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A Review of Paper on Design of Autonomous Robotic Boat for Rescue Application

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Abstract: *The project titled "Design of Autonomous Robotic Boat for Rescue Application" aims to develop a reliable, efficient, and self-operating boat capable of conducting rescue operations in aquatic environments. This autonomous vessel is designed to navigate through water bodies, identify distressed individuals, and provide assistance without human intervention. Equipped with GPS, ultrasonic sensors, cameras, and communication modules, the boat can detect obstacles, locate victims, and communicate with a central control system. The primary focus is to enhance the boat's adaptability and responsiveness in diverse rescue scenarios, including floods, tsunamis, or other aquatic emergencies. By leveraging machine learning algorithms and advanced path-planning techniques, the boat autonomously calculates optimal routes to reach individuals in need. This project contributes to emergency response technology, offering a scalable and cost-effective solution to save lives in hazardous water environments. The proposed design can significantly improve the speed and safety of rescue operations, potentially reducing the risks faced by human rescuers in dangerous situations.*

Keywords: Flood, Security ,Rescue , Remote Control, Maneuvering

I. INTRODUCTION

The Rescue Boat Project is a dedicated initiative aimed at enhancing maritime safety and response capabilities. The primary goal is to design, develop, and deploy advanced rescue boats that can be rapidly deployed in emergency situations, ensuring the safety of individuals in distress at sea. This project involves a multidisciplinary approach, integrating expertise from naval architecture, marine engineering, rescue operations, and technology. The Rescue Boat Project is a dedicated initiative aimed at enhancing maritime safety and response capabilities. The primary goal is to design, develop, and deploy advanced rescue boats that can be rapidly deployed in emergency situations, ensuring the safety of individuals in distress at sea. This project involves a multidisciplinary approach, integrating expertise from naval architecture, marine engineering, rescue operations, and technology. By leveraging this technology, the robotic rescue boat could significantly reduce response times, lower risks to human rescuers, and increase the chances of successful rescue operations, particularly in situations where traditional methods are limited or unsafe.

II. LITERATURE REVIEW

Abdul Haq, M., Afakh, M., & Sugianto et al. (2020) - "Towards a robust maneuvering autonomous surface vehicle": In this paper, the authors explore the development of autonomous surface vehicles (ASVs) for marine operations. The study focuses on improving the manoeuvrability and robustness of ASVs in challenging environments. The paper discusses the use of sensors and control algorithms that enable the vehicle to navigate autonomously in water while maintaining stability and avoiding obstacles. They emphasize the importance of real-time communication systems and the integration of navigation aids like GPS and sonar. The proposed framework aims to address issues like unpredictable water currents, variable terrain, and multi-domain operations. The paper presents experimental results from the Kontes Kapal Cepat Tak berawak Nasional in Indonesia, which tested the manoeuvring capabilities of these vehicles in dynamic scenarios. G. Ferri, F. Ferreira, V. Djapic, Y. Petillot, M. P. Franco, and A. Winfield (2020) - "The euRathlon 2015 grand challenge: the first outdoor multi-domain search and rescue robotics competition-A marine perspective": This paper discusses the results and insights from the euRathlon 2015 Grand Challenge, a multi-domain robotics competition focused on search and rescue (SAR) missions. The competition aimed to simulate real-world rescue scenarios involving land, air, and water domains. The paper highlights the challenges faced by autonomous systems, particularly marine robots, in performing SAR tasks in unpredictable environments. The authors describe the integration of various robotic platforms, including underwater vehicles, autonomous boats, and aerial drones, which collaborated in the competition. The paper analyses how these systems addressed real-time data collection, navigation, and communication, offering valuable lessons for future SAR missions.

III. TECHNOLOGY STACK

Embedded C : Embedded C is most popular programming language in software field for devel- oping electronic gadgets. Each processor used in electronic system is associated with embedded software. Embedded C programming plays a key role in per- forming specific function by the processor. In day-to-day life we used many electronic devices such as mobile phone, washing machine, digital camera, etc. These all device working is based on microcontroller that are programmed by embedded C.

Keilμ Vision:

Keil µVision (Micro Vision) is an integrated development environment (IDE) developed by Arm Keil that is widely used for developing embedded systems, particularly those based on ARM Cortex-M microcontrollers. It offers a comprehensive suite of tools to facilitate all stages of embedded software development, from code writing and debugging to compiling and flashing the firmware onto the target hardware. Known for its efficiency and versatility, Keil µVision is a preferred choice among embedded systems engineers for ARM-based microcontroller projects.

IV. PROPOSED SYSTEM

System Architecture:

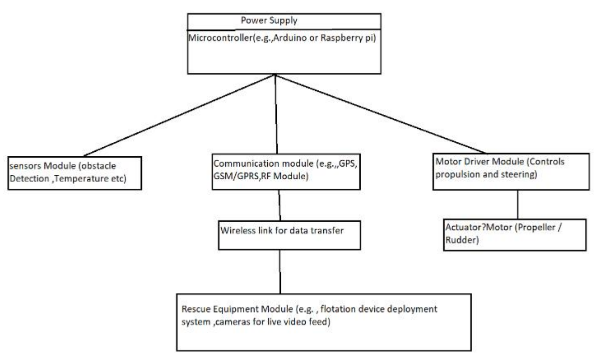

Fig .1 Architecture of Autonomous Robotic Boat for Rescue Application

ESP8263 Microcontroller: A low-cost, Wi-Fi-enabled microcontroller commonly used in IoT applications. Supports multiple GPIO pins and communication protocols (UART, SPI, I2C), allowing easy integration with sensors and modulus'**s SIM 800C:** A GSM module that allows communication over cellular networks for SMS, voice, and data transmission. Useful for remote control and monitoring applications, enabling real-time data transfer over long distances. **GPS Module Neo 6M:** A GPS receiver module that provides location data such as latitude, longitude, and altitude. Compatible with various microcontrollers, it's often used in navigation and tracking applications. **Motor Driver (H Bridge) L298N:** A dual H-Bridge motor driver that can control two DC motors or one stepper motor. Provides control over motor direction and speed, making it ideal for robotic applications. **DC Motor:** Converts electrical energy into mechanical motion, commonly used for driving wheels or actuators. Direction and speed can be controlled using a motor driver, enabling movement in robotic projects. **Ultrasonic Sensor HC SR40:** A distance measurement sensor that emits ultrasonic waves and measures the time taken for the echo to return. Useful in obstacle detection, distance sensing, and navigation in autonomous vehicles or robots. **Camera Image Sensor Module 0V7670:** A CMOS image sensor capable of capturing images and videos, often used in basic image processing projects. Supports low-resolution output suitable for object detection or vision-based applications. **Battery 12V:** Provides the required power for electronic components and motors, commonly used in portable devices. Rechargeable 12V batteries are ideal for projects requiring high power for extended periods.**SD Card:** A storage device used to save data such as images, GPS logs, and other sensor data. Can be interfaced with microcontrollers for data logging, expanding the storage capabilities of the system. **ESP8266:** A popular Wi-Fi module that provides internet connectivity for IoT devices. Supports multiple protocols and can be programmed to communicate with servers or other devices over Wi-Inj**ustice Module:** An input device for controlling direction and movement, typically used in remote control applications. Provides two-axis movement control, making it useful for navigation and manual control of robots. **Dotted PCB:** A perforated circuit board that allows components to be soldered in custom configurations. Ideal for prototyping, as it provides flexibility in arranging and connecting components. **Push Button:** A simple switch used to trigger actions or start/stop processes in electronic circuits. Often used as an input for manual control in projects, such as activating modes or resetting the system.**PWM Control in an Arduino (or Microcontroller) Context:** In an **Arduino** or microcontroller application, PWM is often used for controlling devices such as: **DC motors** (for speed control), **Servo motors** (for precise position control), **LEDs** (for brightness control)

Fig.2 Boat Pictorial Architecture

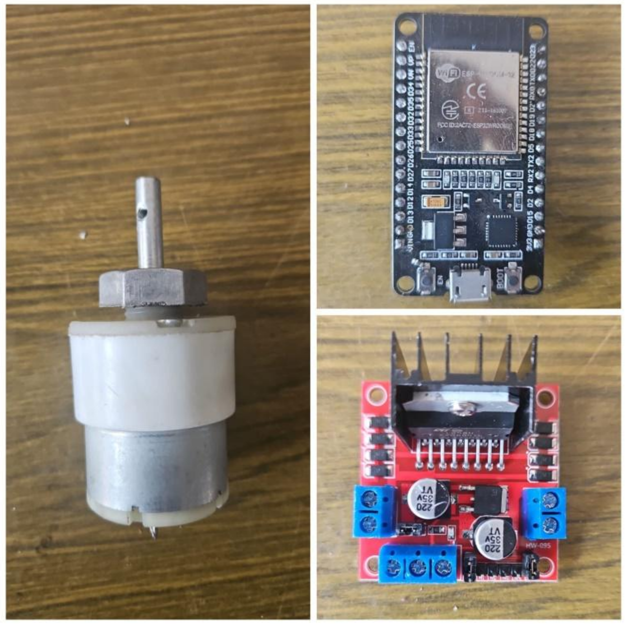

Fig.3 Boat Pictorial Architecture

Flow chart and Algorithm

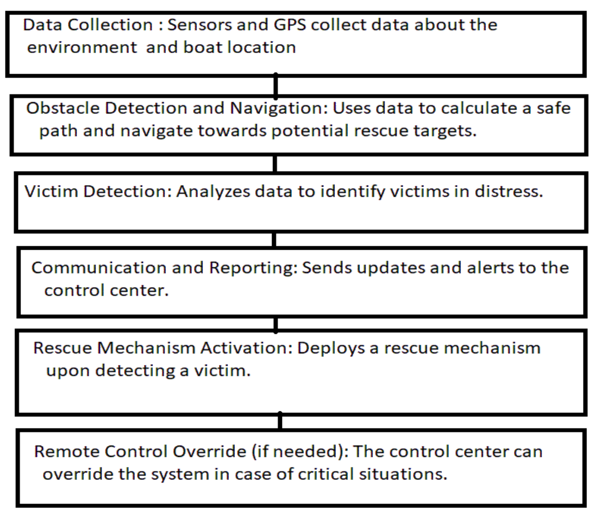

Fig 4. Flow chart

Flowchart is a type of diagram that represents a workflow or process. A flowchart can also b to solving a task. The flowchart shows the steps as boxes of various the system starts and initializes. Initialize Sensors and GPS to gather data about the environment and boat's current location. Store Location Data and Environmental Conditions for processing. Analyse Collected Data to detect obstacles in the boat's path. Calculate Safe Path based on the obstacle locations and the target area. Navigate the boat towards potential rescue targets by following the calculated path. Analyse Sensor and Visual Data to identify any victims in distress in the vicinity. Mark Victim Location for further action. Send Updates about the boat's location, environmental conditions, and detected victims to the control centre. Alert Control Centre if victims are detected. Verify Victim Detection and confirm with control centre if necessary. Deploy Rescue Mechanism (e.g., life buoy or flotation device) to assist the detected victim. Wait for Override Signal from the control centre if a critical situation is identified. Pause Autonomous Functions and allow the control centre to manually navigate the boat if an override is issued. Repeat steps until mission completion or control centre signals end of operation.

VI. CHALLENGES IN AUTONOMOUS ROBOTIC BOAT FOR RESCUE APPLICATION

Environmental and Operational Challenges: **Water Conditions:** Autonomous robotic boats must operate in diverse water environments, including calm lakes, rough seas, and floodwaters with strong currents. Designing for stability and manoeuvrability in unpredictable water conditions is complex.

Weather Conditions: Harsh weather conditions such as heavy rain, storms, fog, or strong winds can impact the boat's navigation, sensor accuracy, and communication reliability, affecting rescue operations. **Power and Endurance Battery Life:** Rescue operations can be time-sensitive and prolonged, requiring the boat to operate for extended periods. Limited battery capacity can restrict mission duration, making efficient power management essential. **Energy Efficiency:** The challenge lies in optimizing energy usage for propulsion, sensors, and communication systems while ensuring that performance is not compromised during critical rescue missions. **Navigation and Obstacle Avoidance Autonomous Navigation:** The robotic boat must be capable of navigating dynamically changing environments, including flooded urban areas with submerged obstacles, floating debris, or varying water depths. **Obstacle Detection and Avoidance:** Using sensors such as LiDAR, sonar, and cameras, the boat must effectively detect and avoid obstacles to prevent collisions and ensure smooth operation in rescue scenarios. **Communication and Data Transmission Signal Interference:** Reliable communication with the control station is essential, but interference from water reflections, obstacles, or extreme weather can disrupt signals, affecting control and data transmission. **Real-Time Data Sharing:** Transmitting live video feeds, GPS locations, and sensor data in real-time is crucial for effective rescue coordination. Maintaining a stable connection in remote or disaster-stricken areas can be challenging. **Security and Reliability Cybersecurity Risks:** Autonomous rescue boats are susceptible to cyber threats, such as hacking or signal jamming, which can compromise the mission and endanger lives. Implementing robust encryption and secure communication protocols is necessary. **System Redundancy:** Failures in propulsion, navigation, or sensors could jeopardize a rescue mission. Designing fail-safe mechanisms and redundant systems ensures continuous operation even in case of partial failures.

VII. ADVANCEMENTS IN AUTONOMOUS ROBOTIC BOAT FOR RESCUE APPLICATION

Artificial Intelligence (AI) and Machine Learning Autonomous Navigation: AI-driven algorithms are enhancing the ability of robotic boats to autonomously navigate complex and dynamic water environments, including flood zones, rough seas, and debris-filled areas. Advanced path planning and obstacle avoidance reduce reliance on human intervention. Enhanced Perception: Machine learning techniques enable robotic boats to analyse sensor data more effectively, improving object recognition, victim detection, and terrain assessment using visual, thermal, and sonar data for more accurate rescue operations. Sensor and Perception Technologies Advanced Sensors: The integration of high-resolution cameras, LiDAR, sonar, and infrared sensors allows robotic boats to detect obstacles, identify survivors, and assess environmental conditions with greater accuracy. Sensor Fusion: Combining data from multiple sensors enhances situational awareness, enabling the boat to operate in challenging conditions such as murky waters, low visibility, and turbulent waves, ensuring more reliable rescue missions. Improved Mobility and Navigation Enhanced Propulsion Systems: Advancements in electric propulsion and hybrid power systems provide greater efficiency, allowing for better manoeuvrability and extended operation time in various water conditions. Autonomous Docking and Deployment: AI-driven docking mechanisms enable robotic boats to autonomously launch, return, and recharge, improving efficiency in repeated rescue missions. Swarm Robotics and Coordinated Rescue Operations Ulti-Boat Coordination: The use of swarm robotics principles allows multiple robotic boats to work together in coordinated rescue missions, covering larger search areas and improving efficiency in disaster response. Human-Robot Collaboration: Autonomous boats are being designed to work alongside drones and human rescue teams, sharing real-time data for better decision-making and quicker response times. Communication and Data Transmission Real-Time Data Sharing: High-speed wireless communication enables real-time video streaming, GPS tracking, and environmental data transmission to rescue teams, ensuring quick and informed decision-making. Resilient Communication Networks: The use of satellite and mesh network technology improves connectivity, even in remote or disaster-affected areas where traditional communication infrastructure may be compromised.

VIII. CASE STUDIES AND REAL-WORLD EXAMPLES

One notable example of an autonomous robotic boat for rescue operations is the **EMILY (Emergency Integrated Lifesaving Lanyard)**, developed by Hydrohalic. EMILY is a remote-controlled, unmanned surface vehicle (USV) designed for swift water rescues. It has been deployed in various emergency situations, including flood rescues and ocean lifeguard operations. The U.S. Coast Guard and other international rescue teams have used EMILY to navigate rough waters and deliver flotation devices to distressed swimmers, significantly reducing the time required to reach victims compared to traditional lifeguard methods Another successful implementation is the **Shark Rescue Boat**, developed for flood and disaster response. This autonomous boat is equipped with sonar and infrared cameras to detect survivors, even in low-visibility conditions. During floods in China and India, the Shark Rescue Boat was used to locate stranded individuals and deliver emergency supplies, demonstrating its effectiveness in disaster response. In Europe, researchers have developed the **Swarm USV Project**, where multiple autonomous boats work together in coordinated search-and-rescue missions. This system was tested in simulated flood scenarios, where the boats autonomously mapped flooded areas, located survivors, and relayed real-time data to rescue teams. The swarm-based approach enhances coverage and efficiency in large-scale rescue operations. Additionally, the **SARBOT (Search and Rescue Robot)** has been utilized in underwater rescue missions. It is an autonomous robotic boat equipped with robotic arms and sonar technology to assist in locating and retrieving drowning victims. SARBOT has been used by law enforcement and emergency responders in the United States to conduct underwater search-and-recovery missions, especially in murky waters where divers face high risks These real-world examples highlight the increasing role of autonomous robotic boats in rescue applications, improving response times, reducing human risk, and enhancing operational efficiency in challenging environments such as floods, rough seas, and disaster-stricken areas.

IX. FUTURE DIRECTIONS AND RESEARCH TRENDS

The future of autonomous robotic boats for rescue applications is centered on enhancing autonomy, improving sensor integration, and developing more efficient and adaptable rescue systems. A key research focus is on advancing artificial intelligence and machine learning to enable robotic boats to autonomously navigate complex and unpredictable water environments, such as flood zones, turbulent seas, and debris-filled waters. This includes improving real-time decision-making, path planning, and obstacle avoidance to ensure effective and rapid response in emergencies. Another important trend is the integration of robotic boats with aerial drones and underwater robotic systems, allowing for a multi-layered search-and-rescue approach. This collaboration enables seamless coordination between autonomous platforms, improving situational awareness and operational efficiency in disaster-stricken areas. Additionally, advancements in sensor fusion, including high-resolution LiDAR, sonar, and infrared imaging, will enhance the boats' ability to detect survivors, submerged objects, and environmental hazards, even in low-visibility conditions. Research is also focused on improving energy efficiency through hybrid power systems, such as solar-electric propulsion, to extend mission duration and operational range. Moreover, the development of swarm robotics, where multiple autonomous boats work collaboratively in coordinated rescue missions, is gaining traction, as it can significantly enhance coverage and efficiency in large-scale disaster response. Lastly, efforts are being made to strengthen communication networks through satellite and mesh networking technology, ensuring real-time data transmission and control even in remote or infrastructure-damaged locations. These advancements will collectively enhance the effectiveness, reliability, and scalability of autonomous robotic boats in life-saving operations.

X. CONCLUSION

In this project, we successfully designed and developed an autonomous robotic boat capable of assisting in rescue operations. The system integrates advanced sensor technology, navigation algorithms, and a reliable communication

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module to ensure efficient and timely responses in emergency situations. Our prototype demonstrated the ability to autonomously detect and reach designated targets while maintaining stability and speed suitable for rescue scenarios.

This innovative approach to rescue operations highlights the potential of autonomous systems in enhancing safety and response times, particularly in scenarios where human intervention may be limited or hazardous. Future enhancements could include improving sensor accuracy, expanding operational range, and incorporating real-time data analysis for better decision-making. Overall, this project has laid a foundation for the practical application of autonomous rescue technologies, promising significant contributions to safety and emergency management.

Fig .6 Autonomous Roboatic Boat

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