

Development of a Smart Borewell Surveillance and Emergency Response System for Child Rescue Application

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Abstract: Bore wells are narrow and deep cylindrical excavations used for various purposes, such as water extraction or geological exploration. Accidental falls or entrapments in bore wells pose significant challenges for rescue operations due to limited access and potential hazards. Therefore, developing a specialized robot for borewell rescue can enhance the efficiency and safety of such operations. The present work involves the development of a bore well rescue robot equipped with an ESP32 microcontroller, high torque DC motors, a camera module, and a mechanical gripper. The robot is designed to navigate and perform rescue operations in narrow bore well environments, where human access is limited or hazardous. Thus a robust and efficient robot has been developed capable of reaching and retrieving individuals trapped in borewells, thereby reducing the risks and time associated with manual rescue operations.

Keywords: Borewell rescue, Smart monitoring, Child safety, Robotic automation

1.0 Introduction: In many regions, open and abandoned bore wells pose a significant threat to child safety, often leading to complex and time-sensitive rescue challenges. Traditional rescue methods, which frequently involve digging a parallel pit, are extremely slow and can further endanger the victim. A Smart Bore well Child Rescue System is an innovative robotic solution designed to descend into the narrow shaft, monitor the victim's condition, and perform a safe retrieval. The system is equipped with high-resolution cameras and sensors to provide rescuers with live visual feedback and vital environmental data. It utilizes specialized mechanical arms or grippers to securely hold the child during the ascent. This robotic

platform minimizes the need for manual excavation, significantly reducing rescue time and improving the chances of a successful outcome.

2.0 Literature Review: Albert Martin Ruban et al [1] developed portable real-time smart child rescue system. The equipment module in this task will make use of an ESP32S as a camera is used to continuously monitor the child's condition to analyze a child's facial expressions to determine whether or not. If they are in danger Music is played to keep the children quiet. A web application is used to control and monitor the entire system. R.Logarasu et al [2] The system integrates advanced hardware, wireless monitoring technologies, and Artificial Intelligence (AI) to offer a proactive and intelligent approach to bore well safety. Employing a network of strategically placed sensors and wireless communication protocols, the hardware architecture enables real-time data processing at a central control unit. The incorporation of AI algorithms enhances the system's intelligence, allowing it to discern between routine activities and emergencies by analyzing sensor data patterns. This intelligent approach minimizes false alarms and ensures timely responses to critical situations. Notably, the system not only focuses on monitoring but actively assists in rescue operations, providing real-time data on the child's location within the bore well. This information aids rescue teams in optimizing efforts, reducing response times, and increasing the likelihood of successful rescue missions.

3.0 Methodology: The Smart Borewell Child Rescue System is designed to monitor and assist in rescuing a child trapped inside a borewell using IoT-based

technologies. Initially, the system is powered through a regulated supply using the LM2596 DC step-down module, which ensures stable voltage to all components. Once deployed into the bore well, the ESP8266 Node MCU acts as the main controller, coordinating all sensor inputs and communication processes. The HC-SR04 ultrasonic sensor is used to measure the depth and detect the position of the child inside the bore well. Simultaneously, the DHT sensor continuously monitors temperature and humidity levels, while the MQ135 gas sensor detects air quality and identifies the presence of harmful gases. The FC-28 sensor is used to sense soil moisture or underground conditions, which may affect rescue operations.

3.1 System Architecture: The System consists of the ESP8266 NodeMCU as the main controller connected to sensors and modules. Sensors like DHT, MQ135, HC-SR04, and FC-28 collect environmental and positional data. ESP32-CAM provides live video monitoring, while LM2596 ensures stable power supply. A servo motor with a robotic gripper performs the rescue operation based on processed data.

3.1.1 Power Generation and Management Module: Utilizes a high-capacity Lithium Polymer (LiPo) battery to provide stable current to high-torque DC motors and the control unit.

3.1.2 Control Unit: An ESP32 or ESP8266 Node MCU brain that processes user commands from a remote station and manages the movement of rescue arms.

3.1.3 Sensing and Detection Module: Integrated with an ESP32-CAM to provide 360-degree visual monitoring and an O2 sensor to ensure the child's breathing environment is stable.

3.1.4 Mobility and Actuation Module: High-torque DC geared motors drive a lead-screw mechanism or a pulley system to provide the necessary lifting force.

3.1.5 Communication Module: Operates via Wi-Fi modules to allow rescuers to operate the robot from a safe distance using a mobile app. It serves as the vital link between the robot's on board microcontroller and the user, allowing for real-time monitoring of Child.

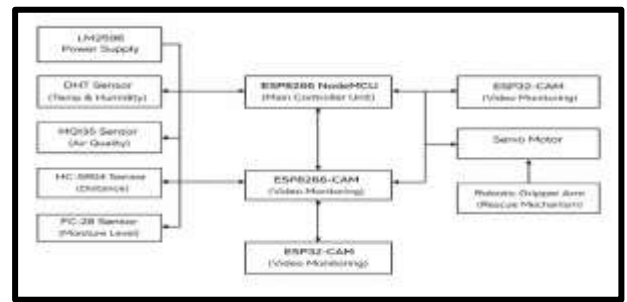


Fig.1. Block Diagram of Implemented Work

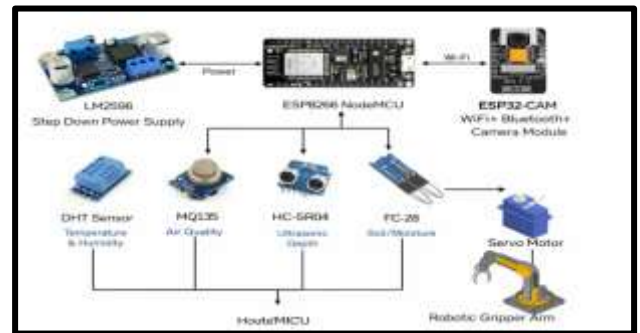


Fig.2. Diagram indicating various components of Smart Rescue Robot

4.0 Working of Robot: The robot is lowered into the bore well using a motorized winch or a rack-and-pinion setup. The ESP32-CAM transmits live footage to the rescue team's monitor. The team checks the child's position and health via onboard sensors. If the MQ-135 sensor detects low oxygen, an integrated tube attached to the robot provides a fresh air supply to the victim. Once the robot reaches the victim, the operator uses the mobile app to position the robotic arms. The high-torque motors engage the grippers. After securing the child, the winch mechanism safely pulls the robotic platform back to the surface.

5.0 Hardware: The smart rescue robot equipped with several hardware components which are described under following section with specifications.

5.1 Step Down Power Supply: The LM2596 is a popular monolithic step-down (buck) switching regulator designed to efficiently reduce a higher DC input voltage to a lower, stable output voltage. It is widely used in DIY electronics, robotics, and battery powered projects because it can handle up to 3A of load current with high efficiency (up to 92%).

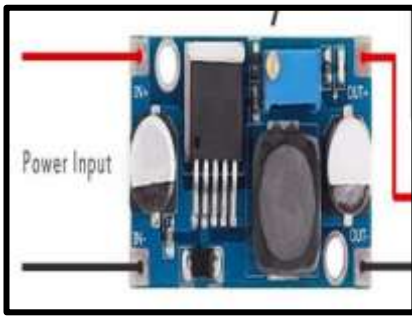


Fig.3 Step Down Power Supply

5.2 DC Motor: Motor is a compact electro mechanical actuator designed for applications that demand controlled low speed and reliable torque output. Operating typically on 6-12 V DC, this motor converts electrical energy into smooth rotational motion through an integrated gear reduction system.



Fig.4 DC Motor

5.3 Microcontroller (ESP8266): is a low-cost, high-performance Wi-Fi microcontroller module developed by Systems, engineered to enable seamless Internet of Things connectivity. It integrates a 32-bit Ten silica L106microprocessor, operating at 80 MHz.



Fig 5.ESP8266 Microcontroller

5.4 Vision Module (ESP32): is a compact, low-cost embedded vision module developed by Systems, designed to deliver Wi-Fi and Bluetooth-enabled image processing in resource- constrained environments. It is powered by the ESP32 dual-core 32-bit microcontroller, operating at up to 240 MHFz.



Fig.6 ESP32 Vision Module

5.5 Lithium Polymer battery:A rechargeable battery commonly used in drones, RC cars, robotics, and other portable electronics 6 batteries with 2.7 Volts each.



Fig 7.LithiumPolymer (LIPO) Battery

5.6 DHT Sensor :A DHT sensor (Digital Humidity and Temperature) is a low-cost electronic device used to measure ambient temperature and relative humidity. It typically combines a capacitive humidity sensor and a thermistor to sense environmental changes, which are then converted into a digital signal by an integrated 8-bit microcontroller.

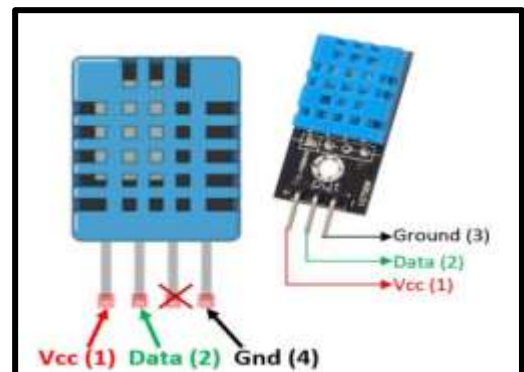


Fig8. Digital Humidity and Temperature Sensor.

5.7 Air Quality Sensor :The MQ-135 is a versatile semiconductor sensor designed for monitoring air quality by detecting a broad range of gases, including ammonia (NH3), nitrogenoxides(NOx), alcohol, benzene, smoke , and carbon dioxide (CO2). It is commonly used in both domestic and industrial air pollution detection systems due to its low cost and high sensitivity.



Fig 9. Air Quality Sensor

5.8 Ultrasonic Sensor (HC-SR04) : The HC-SR04 is a popular, low-cost ultrasonic distance sensor that uses sonar to measure the distance to an object. It is widely used in hobbyist electronics, robotics for obstacle avoidance, and security systems.



Fig 10. Ultrasonic sensor

5.9 Soil Moisture Sensor : The FC-28 is a low-cost, resistive soil moisture sensor used to measure the water content in soil. It operates by passing an electric current between two probes; since water is a conductor, wet soil has lower resistance, while dry soil has higher resistance.

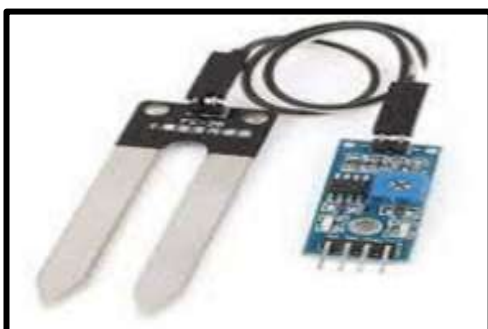


Fig 11. Soil Moisture Sensor

5.10 Servo Motor : The SG90 is a popular 9g micro servo motor widely used in hobbyist electronics, robotics, and RC models. It is a "closed-loop" system,

meaning it uses internal feedback from a potentiometer to move to and hold a specific angular position (typically 0° to 180°) based on a Pulse Width Modulation (PWM) signal.



Fig 12. Servo Motor

5.11 Robotic Gripper Arm : Robotic gripper arms, or end-effectors, serve as the "hands" of a robot, allowing it to interact with and manipulate physical objects. Depending on your needs—whether you're looking for an industrial solution, a research platform, or a DIY hobby kit—there are several specialized types available.



Fig. Robotic Gripper Arm

- **6.0 Results and Discussion:** The system successfully uses ultrasonic sensors to accurately determine the child's depth.
- camera modules (ESP32-CAM) to provide live video feeds, ensuring constant surveillance of the child's condition.
- Temperature (DHT11) detects the humidity and temperature accurately.
- A robotic arm/grapppler mechanism, driven by DC motors, securely handles the child.
- The system uses IoT (Blynk/Wi-Fi) to send real-time data and alerts to officials' smartphones, allowing for efficient, data-driven decision-making.
- Camera enabled real-time monitoring.
- Controlled wirelessly with good response.



Fig.14 Smart Resuce Robot

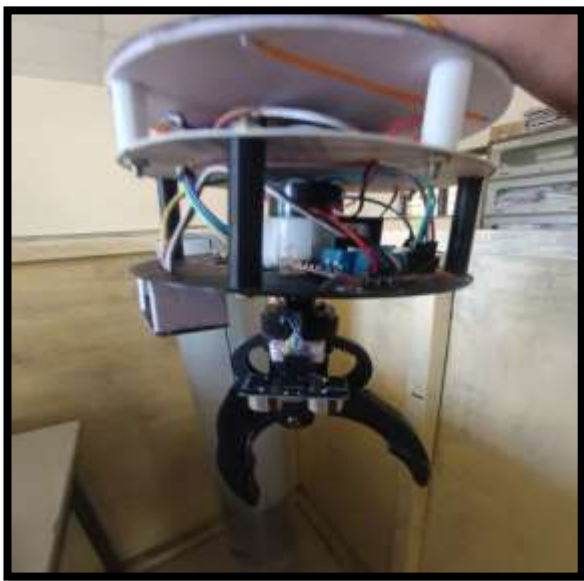


Fig.15 Smart Rescue Robot Arm

7.0 Conclusions: The smart borewell child rescue system proves to be a practical, life-saving alternative to traditional digging methods. By integrating real-time monitoring and specialized mechanical grippers, the system significantly reduces the time required for a rescue operation. It is a cost-effective, portable, and efficient solution for national disaster response teams.

8.0 Future Scope of Work: Implementing Artificial Intelligence (AI) and Machine Learning to automatically identify the best "grip points" on the victim to prevent slipping. Integrating a dedicated medical-grade oxygen concentrator attachment. Using fiber-optic cables for communication to allow the robot to operate at depths exceeding 500 feet where wireless signals fail. Adding night vision and thermal cameras to locate victims in pitch-black or muddy conditions.

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