International Scientific Journal of Engineering and Management (ISJEM) ISSN: 2583-6129
Volume: 04 Issue: 06 | June – 2025 DOI: 10.55041/ISJEM04502
An International Scholarly || Multidisciplinary || Open Access || Indexing in all major Database & Metadata

Emergency Robotic Water Rescue System

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Abstract -
Drowning incidents often require immediate response to prevent loss of life, but traditional rescue methods can be delayed or risky. This paper presents a combined Emergency Robotic Water Rescue System that uses both a water robot and a drone to improve rescue efficiency and safety. The aerial drone is used for real-time surveillance, victim detection, and location tracking, while the water robot is deployed to reach the victim with a flotation device or towing support. The system is remotely controlled and designed to operate in various water environments, such as lakes, rivers, and flood zones. By integrating drone technology with robotic rescue, this system offers a faster, safer, and more effective solution for emergency water rescues.

Key Words: Hexacopter, Dropping Mechanism

1. INTRODUCTION

Water-related emergencies such as drowning incidents continue to be a major cause of accidental deaths around the world. Swift and effective response in such situations is often the difference between life and death. However, conventional rescue methods such as lifeguards swimming to the victim or using boats are frequently limited by distance, time, water currents, and environmental challenges. These limitations can put both the victim and the rescuer at significant risk, particularly in cases of floods, rough water conditions, or when the victim is panicking and difficult to reach quickly. To overcome these challenges, this paper presents the design and implementation of an Emergency Robotic Water Rescue System using a hexacopter drone. This system is developed as a fast-response, unmanned aerial solution capable of delivering a flotation device directly to a person in distress during water emergencies. By leveraging aerial mobility and remote operation, the system reduces rescue time and eliminates the need for rescuers to enter the water, thus enhancing both victim and rescuer safety. The hexacopter drone is chosen due to its stability, payload capacity, and ability to hover precisely over the target area. It is equipped with a simple mechanical payload release mechanism that can drop a life-saving.

Device such as an inflatable tube or life jacket into the water where the victim is located. The drone is manually operated via a handheld transmitter, allowing rescue personnel to maintain full control of the flight path and drop operation without relying on complex systems like GPS or cameras. This simplicity ensures that the system is affordable, easy to maintain, and reliable even in basic rescue environments or rural settings. The drone can be rapidly deployed within seconds and can cover distances faster than any swimming or boat-based response, especially in environments where access to the victim is obstructed or delayed. Moreover, the use of a hexacopter ensures redundancy in flight; even if one motor fails, the system can maintain stable operation, making it safer and more dependable in emergency conditions. This paper details the motivation, system design, components, working principle, and application scenarios of the Emergency Robotic Water Rescue System. The focus is on developing a cost-effective, portable, and efficient rescue tool suitable for use by lifeguards, disaster response teams, and community rescue volunteers. By integrating basic drone flight technology with a life-saving delivery mechanism, this system provides a valuable advancement in emergency rescue methods and contributes to enhanced public safety in water-prone areas.

OBJECTIVES

To utilize a hexacopter drone for rapid deployment over water bodies.
To design a lightweight and reliable dropping mechanism for payload release.
To reduce response time in drowning emergencies where traditional rescue methods are not immediately available.
To enhance safety by eliminating the need for human rescuers to enter dangerous or inaccessible waters.
To demonstrate the feasibility of aerial delivery systems in life-saving applications through prototype development and field testing.

WORKING PRINCIPLE

The system works on the principle of aerial delivery using a remotely operated drone, which employs a servo motor–based payload release mechanism to deliver a life-saving object, such as a life jacket, to a person in distress in a water body.
1. Remote Navigation of Drone: The hexacopter drone is flown from the shore using a remote controller or mobile app. A mounted FPV camera provides real-time visuals to locate the drowning victim.
2. Target Positioning: The drone hovers directly above or near the victim using GPS coordinates or manual control, maintaining a safe altitude.
3. Payload Holding Mechanism: A servo motor connected to a rotating shaft holds the life jacket (or rescue device) securely using clips or a hook mechanism.

4. Payload Release: Upon reaching the target, the servo is triggered remotely. It rotates the shaft, releasing the hook or moving the clip out of position, causing the life jacket to drop accurately into the water near the victim.
5. Rescue Completion: The victim uses the life jacket for flotation while rescue services are alerted or arrive by boat. The drone may remain overhead for monitoring or return to base. This principle combines aerodynamic flight, precision servo control, and remote communication to perform fast, contactless rescue assistance minimizing human risk and improving emergency response times.

3. PROPOSED METHODOLOGY

The proposed methodology aims to develop an aerial rescue system using a hexacopter drone equipped with a servo-based payload dropping mechanism to deliver a life-saving device (e.g., a life jacket) to a drowning victim.

1. System Architecture Design-Design the overall structure of the rescue system, including: Hexacopter frame, Flight control system, Camera module, Payload release mechanism. Decide component placement for optimal balance and center of gravity

2. Component Selection and Integration-Select appropriate components: Drone Frame: 6-arm hexacopter for better stability, Motors & ESCs: Brushless motors with suitable thrust, Flight Controller: GPS-enabled (e.g., Pixhawk, APM), Payload Mechanism: Servo motor (e.g., SG90 or MG90s), hooks/clips,Camera: Real-time video feed (FPV module or Wi-Fi camera) Integrate and wire all components on the drone.

3. Development of Dropping Mechanism-Design and 3D-print (or fabricate) a lightweight hook or latch system. Connect the system to a microcontroller (Arduino Nano/Uno) that controls the servo motor rotation. Test the mechanism for reliable opening and closing under payload stress.

4. Programming and Communication Setup-Code the servo motor to respond to a trigger signal from the remote control or mobile app. Use wireless communication (RF module or Bluetooth/Wi-Fi) to send commands to the drone's onboard controller.

5. Testing and Calibration-Conduct ground-level testing to ensure servo accuracy and payload stability. Perform flight testing to: Evaluate drone flight performance with load.Test the precision and reliability of the dropping mechanism.Measure the drop accuracy near the target area.

6. Real-Time Deployment Scenario-Simulate a drowning rescue operation: Fly drone to victim's location (50–100 meters from shore). Identify and stabilize above the victim using camera feed. Activate servo to drop the life-saving device.Monitor the victim until further help arrives

7. Performance Evaluation-Record drop success rate, time taken to reach victim, and stability of the drone during operation. Identify limitations and propose improvements (e.g., automated targeting, dual payloads).

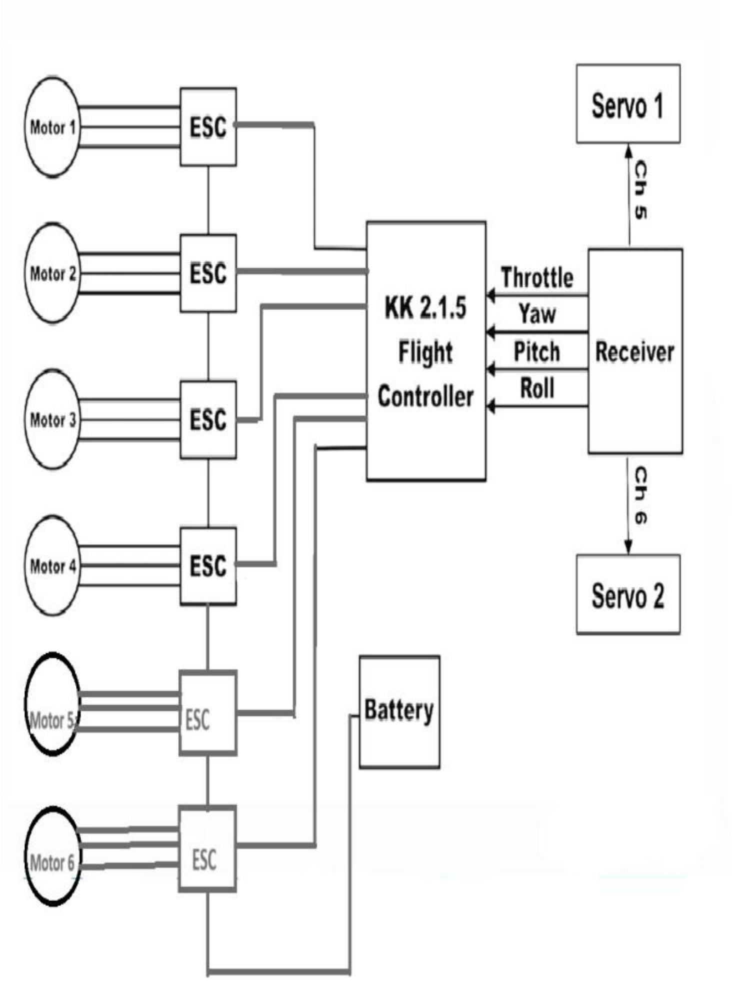

Fig 1. Block Diagram of the proposed model
The proposed model contains the following component as follows:

1. BLDC Motor (Brushless DC Motor - A2212/12T 1200KV): -

A Brushless DC Motor (BLDC) is a synchronous motor powered by direct current via an inverter or switching power supply. It does not use brushes like traditional DC motors. In this project, six A2212/12T 1200KV outrunner motors are used to provide thrust for the hexacopter.

Specifications:

Type: Outrunner motor
KV rating: 1200 (RPM per Volt)
Max Efficiency: 80%
Optimal Current Range: 4–10A
Applications: Suitable for drones and UAVs due to high efficiency and torque-to-weight ratio

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Fig.2 BLDC Motor (A2212/12T 1200KV)

2. Electronic Speed Controller (ESC – 30A)
The ESC is an electronic circuit used to control and regulate the speed and direction of the BLDC motors. It translates signals from the flight controller into electrical pulses that adjust motor speed.

Specifications
Input Voltage: 12V
Drive Current: 30A (Max 40A for short bursts)
BEC Output: 5V/3A (used to power other electronics)
Dimensions: 50mm × 23mm × 8mm
Function: Provides fast and efficient switching for precise motor speed control

Fig.3 Electronic Speed Controller (ESC – 30A)

3. Flight Controller (KK 2.1.5)
The flight controller serves as the central processing unit of the drone. It receives input signals from the transmitter, stabilizes the drone using onboard gyroscopes and accelerometers, and outputs signals to the ESCs.

Specifications:

Processor: Atmega644PA microcontroller
Sensors: InvenSense MPU6050 (3-axis gyro and accelerometer)
Input Voltage: 4.8V–6V
Features: Auto-leveling, LCD display for setup, real-time adjustment.
Output Signal: 1520µs PWM signals to ESCs
Ports: 6-pin AVR interface for firmware updates and debugging.

Fig.4 Flight Controller (KK 2.1.5)

4. Hexacopter Frame (F550)
The mechanical structure that holds all components together. It includes six motor arms with mounting brackets and a central body to house electronics and battery.

Specifications:
Model: F550
Material: Glass fiber and nylon composite arms
Wheelbase: 550 mm (distance between opposite motors)
Weight: Approx. 424 grams
Features: Lightweight, durable, modular design for easy assembly

Fig.5 Hexacopter Frame (F550)

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5. Transmitter (FS-i6 2.4GHz, 6 Channel)
A handheld radio transmitter used to send control commands to the drone via 2.4GHz frequency.

Specifications:
Frequency Range: 2.40–2.48GHz
Channels: 6 (configurable)
RF Power: <20dBm
Sensitivity: 1024 levels
Control Range: Up to 500 meters
Power Supply: 6V (4 x AA batteries)
Protocol: AFHDS 2A and AFHDS (automatic frequency hopping)

Fig.6 Transmitter (FS-i6 2.4GHz, 6 Channel)

Fig.7 Receiver (FS-iA6B)

7. Receiver (FS-iA6B)

Receives signals from the transmitter and relays them to the flight controller. It is mounted onboard the drone.

Specifications:
Channels: 6
Frequency Range: 2.4055–2.475GHz
Sensitivity: -105dBm
Antennas: Dual 26mm antennas for better reception
Input Voltage: 4.0–6.5V
Interfaces: i-BUS, PPM output for modern flight controllers

8. Li-Po Battery (11.1V, 2200mAh, 3S, 80C)

Provides power to the motors, flight controller, receiver, and servo. Chosen for its lightweight and high discharge capability.

Specifications:

Voltage: 11.1V (3 cells in series)
Capacity: 2200mAh
Discharge Rate: 80C (176A peak)
Charge Rate: 1–3C (5C max)
Connectors: XT-60 discharge, JST-XH balance plug
Weight: 175 grams
Use: Ideal for short, high-power drone flights

Fig.8 Li-Po Battery (11.1V, 2200mAh, 3S, 80C)

9. Servo Motor (MG995)

Used for the drop mechanism to release life-saving devices. Controlled via the receiver's auxiliary channels.

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Specifications:

Operating Voltage: 3.0–7.2V
Torque: Approx. 1.8 kg·cm (at 4.8V)
Speed: 0.10 sec/60° (at 4.8V)
Dimensions: 22.8 × 12.6 × 34.5 mm
Weight: 9 grams
Control Signal: PWM (pulse width modulated)

Fig.9 Servo Motor (MG995)

4. PROTOTYPE

To validate the functionality of the proposed drone-based rescue system, a working prototype was developed using a hexacopter drone platform. The hexacopter was chosen due to its superior stability, payload capacity, and flight control in comparison to quadcopters, especially in emergency situations. The drone frame was built from lightweight materials such as carbon fiber or reinforced plastic, and it was powered by a rechargeable lithium-polymer (Li-Po) battery to ensure sufficient flight time and reliable performance.

At the core of the rescue function lies a servo-operated dropping mechanism designed to release a life-saving payload, such as a life jacket. A compact micro servo motor was mounted beneath the drone and connected to a hook-based release system. The payload was securely held by the hook, which could be released by rotating the servo arm through a simple command. The servo was controlled either directly through a microcontroller like an Arduino Nano or through the auxiliary channel of the drone's flight controller, allowing remote triggering during flight.

For navigation and accurate delivery, the drone was equipped with a downward-facing camera, either an FPV module or a Wi-Fi-enabled camera, to provide a real-time video feed to the operator on the ground. This live feed enabled precise positioning of the drone above the target area where the victim was assumed to be struggling in the water.

Fig.10 Proposed Prototype

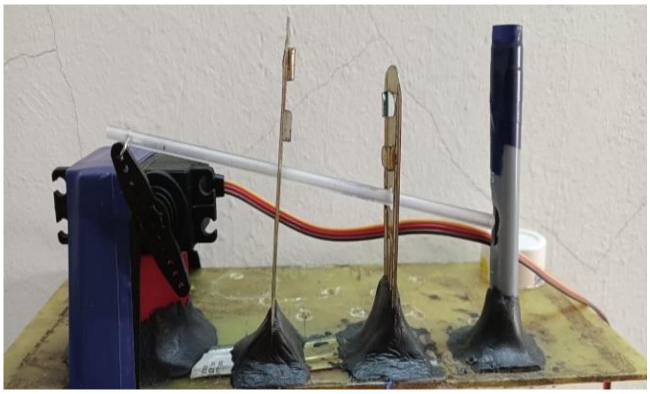
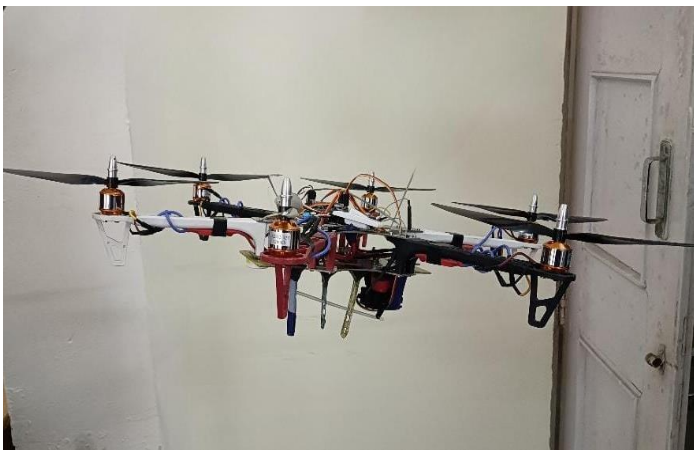


Fig.11 Rescue system



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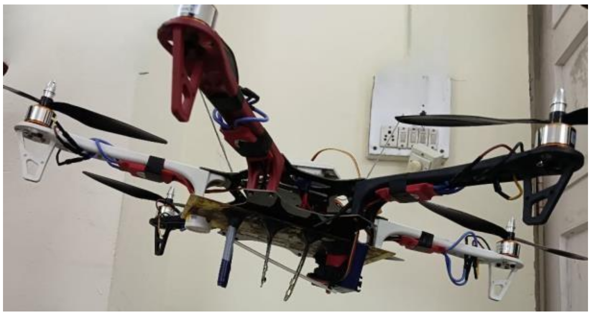

Fig.12 proposed prototype with application mounted

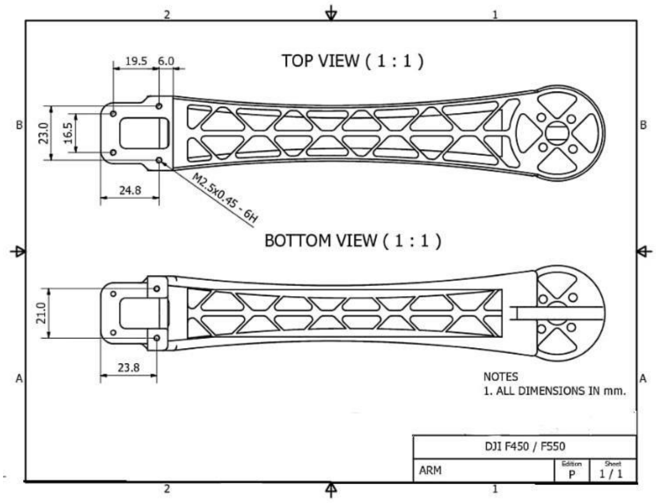

Fig.13 Hexacopter Arm structure with dimensions. (Top & Bottom view)

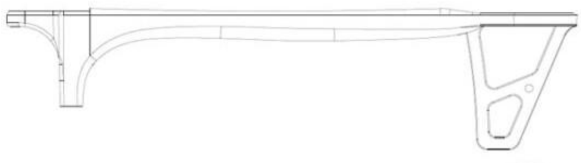

Fig.14 Hexacopter Arm Side view

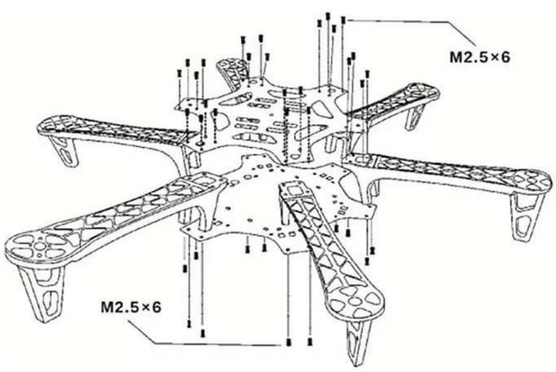

Fig.15 Hexacopter Structure With Dimensions

The entire system was operated using a standard 2.4 GHz remote controller for piloting, while the servo motor could be triggered either by the onboard system or a separate wireless control module.The prototype was tested in both open land and controlled water environments to assess its flight stability, payload release accuracy, and effectiveness in simulated rescue scenarios. The life jacket used for testing was a lightweight dummy to represent an actual emergency flotation device.

Overall, the prototype demonstrated the feasibility of using drone technology in emergency rescue operations by successfully flying to the target, hovering stably, and releasing the payload within an acceptable margin of accuracy. The system also showed potential for future enhancements, such as automated victim detection and GPS-guided navigation, making it a promising tool for rapid-response applications in drowning rescue situations.

5. MERITS OF THE SYSTEM.

The proposed drone-based water rescue system offers several significant advantages over traditional rescue methods. One of the primary merits is the rapid response time. Drones can be deployed almost instantly and can reach victims in distress within minutes, especially in areas where human access is limited or delayed. This is crucial in drowning situations, where every second counts. The system also ensures safety for rescuers, as there is no need for immediate human entry into dangerous or deep waters.

The hexacopter's stability and multi-rotor configuration provide high precision and control, enabling accurate payload drops even in moderately windy or unstable conditions. The use of a servo-controlled mechanism ensures reliable and repeatable operation of the payload release, making the system highly dependable. Additionally, the entire setup is cost-effective compared to deploying rescue boats or helicopters and can be easily maintained or scaled for wider coverage. The real-time camera feed further enhances situational awareness, allowing operators to make informed decisions during emergencies. Overall, the system is versatile, portable, and user-friendly, making it ideal for use by local authorities, lifeguards, or disaster response teams Environmental Impact Assessment.

The environmental impact of the drone-based rescue system is relatively low when compared to conventional rescue operations that involve fuel-powered boats or helicopters. Drones are powered by rechargeable lithium-polymer batteries, which produce no direct emissions during operation, thereby reducing the carbon footprint of rescue missions. The system produces minimal noise pollution, especially compared to engine-driven rescue vehicles, making it more suitable for use in natural habitats and ecologically sensitive zones. The lightweight construction materials and electronics used in the drone are typically non-toxic and have a low impact on the surrounding environment when handled and disposed of properly.

However, it is important to consider the life cycle impact of the components used. The batteries and electronic parts may pose a hazard if not disposed of responsibly, as they can lead to soil or water contamination. Therefore, proper recycling and e-waste management practices must be followed. Additionally, the drone should be operated in compliance with wildlife protection regulations, especially in areas near bird habitats or protected reserves, to avoid disturbing natural ecosystems.

In conclusion, the environmental impact of this system is minimal and manageable, especially when best practices in component disposal and flight regulation are followed. The system represents a sustainable and eco-friendly alternative to traditional emergency response method in aquatic environments.

CONCLUSION

The development and implementation of a drone-based water rescue system provide a practical, efficient, and innovative solution to the challenges faced in traditional rescue operations. By utilizing a hexacopter drone equipped with a servo-based dropping mechanism and a real-time camera system, rapid and precise delivery of life-saving equipment to drowning victims is made possible, even in remote or hard-to-reach locations.

The system significantly reduces response time, enhances the safety of rescuers, and improves thechances of survival for victims. Its portability, low cost, and minimal environmental impact make it highly suitable for use by emergency services, lifeguards, and disaster management agencies. With further enhancements such as GPS navigation, autonomous flight, and AI-based victim detection, the system holds strong potential for large-scale deployment and greater impact in emergency response scenarios.

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National Institute of Technology Silchar, Silchar 788010, India. This work
was supported by the Ministry of Electronics and Information
Technology, Government of India, through the program "Development of
National Disaster Spectrum (NDS) and Disaster Communication
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