BOREWELL RESCUE SYSTEM

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ABSTRACT

Child fatalities due to borewell accidents remain a pressing issue in developing nations, with conventional rescue methods often proving ineffective. This research explores the development and implementation of an automated borewell rescue system, emphasizing its significance in emergency rescue operations. The study presents an in-depth analysis of the system's design, components, and functionality, highlighting innovative methodologies and findings. The proposed approach aims to enhance the efficiency and accuracy of borewell rescues, ensuring the safe retrieval of trapped individuals. The system integrates real-time environmental monitoring, controlled actuation, and wireless communication. It employs a motorized retrieval mechanism controlled by an Arduino Uno microcontroller, with a DC motor-driven lifting mechanism ensuring stable vertical movement and precise control during rescue operations. Environmental sensing includes a DHT11 sensor for temperature/humidity (±2°C, ±5% RH accuracy) and an MQ-7 gas sensor with a detection range of 20-2000 ppm CO. Real-time visualization is achieved through a CCTV camera, while a two-way audio system (20 Hz-20 kHz bandwidth) maintains rescuer-child communication. The system's modular design, low cost, and effectiveness in confined rescue operations make it a viable solution for widespread deployment in rural areas.

Keywords: Borewell Rescue, Arduino, Robotic Arm, Sensors, Real-Time Monitoring, Automation.

1. Introduction

The frequent and tragic incidents of children falling into abandoned borewells have emerged as a critical public safety concern in India, particularly in rural regions. These narrow, deep vertical shafts—often ranging from 100 to 1,000 feet—are typically left uncovered after use, inadvertently creating hazardous traps. The victims, often young children, face life-threatening conditions within minutes, while rescue operations remain complex, resource-intensive, and frequently unsuccessful due to technological and logistical limitations.

Traditional rescue approaches, such as drilling parallel shafts, are slow, laborious, and fraught with uncertainty. Depending on soil conditions and borewell depth, these methods can take over 30 hours to complete—time during which the child is exposed to severe environmental hazards including oxygen depletion, accumulation of toxic gases such as methane, and extreme temperature variations. Furthermore, the lack of visualization and environmental sensing significantly impedes accurate assessment and timely intervention.

This paper proposes a novel, automated borewell rescue system that addresses the limitations of current methods through the integration of advanced technologies. The system is centered around a flexible robotic arm controlled by an Arduino microcontroller, outfitted with temperature and gas sensors, and a real-time video camera. This configuration enables continuous environmental monitoring and live visual feedback, allowing rescuers to make informed decisions during the operation. The design also minimizes the need for human entry into confined spaces, thereby reducing risk to rescue personnel.

By leveraging embedded systems, robotic manipulation, and sensor integration, the proposed solution aims to enhance the efficiency, precision, and safety of borewell rescue operations. It provides a technologically advanced alternative to traditional methods, offering the potential to significantly improve survival outcomes in such emergencies. The development and deployment of this system could represent a critical step toward mitigating the recurring tragedy of borewell-related fatalities in India.

2. Literature Review

The alarming rise in borewell accidents, particularly involving children, has prompted extensive research into advanced technological solutions for improving rescue efficiency and safety. Several innovations have emerged in recent years, spanning robotic systems, Internet of Things (IoT)-based frameworks, and automated mechanical interventions.

One notable development is the air-assisted pneumatic borewell rescue system, which utilizes inflatable airbags to provide cushioning and support to the trapped child. These airbags, precisely controlled via a pneumatic mechanism, prevent further descent and stabilize the child during rescue. The system also incorporates real-time monitoring using an onboard camera and oxygen supply, thereby reducing physical strain on the child and enhancing rescue safety and speed [1].

Another significant innovation is the autonomous subsurface exploration and extraction system, which employs a robotic arm capable of manoeuvring within narrow borewell confines. Equipped with environmental sensors, vision modules, and a gripper mechanism, the robotic arm autonomously navigates and interacts with its surroundings. Advanced control algorithms and real-time data processing facilitate the gentle extraction of the child, minimizing human involvement and enhancing operational accuracy [2].

The integration of IoT technologies into borewell rescue operations has further enhanced remote monitoring and control capabilities. Systems based on microcontrollers such as the ESP32 utilize sensors (e.g., ultrasonic, temperature) and cameras to gather live data, which is transmitted to a cloud interface accessible through mobile applications. These systems not only provide situational awareness but also enable precise robotic interventions, significantly reducing reliance on traditional, labour-intensive methods [3].

The Octobot, a bio-inspired soft robotic solution, presents another innovative approach. Featuring inflatable balloon technology, a soft gripping mechanism, night-vision capabilities, and an oxygen delivery system, the Octobot autonomously descends into the borewell. It secures the child with minimal force and relays real-time video to the surface. Controlled via a mobile app, the system offers a balance of flexibility, safety, and precision [4].

Several borewell rescue robots have also been engineered to function within the constrained geometry of borewells. These robots combine robotic arms, mechanical grippers, and advanced sensors to facilitate child retrieval. Integrated with artificial intelligence (AI) and machine learning (ML), these systems can adapt to dynamic conditions, making real-time decisions to optimize rescue procedures [5].

A preventive strategy is exemplified by the Smart Child Rescue System (SCRS), which seeks to avert fatalities by intervening early. Utilizing PIR sensors at the borewell opening, the system detects a fall and activates an automatic horizontal barrier at a depth of five feet to arrest further descent. Simultaneously, it alerts emergency responders via a GSM module. Built on a Raspberry Pi platform, the SCRS offers a low-cost, proactive solution to borewell safety [6].

These studies and innovations collectively underscore the potential of technology-driven solutions in addressing the challenges of borewell rescue operations. However, there remains a need for systems that integrate these advancements into a unified, deployable rescue platform that combines precision, speed, and continuous situational awareness.

3. Methodology

The Borewell Rescue System is designed with multiple components to ensure a safe and efficient rescue process. The system operates through the following key phases:

Deployment of the System: The robotic system, equipped with a camera, sensors, and a robotic arm, is lowered into the borewell using a Johnson Gear Motor-driven pulley system. The controlled descent ensures stability and prevents unnecessary impact with borewell walls.

Real-Time Monitoring: An WIFI camera continuously transmits live video feedback to a monitor or mobile device. The infrared capability ensures visibility in dark borewell environments. The camera assists in locating the trapped child and assessing their physical condition.

Environmental Analysis and Safety Assessment: DHT11 Sensor: Measures temperature and humidity inside the borewell, ensuring the environment is safe for the trapped child.

MQ-7 Sensor: Detects carbon monoxide levels and alerts rescuers if the concentration exceeds safe limits. The environmental data is continuously updated and displayed to rescue operators.

Robotic Arm Operation: The robotic arm, controlled by servo motors, is maneuverer using an Arduino system. The arm is programmed to extend, grip, and adjust movements based on real-time feedback from the camera. The servo motors allow precise control over the gripping mechanism, ensuring a secure yet gentle hold on the child.

Two-Way Communication: A built-in microphone and speaker facilitate real-time communication between the trapped child and the rescuers. This allows rescuers to provide reassurance, gather information about the child's condition, and give necessary instructions. Communication is enabled through a wireless module and can be accessed via a mobile interface.

Lifting Mechanism and Safe Retrieval: Once the child is securely held, the system is raised using the motorized pulley system. The PWM speed controller ensures smooth lifting without sudden jerks, minimizing risk during extraction. continuous video feedback ensures that adjustments can be made in real time to prevent injuries.

Post-Rescue Safety Checks: Once retrieved, the child is immediately assessed for oxygen levels and any potential exposure to toxic gases. The data collected during the rescue process is analysed to improve future rescue operations. This methodology ensures a systematic, controlled, and precise rescue operation, significantly reducing risks and improving success rates.

A. ***System Components***

The proposed borewell rescue system is a modular, sensor-integrated robotic platform designed to enable safe, rapid, and autonomous extraction of children trapped in borewells. It incorporates several critical components that work in coordination to provide environmental monitoring, real-time communication, and precision control within the constrained vertical shaft of a borewell.

- Microcontroller Unit: At the core of the system is the Arduino Uno, which serves as the central processing unit. It is responsible for acquiring sensor data, controlling the servo motors, and managing system logic. Its lightweight architecture and compatibility with a wide range of sensors make it ideal for real-time embedded applications.
- DHT11 Sensor: This sensor measures temperature and humidity within the borewell. Continuous monitoring of environmental conditions helps ensure the safety of the trapped child and informs necessary actions for ventilation or thermal management.
- MQ-7 Gas Sensor: Specifically designed to detect carbon monoxide (CO), the MQ-7 triggers alerts when toxic gas concentrations exceed predefined safety limits. Early detection of harmful gases is essential for planning effective rescue strategies and supplying clean air.

Visual Monitoring System

A Wi-Fi-enabled camera module provides real-time video streaming of the borewell interior. This visual feedback is crucial for assessing the child’s condition, positioning the robotic arm, and guiding the overall rescue operation.

Robotic Manipulation Mechanism

The robotic arm is actuated using SG90 servo motors, which offer precise angular control necessary for maneuvering within the narrow borewell. The arm is equipped with a gripper mechanism to gently secure and retrieve the child without causing harm.

Communication Interface

To provide psychological reassurance and enable interaction with the child, the system integrates a microphone and speaker. This two-way communication module allows rescuers to talk to the child, reducing panic and gathering important information about the child’s physical state.

Motorized Descent and Ascent Control

The vertical movement of the rescue system is managed by a Johnson Gear Motor coupled with a Pulse Width Modulation (PWM) speed controller. This configuration ensures smooth and controlled lowering and lifting of the robotic unit, preventing abrupt motions that might cause distress or further risk to the trapped child

Figure 1. Borewell Interior View Captured by Camera

Figure 2. Borewell Rescue System

4. Results and Discussion

To validate the efficiency and practicality of the proposed borewell rescue system, a functional prototype was developed and rigorously tested under controlled conditions simulating real-world scenarios. The results demonstrated a significant reduction in rescue time when compared to traditional manual methods, with the system completing the retrieval process within minutes rather than the several hours typically required for conventional digging operations. The inclusion of real-time monitoring through sensors and a camera module enabled rescuers to make informed decisions during the rescue process, thereby minimizing risks associated with blind or imprecise extraction efforts. The system also exhibited strong environmental adaptability, functioning effectively in borewells of varying depths and diameters, which highlights its versatility for deployment across diverse geographical locations. Additionally, the motorized pulley system and servo-controlled robotic arm operated with high stability and precision, ensuring smooth vertical movement and careful handling of the trapped subject without sudden jerks or mechanical faults. Overall, the integration of robotics, environmental sensors, and communication technologies into a single cohesive platform has proven to be an effective and scalable approach to enhancing the speed, safety, and reliability of borewell rescue operations.

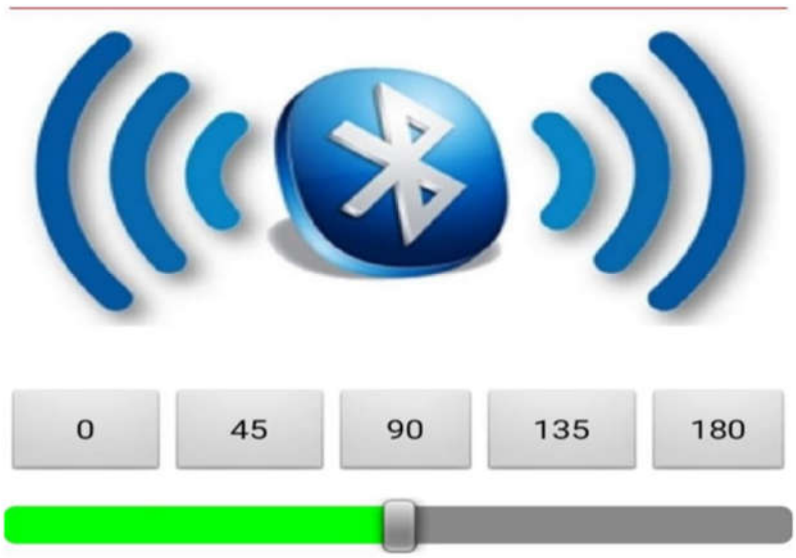

Figure 3. Mobile app interface for servo motor control

Figure 4. DHT11 Sensor output displayed on LCD

Figure 5. MQ7 Sensor output displayed on LCD

5. Conclusion

The proposed Borewell Rescue System demonstrates a comprehensive integration of robotics, sensor technologies, and wireless communication to offer a safe, efficient, and automated solution for rescuing individuals trapped in borewells. By leveraging an Arduino-controlled robotic arm, Wi-Fi-enabled camera module, environmental sensors, and a motorized pulley mechanism, the system significantly improves upon conventional manual rescue techniques. The servo motor-actuated robotic arm, adjustable via a mobile interface, enables precise manipulation and secure handling, thereby minimizing the risk of injury to the trapped individual. Continuous real-time monitoring of environmental parameters such as temperature, humidity, and toxic gas concentration facilitates rapid decision-making and enhances operational safety. Furthermore, the incorporation of a two-way communication module allows rescuers to maintain contact with the victim, offering both psychological reassurance and situational awareness. The system's modular design ensures adaptability to borewells of varying diameters and depths, making it a scalable solution for diverse field conditions. Extensive prototype testing has validated the system's performance, confirming its ability to deliver stable lifting operations, accurate remote control, and real-time data transmission. With its emphasis on automation, reduced human intervention, and improved rescue success rates, this system represents a significant advancement in borewell rescue technology. It holds strong potential for deployment by emergency response teams, contributing to faster, safer, and more reliable rescue operations in the future.

References

[1] R. L. Raja Singh, R. Selvamathi, G. Gokul and P. I. P. Jose, "Design and Development of Air Bag Assisted Pneumatic Borewell Rescue System," *2024 7th International Conference on Devices, Circuits and Systems (ICDCS)*, Coimbatore, India, 2024.

[2] M. D. C, G. A, V. A, M. K, A. K. H and J. K. NK, "Autonomous Subsurface Exploration and Extraction System: Robotic Arm-Assisted Borewell Rescue Initiative," *2024 Third International Conference on Intelligent Techniques in Control, Optimization and Signal Processing (INCOS)*, Krishnankoil, Virudhunagar district, Tamil Nadu, India, 2024.

[3] M. Ramkumar, J. K, J. B. M S and B. G, "IoT-based Child Rescue System from Borewell," *2022 6th International Conference on Electronics, Communication and Aerospace Technology*, Coimbatore, India.

[4] Devi, A. & Dhivya, K & Srivani, C & Senthilnayaki, S & Devi, P. Dharanya. (2023), "*Octobot for Child Rescue from Open Bore Well*" 2023 Third International Conference on Smart Technologies, Communication and Robotics (STCR)

[5] Rajarathnam D.R.P, Lakshmi Raj Thilak R, Rithvik K, Vignesh G, Mohamed Marsook Hameed SH, "*Borewell Rescue Robot*" International Journal of Modern Research in Engineering and Technology (IJMRET),Volume 3 Issue 4 , April 2018.

[6] G. Kavianand, K. G. Ganesh and P. Karthikeyan, "*Smart child rescue system from borewell (SCRS)*," 2016 International Conference on Emerging Trends in Engineering, Technology and Science (ICETETS), Pudukkottai, India, 2016