Project Report
Title: Robot supply life essentials for people trapped during a flood

D. Bandara
Department of Electrical Engineering
University of Moratuwa
Moratuwa, Sri Lanka
bandararmdd.21@uom.lk

G. De Alwis
Department of Electrical Engineering
University of Moratuwa
Moratuwa, Sri Lanka
dealwisagt.21@uom.lk

P. Dabarera
Deprtment of Electrical Engineering
University of Moratuwa
Moratuwa, Sri Lanka
dabarerawpjb.21@uom.lk

Date of submission: 12th of December 2023

***Abstract*—This project presents a pioneering solution, the ”Robot Supply Life Essentials for People Trapped During a Flood,” aimed at tackling the urgent challenge of delivering essential resources to communities affected by floods. The innovative robot boat integrates autonomous navigation, a sturdy design, and a versatile robotic arm to enable effective mobility, debris removal, and delivery of life essentials to individuals in flood-stricken areas. This report provides an overview of the robot boat's key features and capabilities, emphasizing its crucial role in disaster relief operations.**

***Index Terms*—robots, floods, debris, UAVs, life essentials**

Fig. 1. The Indian army is providing supplies to those stranded in remote areas(BBC News:https://www.bbc.com/news/world-asia-india-45267014)

Fig. 2. Thousands remain marooned in their houses(BBC News:https://www.bbc.com/news/world-asia-india-45267014)

TABLE OF CONTENTS

1. INTRODUCTION

1.1 Background

Floods bring significant challenges to communities, causing immense harm and emphasizing the urgent need for efficient relief operations. The devastation often leaves people in dire need of life essentials like food and clean water. In response to this pressing demand, various innovative solutions have emerged, focusing on the integration of technology to enhance the effectiveness of flood relief efforts. This project seeks to contribute to this evolving landscape by examining existing technologies and introducing a cutting-edge robot boat solution. This state-of-the-art technology aims to provide essential supplies to individuals stranded during floods, addressing critical needs in a more efficient and timely manner.

It's important to note that during floods, the army often plays a crucial role in rescue operations. Additionally, when people are forced to wade through floodwaters, they face various health risks. Walking in floodwaters can expose individuals to contaminants and pathogens, leading to illnesses such as waterborne diseases, skin infections, and respiratory issues. These health concerns further highlight the significance of rapid and effective relief efforts, emphasizing the importance of technological innovations like the robot boat in providing essential aid during flood crises.

1.2 Objectives and goals

The primary aim of this project is to develop a cutting-edge robot boat that addresses the challenges posed by flood relief operations. The central focus revolves around ensuring the seamless movement of the robot in any direction across the water level surface. This key feature is instrumental in the mission to deliver essential supplies and provide aid to individuals in flood-affected regions. The objectives include developing a robot capable of navigating effectively through various water conditions, including,

- tilt water
- flowing water with high velocity
- and debris-scattered waters.

By achieving these goals, the project aims to enhance the efficiency and effectiveness of flood relief efforts, ultimately minimizing the impact of floods on vulnerable communities.

Fig. 3. Swift current of flood.(abc News)

1.3 Scope and limitations

While the project seeks to make significant strides in flood relief technology, it is essential to acknowledge certain limitations and constraints. The scope of this endeavor encompasses the development of a robot boat designed specifically for seamless navigation in flood-affected areas. However, it is important to recognize that the effectiveness of the robot may be influenced by factors such as extreme weather conditions and unforeseen challenges in real-world deployment. Additionally, resource constraints and technological limitations may impact the full realization of the project's objectives. Understanding these limitations is crucial for setting realistic expectations and guiding the future development of flood relief technologies.

Fig. 4. Flood affected area with debris.(shutterstock)

2. Literature Review

2.1 Existing Flood Relief Technologies

Numerous studies have explored the use of various technologies in flood relief operations. Unmanned Aerial Vehicles (UAVs) have been widely utilized for aerial surveillance, damage assessment, and supply drops in inaccessible areas [2]. Ground-based robots equipped with sensors and communication tools have been employed for reconnaissance and data collection in flooded environments [3]. However, there is a noticeable gap in the literature regarding robust robotic solutions specifically designed for navigating flooded areas with diverse water conditions.

2.2 Challenges in Flood Relief Robotics

Previous research has identified several challenges in the deployment of robotic solutions for flood relief. Navigating through tilt water, rapidly flowing currents, and debris-scattered waters poses significant challenges for existing robotic platforms [4]. The need for versatile and adaptable robotic systems that can address these challenges is evident in the literature, emphasizing the importance of developing solutions like the proposed robot boat.

2.3 Cutting-edge Technologies in Robotic Navigation

Recent advancements in robotic navigation technologies have shown promise in overcoming challenges posed by diverse water conditions. LiDAR-based mapping and obstacle detection systems have enhanced the autonomy of robotic platforms in complex environments [1]. Additionally, machine learning algorithms have been applied to improve navigation and decision-making processes in dynamic and unpredictable flood scenarios [5].

2.4 Gaps and Opportunities

While existing research provides valuable insights, a critical gap remains in the development of robotic solutions specifically tailored for flood relief, especially in the context of diverse water conditions. The proposed robot boat aims to fill this gap by incorporating autonomous navigation, a robust design, and a versatile robotic arm for efficient movement, debris clearance, and delivery of life essentials.

3. Methodology

3.1 Design Process

1) step 1: Problem Definition and Objective Setting:

   As the first step of the design process the problem was clearly defined, primary objectives were established and key constraints were identified.

   problem: Design a robust robot boat for delivering life essentials in flood-stricken regions.

   primary objectives: Timely and efficient transportation of water and food to inaccessible areas, considering the challenges of navigating unpredictable floodwaters and potential debris.

   key constraints: Autonomous navigation, payload management, and communication capabilities.

2) step 2: Conceptual Design and Vision Development:
   - Envisioned a streamlined hull with modular cargo compartments for efficient transport.
   - Conceptualized an autonomous navigation system with obstacle avoidance and adaptability to varying water levels.
   - Considered eco-friendly propulsion mechanisms, such as electric thrusters.
   - Outlined cargo management system with secure locking mechanisms and payload integrity sensors.
   - Integrated communication features for coordination with relief efforts.

   Overall the aim is for a design that balances robustness and agility, addressing unique challenges of flood-stricken regions.

3) step 3: Detailed Design and Optimization
   - Considered the use of solar panels for supplementary power and sustained autonomy.
   - Ensured payload capacity meets essential needs of stranded individuals.
   - Implemented advanced obstacle avoidance sensors for navigational safety.
4) step 4: Simulation
   - Utilized SOLIDWORKS 2023 software for detailed structural design and optimization.
   - Simulated the designed structure using MATLAB R2022b software to ensure its integrity and performance.

3.2 Data Collection

The data collection process for designing the life essentials transport robot boat involves a comprehensive approach.

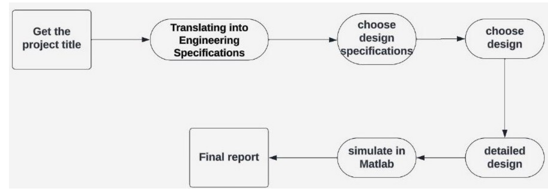

Fig. 5. Design process

It begins with reviewing existing robot boats and research papers to understand architectures, propulsion systems, and navigation strategies. Field studies provide practical insights, considering factors like water levels and debris in flood-prone regions. Online sources contribute additional perspectives and updates on the latest advancements. This holistic approach aims to blend established concepts with fresh ideas, creating an informed and improved design strategy for the robot boat.

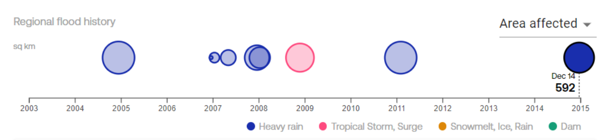

Fig. 6. Srilanka's Regional flood history: https://global-flood-database.cloudtostreet.ai/interactive-map

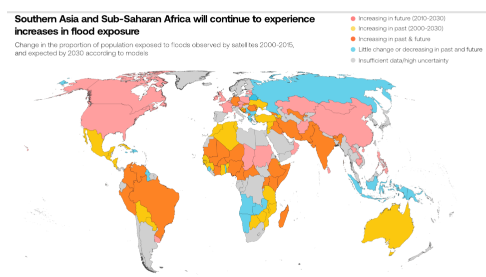

Fig. 7. Increasment or decreasment in flood exposure: https://global-flood-database.cloudtostreet.ai/interactive-map

4. Design and Simulation

4.1 Technical Specifications

In the meticulous design and simulation phase of our life essentials transport robot boat project, paramount importance is given to validate key technical specifications, ensuring the system's robustness and effectiveness. The autonomous navigation system, driven by GPS, IMU, and advanced algorithms, undergoes rigorous simulations to guarantee accuracy and adaptability. Crafted to emulate real-world scenarios, these simulations assess the system's dynamic course adjustments in response to evolving environmental conditions, including water dynamics and mission-specific requirements.

The dual-propeller propulsion system, crucial for versatile travel, undergoes intricate simulations to evaluate its performance across varying water conditions. Special attention is devoted to assessing the precision of the system in controlling the boat's movements, particularly its ability to counteract tilting motions induced by changes in cargo weight. Gyro stabilization technology and buoyancy control systems are scrutinized in simulations to ensure adaptability, maintaining a stable and level platform under diverse load conditions. This holistic simulation approach serves to validate the boat's capability in ensuring a secure and level delivery of essential supplies during flood relief missions.

Furthermore, the simulation phase rigorously examines the boat's performance in high-velocity water flow. Advanced hydrodynamics, the robust propulsion system, and dynamic control algorithms undergo simulations replicating varying water speeds. These simulations validate the boat's adeptness in navigating and maintaining stability in challenging aquatic environments commonly encountered during flood relief operations.

The integration and simulation of the robotic arm for debris clearance represent pivotal aspects of this phase. The simulations entail testing the arm's responsiveness to debris detection, evaluating its flexibility, reach, and overall effectiveness. Continuous monitoring throughout the simulations ensures the safe and efficient handling of debris, thereby validating its substantial contribution to the boat's navigation through debris-laden floodwaters.

This comprehensive approach to simulation and validation underscores our commitment to designing a resilient and effective life essentials transport robot boat, capable of overcoming the complexities inherent in flood relief missions.

Following are the design specifications:

1) Size and Dimensions:
   - Length: 3 meter
   - Width: 1.5 meter
   - Height: 0.9 meter
   - Draft (depth in water): 0.6 meter
2) Construction Material:
   - Hull: Aluminum
   - Frame: Glass-Reinforced-Plastic
3) Propulsion System:
   - Type: DC motors
   - Power Source: solar panels and battery backup
   - Thrust Power: 5 to 10 horse power
4) Mobility:
   - Terrain Compatibility: designed for debris-laden water or shallow areas
5) Navigation System:
   - GPS: Aim for 1 to 3 meters accuracy (Use a multi-constellation system supporting GPS)
   - Obstacle Avoidance: Ultrasonic Sensors, Infrared Sensors, LIDAR sensor Obstacle Avoidance Algorithm using Sensor Fusion.
6) Communication System:
   - Remote Control: VHF (Very High Frequency) radio.(5 to 10 nautical miles)
   - Data Transmission: Satellite Communication System
7) Payload Capacity:
   - Maximum Weight Carrying Capacity: 500kg
8) Power System:
   - Energy Storage: Batteries
   - Charging System: by solar-power
9) Autonomy and Control:
   - Autonomous Features: it can operate without continuous human control
   - Control Interface: operate through a remote control station
10) Sensors:
   - Depth Sensors: Echo Sounder (0 to 5 meter)
   - Environmental Sensors: temperature, humidity

4.2 Challenges and Solutions

- Simulation Complexity
  - Challenge: Difficulty in simulating the boat in matlab for diverse and dynamic environments for effective testing.
  - Explore parallel computing options and distributed computing resources for large-scale simulations.
- Shape Design Optimization
  - Challenge: Challenges in determining the optimal shape of the robot boat for stability, buoyancy, and efficient navigation in flood conditions.
  - Solution: Employ computational fluid dynamics (CFD) simulations and iterative design processes to optimize the boat's shape, considering hydrodynamics and stability factors
- Effective Time Management
  - challenge: Balancing various tasks and deadlines efficiently to ensure the timely completion of the life essentials transport robot boat project.
  - solution: Implement a comprehensive project schedule with clearly defined milestones and allocate specific timeframes for each project phase.
- Efficiency and Cost-Effectiveness
  - Challenge: Achieving optimal efficiency in the life essentials transport robot boat's performance while maintaining cost-effectiveness in design and production.
  - Solutio: Employ lean design principles to minimize material waste and reduce production costs. Implement modular design for ease of maintenance and upgrades. Employ predictive maintenance strategies to maximize the operational lifespan of components and reduce overall ownership costs.

4.3 Simulation

Simulation was done using the MATLAB R2022b simulink software.

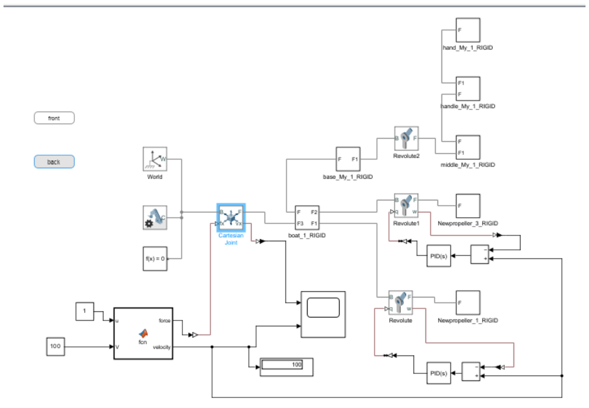

Fig. 8. Simulink diagram

Buttons:
Two buttons are used to analyze the movement of the boat.
Forward button: Upon clicking the button, the boat initiates forward movement. Subsequent clicks on the button bring the boat to a halt. The simulation incorporates viscosity friction by introducing a damping coefficient that affects the boat's motion.

Backward Button: Similarly, activating the backward button initiates reverse movement, and a subsequent click on the same button halts the boat.

The simulation can rotate propellers according to the angular velocity (radians per second) which is provided.
The below function in Fig.9 shows how the propeller's thrust calculation is done.

```
function [force,velocity]= fcn(u,V)

K= 0.001

if u==1
    force = K*(V^2);
    velocity = V;
elseif u==-1
    force = -K*(V^2);
     velocity = -V;
else
    force=0;
    velocity = 0;

end
```

Fig. 9. function

Based on the equation,

$$F = kv^2$$

It was assumed that k = 0.001 .
So, the force will change according to the velocity provided. PID controller is included to provide force to the propellers throughout the simulation.

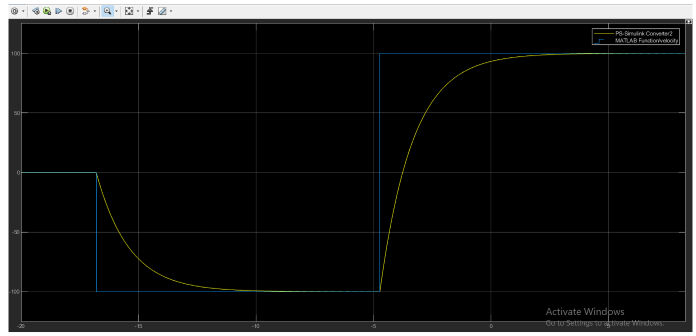

Fig. 10.

Above graph in Fig. 10 shows the movement of the boat with respect to the angular velocity of the propeller.Independent variable is the propellers angular velocity while, dependenet variable is the boats velocity.As it can be seen the first pulse of the graph generated when the forward button is clicked, and next pulse created due to the backward button.

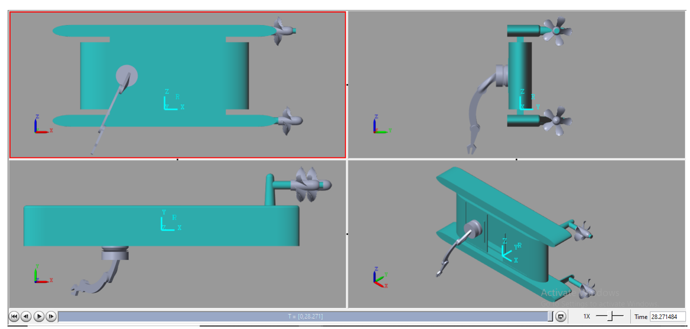

Fig. 11. Different views

5. Results and Discussion

5.1 Outcome of the Project

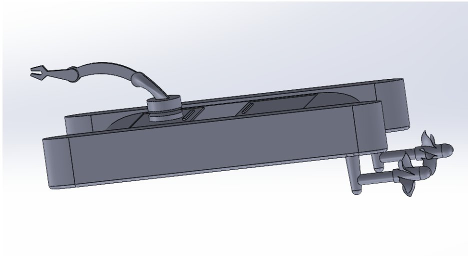

Fig. 12. Robot boat side view

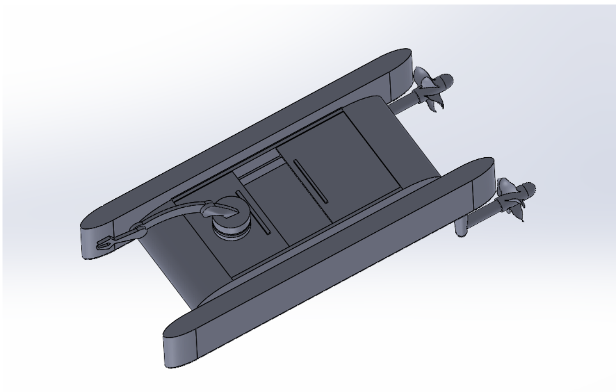

Fig. 13. Robot boat top view

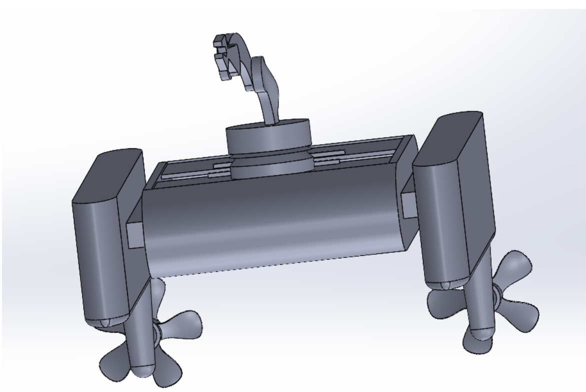

Fig. 14. Robot boat front view

5.2 Comparison with Objectives

Secure Essential Supplies Delivery: A primary objective, the secure transportation of life essentials, has been achieved through the incorporation of a dual-propeller propulsion system. This innovative design not only enhances the boat's stability in varying water conditions but also ensures a significant payload capacity, guaranteeing that essential supplies reach those in need securely.

Robotic Arm for Efficient Debris Clearance: The inclusion of a robotic arm has demonstrated remarkable efficiency in clearing debris and obstacles. Equipped with advanced sensors and specialized tools, the robotic arm swiftly detects, grasps, and lifts debris from floodwaters, preventing interference with

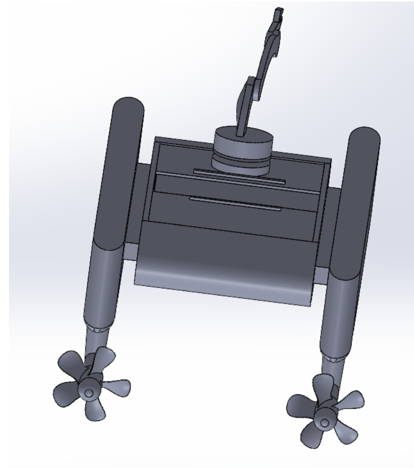

Fig. 15. Robot boat back view

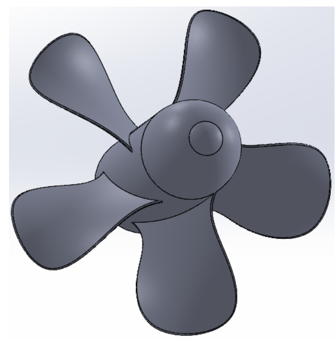

Fig. 16. Propeller

the propulsion system. This capability significantly enhances the boat's ability to navigate through challenging flood conditions, ensuring unimpeded movement.

Parts of the Robotic Arm: Holder, Handle, Hand

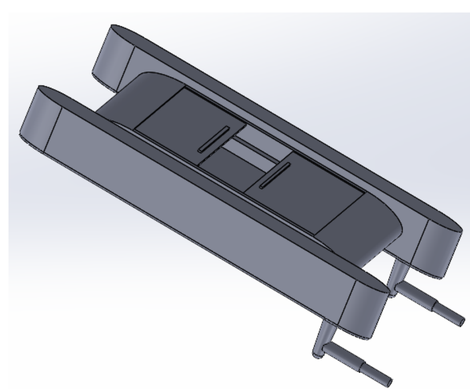

Fig. 17. Essential supplies store

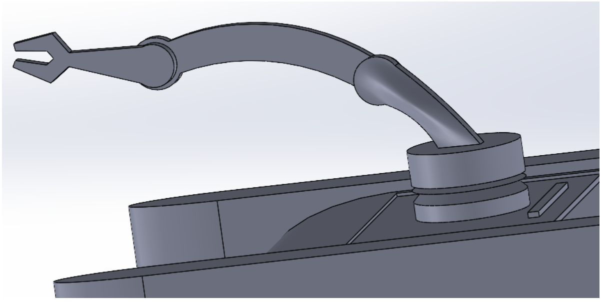

Fig. 18. Robotic arm

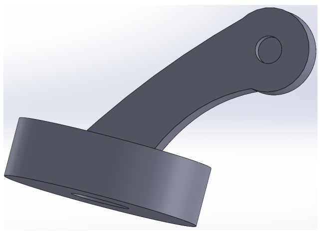

Fig. 19. Holder

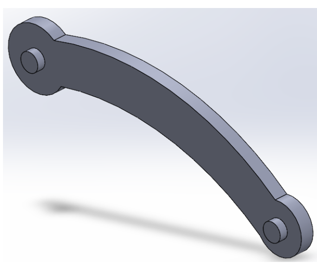

Fig. 20. Handle

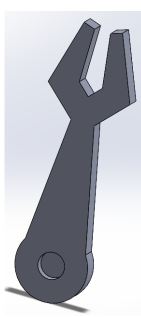

Fig. 21. Hand

5.3 Limitations of the Study

- Debris Variability: Although the robotic arm is a pivotal tool for debris clearance, the study faces limitations in accounting for the diverse nature and size of debris encountered in real-world flood conditions. The effectiveness of the robotic arm may vary based on the specific characteristics of the debris, posing challenges in achieving uniform and efficient debris clearance in all situations.

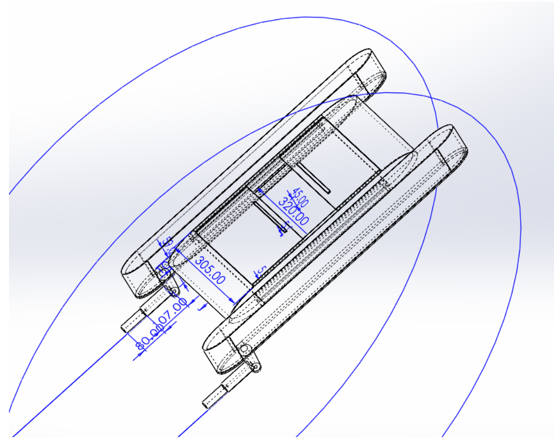

Fig. 22. Dimensions

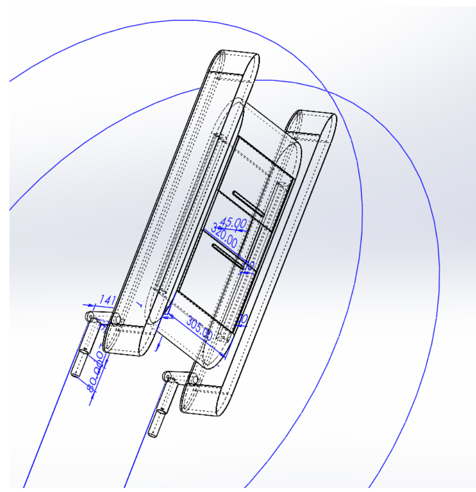

Fig. 23. Dimensions

- Payload Constraints: While the robot boat boasts a significant payload capacity, variations in the type and volume of essential supplies may impact its optimal performance. The study's limitations include addressing potential constraints related to payload management, especially when dealing with irregularly shaped or oversized supplies.
- Limitations in robotic Arm Flexibility: The effectiveness of the robotic arm in navigating through complex debris-laden environments is subject to its flexibility and reach. Limitations may be encountered in scenarios where debris is tightly packed or submerged, potentially impeding the arm's optimal functionality.
- Limitations in integration of Operator Feedback: While remote monitoring and control are integral features, the study recognizes the importance of human intervention and decision-making during critical missions. Limitations include addressing the seamless integration of operator feedback into the autonomous system for enhanced adaptability to evolving mission requirements.

6. CONCLUSION

6.1 Significance of the project

In addressing the challenges of flood relief, our autonomous flood relief robot, the Robot boat, is designed to excel in diverse water conditions. It offers adaptable solutions for tilting water, high-velocity flows, and debris-laden waters. These solutions are enabled by a combination of advanced control algorithms, dual-propeller propulsion, gyro stabilization technology, and a versatile robotic arm. Furthermore, the robot's autonomous navigation system ensures precise and adaptable movement, dynamically adjusting to environmental changes in real-time. The Robot boat stands as a resilient and technologically advanced asset in flood disaster relief efforts, promising efficient and secure navigation for the delivery of essential supplies to those in need.

6.2 Suggestions for future research

While our autonomous flood relief robot, the Robot boat, represents a significant advancement in addressing the challenges of flood relief, there are avenues for future research that could further enhance its capabilities. Firstly, investigating the integration of machine learning techniques into the autonomous navigation system could contribute to even more adaptive and predictive responses to dynamic environmental conditions. Additionally, exploring materials and designs for the boat's structure that optimize buoyancy and stability under extreme conditions could further improve its performance in challenging flood scenarios. Moreover, assessing the scalability of the technology and its cost-effectiveness for large-scale deployment in different geographical and socio-economic contexts would be crucial for widespread adoption. Lastly, considering community engagement strategies and the social impact of the Robot boat in disaster-prone regions could provide insights into optimizing its integration into existing disaster response frameworks. Future research endeavors in these directions would contribute to the continuous improvement and applicability of autonomous flood relief technologies, making them more robust and beneficial in real-world disaster scenarios.

ACKNOWLEDGMENT

Heartfelt gratitude is extended to Professor A.G.B.P. Jayasekara and Dr. R.M.M. Ruwanthika of the Department of Electrical Engineering at the University of Moratuwa for their invaluable guidance and support during this project. Their expertise has been instrumental in shaping the success of this endeavor.

REFERENCES

[1] A. Asvadi, C. Premebida, P. Peixoto, and U. Nunes, "3D Lidar-based static and moving obstacle detection in driving environments: An approach based on voxels and multi-region ground planes," Robotics and Autonomous Systems, vol. 83, pp. 299-311, 2016.

[2] Afridi, A., Samim, I., Ullah, S., Minallah, N., Ali, Z., and Khan, A. (2019, December). "Flood Rescue Operations Using Artificially Intelligent UAVs." In 2019 International Conference on Emerging Trends in Electrical, Electronic and Communications Engineering (ICETEECE), pp. 1-6.

[3] H. Osumi, "Application of robot technologies to the disaster sites," Report of JSME Research Committee on the Great East Japan Earthquake Disaster, pp. 58-74, 2014.

[4] I. M. Siregar, M. Yunus, and V. M. M. Siregar, "A Prototype of Garbage Picker Ship Robot Using Arduino Nano Microcontroller," Internet of Things and Artificial Intelligence Journal, vol. 2, no. 3, pp. 150-168, 2022.

[5] M. L. Edamo, T. Y. Ukumo, T. K. Lohani, M. T. Ayana, M. A. Ayele, Z. M. Mada, and D. M. Abdi, "A comparative assessment of multi-criteria decision-making analysis and machine learning methods for flood susceptibility mapping and socio-economic impacts on flood risk in Abela-Abaya floodplain of Ethiopia," Environmental Challenges, vol. 9, p. 100629, 2022.

[6] M. Melo, F. Mota, V. Albuquerque, and A. Alexandria, "Development of a Robotic Airboat for Online Water Quality Monitoring in Lakes," Robotics, vol. 8, no. 1, p. 19, 2019.

[7] R. R. Murphy, S. Tadokoro, and A. Kleiner, "Disaster Robotics," Springer Handbook of Robotics, pp. 1577-1604, 2016.