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# "Design and Implementation of a Microcontroller-Based Borewell Rescue System with Drone-Assisted Monitoring."

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**Abstract:** Borewell accidents involving children have become a distressing and recurring tragedy, particularly in developing regions. Traditional rescue methods are time-consuming and often life-threatening. This paper presents the design and implementation of an innovative, cost-effective, and modular Microcontroller-Based Borewell Rescue System integrated with Drone-Assisted Monitoring. The system uses a NodeMCU microcontroller to control mechanical components such as a motorized rescue platform and a gripper unit, while a drone provides real-time visual surveillance. The proposed system was successfully tested under simulated conditions and offers a significant step toward safer and more efficient borewell rescue operations.

## I. INTRODUCTION

Uncovered borewells pose a critical safety threat, especially to children in rural and semi-urban areas. Rescues are often delayed due to narrow bore diameters and poor visibility. This research addresses these challenges through a microcontroller-driven system that combines embedded control, mechatronics, and drone-based aerial monitoring for accurate victim localization and safe extraction.

## II. RELATED WORK

Previous systems have used sensor-based autonomous robots or drone surveillance for search and rescue operations. However, these systems are typically expensive and complex, requiring advanced processing and sensor fusion. Our proposed system minimizes reliance on costly sensors by emphasizing remote human control via live camera feedback and affordable microcontrollers, simplifying deployment and reducing costs.

## III. SYSTEM DESIGN

### 3.1 Architecture

The system is divided into:

- **Part A**: A motorized up-down mechanism controlled via NodeMCU and L298N motor driver.
- **Part B**: A gripper-based rescue module equipped with a live-stream camera and Wi-Fi-controlled gripper.

### 3.2 Modules

- **NodeMCU Control Unit**: Handles all coordination using Wi-Fi communication.
- **Drone Monitoring Unit**: Equipped with a high-resolution camera for borewell inspection.
- **Mechanical Gripper**: Motor-actuated and padded for safe victim handling.
- **Power Supply Unit**: Portable 12V battery with buck converters for voltage regulation.

### 3.3 Drone Integration for Monitoring and Guidance

Drone-assisted monitoring is a key innovation in this rescue system. The drone is equipped with a high-resolution Wi-Fi camera and communicates with the rescue command unit to provide continuous visual feedback of the borewell surroundings and interior.

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**Key Roles of the Drone:**

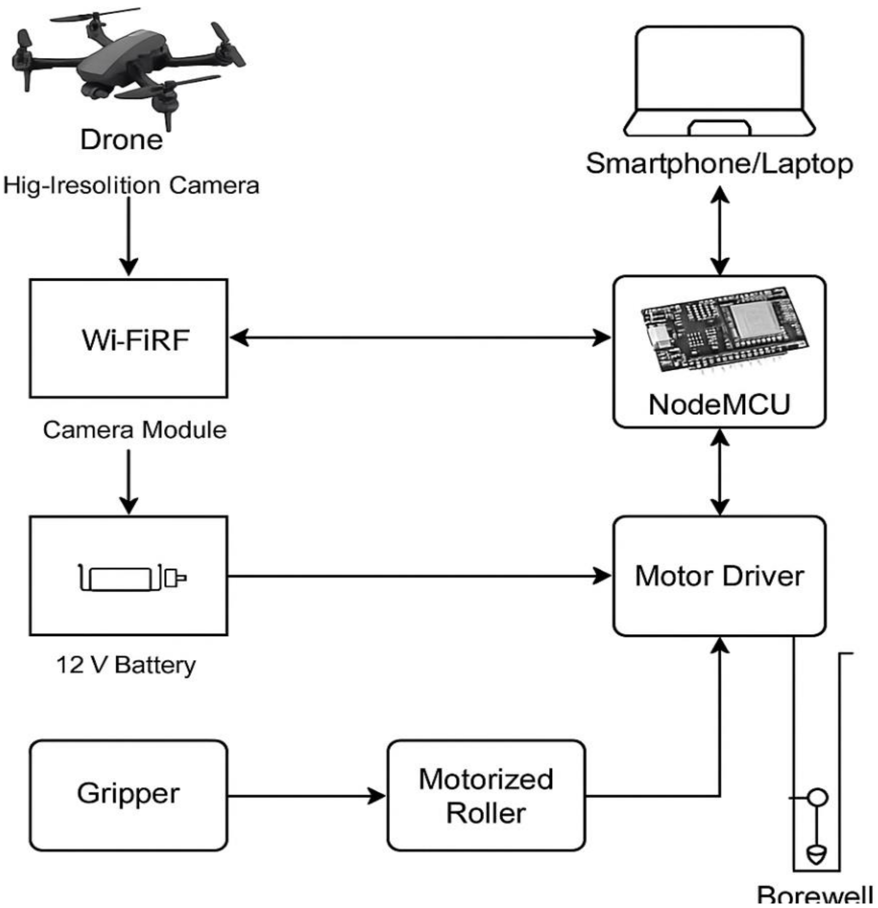
- **Pre-deployment Surveillance:** Before deploying the rescue platform, the drone is flown above and around the borewell to assess the terrain, confirm borewell diameter, and detect any obstacles or hazards near the mouth.
- **Interior Borewell Inspection:** A compact drone (or drone-mounted camera module on a tether) is lowered partway into the borewell for initial scanning. It helps determine the depth, victim's position, and any obstructions.
- **Live Feed Transmission:** The camera onboard the drone transmits real-time video feed to a smartphone or laptop via Wi-Fi or RF module. This feed is critical for guiding the gripper and vertical movement accurately.
- **Lighting and Visibility:** For dark or deep borewells, the drone may include an LED lighting system synchronized with the camera, improving visual clarity in low-light conditions.

**Technical Features:**

- **Camera Resolution:** 720p or 1080p with 30 fps for clear image recognition.
- **Transmission Protocol:** TCP/IP over 2.4 GHz Wi-Fi; alternative configurations can use 5.8 GHz RF modules for extended range.
- **Stabilization:** Drone includes basic altitude hold and gyroscope-based stabilization for steady video during hover.

**Battery Life:** 10–15 minutes of continuous flight; tethered options considered for extended operation.

Block diagram:




## IV. IMPLEMENTATION

### 4.1 Hardware

- NodeMCU ESP8266/ESP32
- L298N motor driver
- 60 RPM Box Gear Motor
- ESP32-CAM

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- Servo-actuated Gripper
- 12V Lithium-ion battery
- 2-channel relay module

### 4.2 Software

- Programmed using NodeMCU IDE (Arduino framework).
- Embedded C code handles motor and relay control, gripper actuation, and serial communication.
- Live feed from the ESP32-CAM displayed via mobile/web interface.

### 4.3 Drone-Assisted Monitoring Module (Hardware and Software Integration)

This module supports aerial reconnaissance and visual guidance throughout the rescue operation.

#### 4.3.1 Hardware Components:

- **Quadcopter Drone:** Medium-sized drone with 6-axis stabilization and 2 kg payload capacity.
- **Camera Module:** Integrated HD camera with pan/tilt servo mount (optional) for adjustable viewing angles.
- **Lighting System:** Low-power LED array powered by the drone battery or external tether line.
- **Wireless Communication:** Wi-Fi-based ESP32-CAM or analog FPV transmitter module for real-time video stream.

#### 4.3.2 Software & Control:

- **Mobile App Interface:** Custom or existing app (like FPV Viewer) used for viewing the live stream and capturing footage.
- **Optional AI Add-on:** Future upgrades include object tracking or thermal imaging for enhanced victim localization.
- **Command Relay:** Drone can operate in conjunction with the NodeMCU system; rescue commands are aligned based on drone feedback.

#### 4.3.3 Operational Workflow:

1. **Initial Scan:** Drone is deployed to inspect the area and borewell shaft.
2. **Live Feed Monitoring:** Operators observe the drone’s video feed to guide the rescue platform.
3. **Real-Time Adjustments:** Feedback from the drone is used to fine-tune gripper position and vertical movement.
4. **Post-Rescue Confirmation:** After victim extraction, drone reassesses the shaft to ensure no obstruction remains.

**Benefits of Drone Integration:**

- **Non-contact Situational Awareness:** Drones provide critical visual data without interfering with the rescue hardware.
- **Remote Operation:** Enables safe reconnaissance without physical access to the borewell.
- **Precision and Speed:** Visual feedback helps reduce guesswork and speeds up rescue decision-making.
- **Scalability:** The drone system can be reused or repurposed for other emergency or inspection tasks.

## V. RESULTS AND TESTING

### 5.1 Testing Scenarios

- Simulated borewell descent and rescue.
- Gripper functionality tested with various object sizes.
- Drone tested for indoor hovering and video transmission.
- Relay and motor circuits validated under different loads.

### 5.2 Observations

- Stable Wi-Fi communication and real-time monitoring.
- Controlled and safe operation of gripper and platform.
- Clear video transmission from drone and borewell camera.

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## VI. DISCUSSION

The system's modular architecture allows easy troubleshooting, future upgrades (IoT, AI-based vision), and flexible testing. Human-controlled decisions based on live video improve safety and responsiveness compared to autonomous systems prone to sensor errors.

## VII. CONCLUSION

The borewell rescue system developed offers a functional, low-cost, and scalable solution for real-time rescue operations. It effectively combines embedded systems, mechanical actuation, and drone monitoring to enhance rescue speed and victim safety.

## VIII. FUTURE WORK

- Integrate IoT dashboards for environmental monitoring.
- Add AI-enabled object detection and thermal imaging.
- Include vital sign sensors for victim health monitoring.
- Enhance night operation capabilities with infrared support.

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