autonomously and remotely, resulting in safer working conditions for them. Regarding the stage of realization in production, there are several difficult aspects which need to be taken under consideration, like creating and implementing an artificial intelligence capable of searching and finding the distress victims, a versatile and efficient boat shape to resist any meteorological conditions, and to be capable of executing the saving maneuvers correctly.

The article chapters are focused on detailing the team study in this domain, and the steps taken in the process of creating a small-scale vessel which will strengthen the idea of introducing an autonomous search and rescue service in the Romanian Naval Forces.

In this article are presented the design of this system, its integration with the artificial intelligence capable of executing search and rescue maneuvers, even autonomous or remotely.

2. STATE OF THE ART

Search and rescue (SAR) operations in maritime environments are increasingly benefitting from advancements in autonomous vessel technology. These Search and Rescue Autonomous Vessels (SRAVs) represent the cutting edge in maritime safety and emergency response capabilities.

Next is outlined the state of the art in SRAVs, key developments, challenges, and potential future directions.

2.1 Autonomy and Navigation:

Autonomous Control: SRAVs are equipped with advanced autonomous control systems that enable them to operate independently, follow predefined routes, and adapt to dynamic environments. Machine learning and AI algorithms enhance their decision-making capabilities[1], [2].

Obstacle Avoidance: State-of-the-art SRAVs integrate LiDAR, radar, and computer vision to detect obstacles and navigate through complex maritime scenarios, including crowded harbours and adverse weather conditions[1], [3].

2.2 Sensing and Detection:

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Sensor Fusion: SRAVs incorporate a multitude of sensors, including sonar, thermal imaging, and AIS (Automatic Identification System) receivers, to detect and locate distressed vessels or individuals accurately.

Distress Signal Recognition: AI-driven algorithms enable the identification of distress signals, such as flares or emergency radio broadcasts, allowing for rapid response[4], [5].

2.3 Communication and Coordination:

Satellite Communication: SRAVs utilize satellite communication systems to maintain connectivity in remote areas, ensuring seamless coordination with onshore rescue centres and other vessels[3], [6], [7].

Interoperability: Integration with the GMDSS (Global Maritime Distress and Safety System) allows SRAVs to communicate with conventional maritime safety infrastructure[8].

2.4 Remote Operation and Monitoring:

Remote Control Centres: Some SRAVs can be remotely operated from command centres, where human operators can take control in complex situations or perform detailed assessments of the situation[1], [5].

Live Video Feeds: Onboard cameras provide live video feeds to aid in situational awareness for remote operators and facilitate communication with those in distress[1], [3], [5].

2.5 Enhanced Safety and Durability:

Redundancy: SRAVs are designed with redundancy in critical systems, ensuring reliability in challenging conditions.

Durability: They are often built to withstand harsh marine environments and extreme weather conditions, allowing them to operate effectively in emergencies[3].

2.6 Regulatory and Ethical Considerations:

International Regulations: Compliance with international maritime regulations, including those set by the International Maritime Organization (IMO), is crucial for SRAV deployment.

Ethical and Legal Issues: The use of autonomous vessels raises ethical and legal questions, including liability, privacy, and the role of human intervention[9].

2.7 Future Prospects:

Integration with Unmanned Aircraft: Future SRAVs may incorporate drones for aerial surveillance and rescue, expanding their search capabilities.

Collaborative Operations: Enhanced collaboration between autonomous vessels, manned vessels, and aerial assets can further improve SAR effectiveness[2].

Environmental Considerations: Sustainable propulsion methods, such as electric or hydrogen-based systems, are being explored to reduce the environmental impact of SRAVs[4], [10].

3. SRAV'S HARDWARE

To create this system, we chose to make a prototype from lightweight and easily workable materials, and it was made from expanded polystyrene. Expanded polystyrene is a widely used material in the construction industry and in the field of modelling due to its insulating properties, ease of processing, and versatility. Additionally, a few structural and propulsion elements were 3D printed.

The structure of the SRAV is presented in the next picture.

Figure 1 SRAV prototype

3.1 SRAV's Electronics

To highlight the previously presented concept, it is imperative to develop a prototype consisting of creating a scaled-down demonstrator, following the principles mentioned earlier, which should yield promising results in the tests conducted.

The electronic components included in the system are:

- ESP32 microcontroller
- 5V water pump
- Relay
- Power supply with Li-Ion battery
- Prototyping board
- Servo motor

The ESP32 microcontroller has revolutionized the field of embedded systems, especially in the context of the Internet of Things (IoT). Its dual-core architecture, built-in Wi-Fi and Bluetooth connectivity, as well as its extensive range of peripherals, provide a powerful and versatile platform for developing IoT solutions[11], [12].

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The MG996R servo motor is widely recognized and highly regarded in the robotics industry, in the field of automation, and among enthusiasts. Thanks to its remarkable features, it has become one of the most reliable and versatile servo motors available. In this project, we will explore the key features and applications of the MG996R, highlighting its power, precision, and versatility in a diverse range of fields.

This digital servo motor can generate a maximum torque of approximately 10 kg/cm (138.9 oz/in) at a voltage of 6V. In addition to its powerful torque, the MG996R stands out for its precision in positioning. With a rotation speed of approximately 0.17 seconds for 60 degrees of rotation at 6V, this servo motor ensures precise control of the angle and position of attached components.

The water pump is used for propulsion of the SRAV and for the power driver we used a simple relay but also PWM analog signal[13], [14].

Lithium-ion (Li-ion) cells are rechargeable energy storage devices known for their high energy density, making them popular for portable electronics. They utilize lithium as the key component in their electrodes, enabling efficient charge and discharge cycles. Li-ion cells have a relatively low self-discharge rate, making them ideal for applications where long-term energy storage is necessary. Despite their advantages, proper handling and charging are crucial to prevent safety risks associated with overcharging or overheating[15].

In the figure below is presented the firs prototype of the electrical circuit of the SRAV.

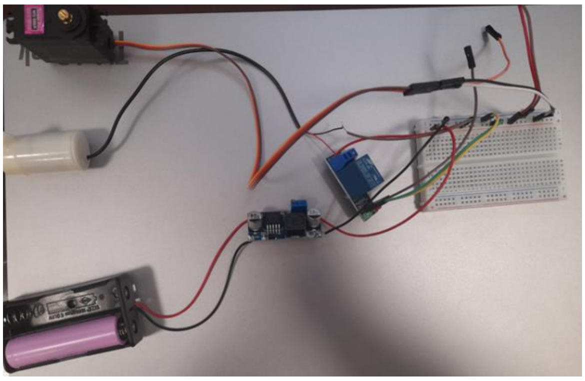

Figure 2 SRAV real electrical circuit

3.2 SRAV's system diagram

Each hardware element within the circuit, graphically depicted in the figure below, meets the specific operational requirements for the efficiency of the autonomous sea search and rescue vessel.

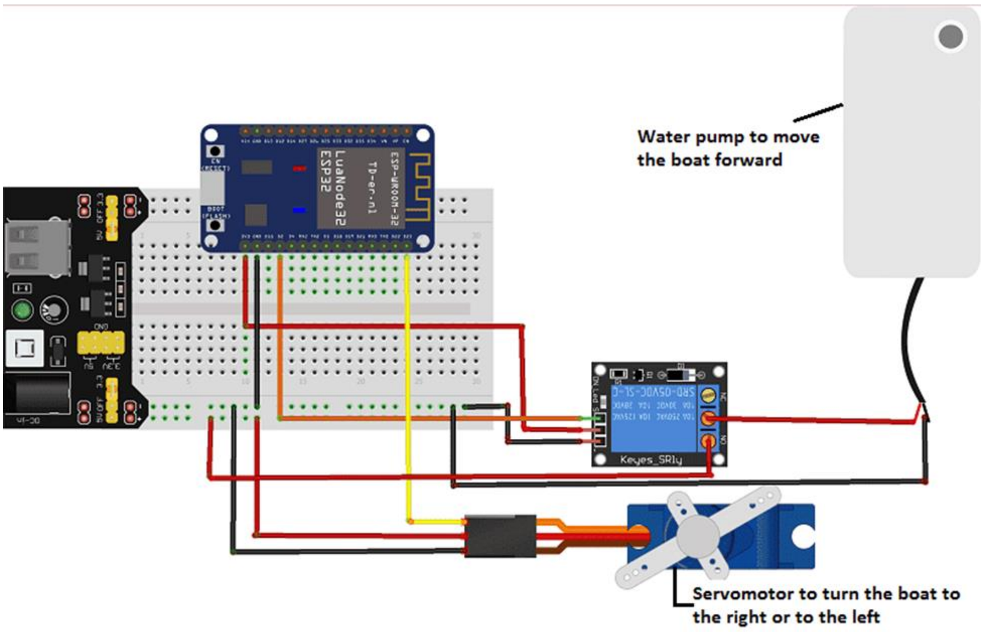

Figure 3 SRAV's main electrical diagram

The chosen prototype, one of the most optimal and efficient options, is designed with the purpose of autonomously navigating and conducting a continuous and efficient search.

4. SRAV'S SOFTWARE

For programming the ESP32 microcontroller, the Arduino IDE was used, utilizing the dedicated compatibility module.

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To facilitate the transmission of commands from the user to the microcontroller and, consequently, to the entire system designed within the scope of the thesis, the Blynk library was used. Blynk is an intuitive Internet of Things (IoT) platform that simplifies the process of building connected projects. This platform provides a comprehensive solution for developing interactive and networked applications that can be managed and monitored remotely. Blynk offers a wide range of features and tools that developers can use to design custom user interfaces (UIs), visualize data, and communicate with various IoT devices.

4.1 SRAV's GUI

In the presented figures, you can observe the graphical interface that underlies the command transmission, and it consists of:

Figure 4 SRAV's manual operation GUI

- Arrow buttons for remotely controlling the ship (Figure 4).
- Selector buttons for choosing various sea rescue maneuvers (Figure 5).

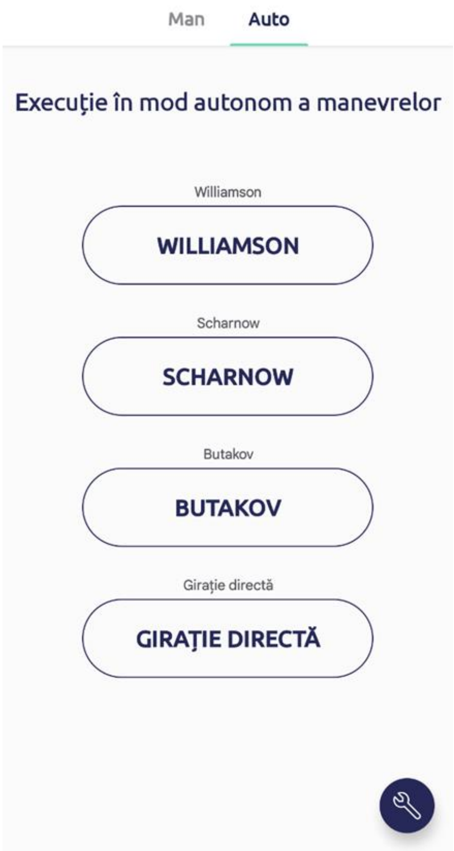

Figure 5 SRAV's auto operation GUI

4.2 SRAV's software code

The code was based on libraries for every main part of the SRAV. An Arduino library refers to a set of pre-written, reusable functions, classes, and resources that extend the capabilities of the Arduino platform. These libraries are created to simplify the programming process for specific hardware or functionalities, allowing Arduino developers to easily integrate complex features into their projects without having to write all the code from scratch.

The "WiFi.h" library in Arduino provides a set of functions and classes for configuring and managing Wi-Fi connectivity on Arduino boards that have built-in or external Wi-Fi modules.

The "WiFiClient.h" library in Arduino provides a lightweight and streamlined client interface for creating TCP and UDP network connections over Wi-Fi. It allows Arduino devices to connect to remote servers, communicate with web services, and exchange data with simplicity, making it ideal for various IoT and networking applications.

The "BlynkSimpleESP32" library is an essential component for connecting ESP32 microcontrollers to the Blynk IoT platform, simplifying the development of remote monitoring and control applications. It provides a seamless integration of the ESP32 with the Blynk ecosystem, allowing developers to quickly build IoT projects with a user-friendly mobile app interface. The library handles authentication, data synchronization, and real-time communication between the ESP32 and the Blynk cloud server. This simplifies the process of creating interactive and connected IoT applications that can be remotely managed, monitored, and controlled via smartphones or other devices, making it a valuable tool for IoT enthusiasts and developers.

The "ESP32Servo" library is a valuable extension for ESP32 microcontrollers, enabling precise control of servo motors. It simplifies servo motor management, providing functions for setting angles and controlling positions with ease. This library is essential for robotics, automation, and other projects requiring accurate and smooth servo motor control, making it a key tool for ESP32 developers seeking precise motion control capabilities.

5. SRAV'S TESTING, CONCLUSIONS AND FUTURE

The testing and maneuvering of the SRAV for MOB (Man Overboard) were conducted both at sea (in the military harbor) and on Lake Siutghiol near Naval Academy training camp. We encountered no big issues; the drone operated within normal parameters with no incidents. The maximum tested operating range was 500 meters.

Considering that the system has certain limitations at this developmental stage, in the future, this MOB SRAV could be significantly enhanced with additional technologies, sensors, radars, and equipment.

An example would be outfitting it with heat sensors, water sensors, pressure sensors, and GPS. In case of an incident, the drone could be thrown overboard, automatically start upon contact with water, detect the victim in the water based on heat sensor input, and move directly towards the base vessel. After the victim grabs onto a lifebuoy, pressure sensors on the handles could trigger the drone to return to the ship based on GPS coordinates. This is a complex example, but it greatly improves upon a simple SOLAS lifebuoy, significantly speeding up response in MOB incidents and increasing the chances of saving the victim.

The future of search and rescue AI vessels is poised for remarkable advancements. These vessels will benefit from cutting-edge technologies such as autonomous navigation, advanced sensor arrays, machine learning algorithms, and real-time data analysis. They will possess the ability to swiftly and accurately detect and respond to emergencies in challenging maritime environments. Improved communication systems will enable seamless coordination with rescue teams and remote command centers. Furthermore, these AI vessels will integrate renewable energy sources for sustainable, long-duration operations. As they become more efficient and capable, they will play a crucial role in enhancing maritime safety, reducing response times, and saving lives in a wide range of emergency situations.

6. ACKNOWLEDGMENTS

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