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AI Integrated Cloud-based Smart Child Rescue System for Open Bore Well Safety

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Abstract: ***Open bore wells pose significant safety risks, especially to children, with many incidents leading to life-threatening situations from accidental falls. Traditional rescue methods are often slow, complex, and lack real-time monitoring, which delays decisions and increases danger to victims. To address these issues, this research introduces a smart, cloud-based rescue management system to improve the efficiency and effectiveness of borehole rescues. The system uses sensor-based monitoring and IoT technology for rapid detection and response. A Passive Infrared (PIR) sensor detects movement and confirms the presence of a trapped person, while a gas sensor monitors for hazardous gases. When a victim is detected, a NodeMCU microcontroller processes the data and automatically activates an air pump to maintain safe oxygen levels. A robotic arm with a mechanical gripper assists in the physical rescue. All components connect to a cloud-based IoT platform, enabling real-time data transmission, remote monitoring, and coordinated control by emergency teams. This connectivity improves situational awareness and supports faster, more informed decisions during rescues. The study shows that integrating sensor technology, automation, and cloud-based communication can reduce response times and increase rescue success rates. This research aims to provide a safer, more reliable, and more advanced solution for borewell rescues, ultimately reducing fatalities and improving emergency response outcomes.***

Keywords: ***NodeMCU, PIR Sensor, Gas Sensor, Ultrasonic Sensor, I2C LCD, ThingSpeak, Random Forest Classifier.***

Nomenclature:
BPNN: Back-Propagation Neural Network
PIR: Passive Infrared
IoT: Internet of Things
GPIO: General Purpose Input/Output

I. INTRODUCTION

Borewells, commonly used for groundwater extraction, are a common feature across rural and semi-urban areas. However, when left unattended or improperly covered, these deep, narrow shafts become deadly hazards, especially for young children. Numerous tragic incidents have been reported where children have accidentally fallen into uncovered borewells, leading to highly challenging, dangerous, and often time-consuming rescue operations. Traditional rescue techniques are slow, risky, and heavily reliant on manual intervention, which significantly reduces the chances of a safe recovery.

Borewell rescues face major challenges due to the narrow shafts (often under 12 inches wide), which prevent direct access and limit equipment movement. Depths over 100 feet, poor lighting, and low oxygen levels make locating and reaching the victim difficult. Toxic gases and temperature extremes further endanger the child. Structural instability in loose soil increases the risk of collapse during rescue. Traditional methods, such as digging parallel shafts, are slow and risky, and the lack of compact, flexible rescue tools limits response effectiveness.

Lack of real-time data in borewell rescues leads to delays and poor decisions. Without continuous monitoring, teams rely on outdated information, reducing rescue success. Coordination among multiple agencies is difficult without a centralised system, causing miscommunication and delays. Additionally, a child's panic and stress, along with emotional pressure on rescuers and families, can lead to risky, rushed actions.

To address these critical challenges, the Cloud-Based Smart Child Rescue System for Open Borewell Safety is proposed as a life-saving innovation. The system intelligently combines IoT-based sensing, real-time data communication, robotic intervention, and cloud computing to enable rapid, organised, and remote-assisted rescue operations.

At the heart of this system is a Passive Infrared (PIR) sensor, strategically installed to detect human presence or movement within the borewell. This immediate detection capability ensures that the rescue process is initiated without unnecessary delay. Simultaneously, a Gas Sensor continuously monitors atmospheric conditions inside the borehole, detecting hazardous gases such as methane and carbon monoxide that could endanger the trapped individual and rescue personnel. If dangerous gases are detected, the system, controlled by an onboard NodeMCU microcontroller, automatically activates an air pump using a motor driver module to supply fresh air, stabilizing oxygen levels and ensuring a safer environment for survival.

A critical component of the system is a mechanical gripper mounted on a robotic arm or a flexible support structure. This robotic unit is designed to operate carefully. reach the trapped child and assist in lifting them to safety without causing

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additional injury or stress. A key innovation of this solution is its cloud-connected IoT platform, which integrates all sensor data and control operations. Through the cloud, authorized emergency responders, medical teams, and technical experts can remotely monitor live sensor feeds, control robotic operations, and collaborate in real-time, irrespective of their physical location. This centralized monitoring and control system drastically improves communication between stakeholders, speeds up critical decision-making, and ensures a well-coordinated rescue effort. Overall, this intelligent and proactive system not only enhances the efficiency and safety of borewell child rescue operations.

II. LITERATURE SURVEY

The rescue of children trapped in open borewells remains a serious global challenge, prompting extensive research into safer and faster rescue solutions. Technological advancements such as borewell rescue robots, smart sensors for human detection, gas and oxygen monitoring systems, and real-time communication platforms have been widely studied. The integration of IoT and cloud-based systems has further enhanced remote monitoring and decision-making during rescue operations. However, issues such as system complexity, adaptability to varying borehole conditions, and limited coordination among rescue teams persist. This literature survey reviews existing rescue technologies, highlights their limitations, and serves as the basis for the proposed Cloud-Based Smart Child Rescue System, which aims to improve rescue efficiency and success rates.

Mr Jouhar C. et al. introduced a robot designed to rescue victims from borewells. This paper details the development of a low-cost robotic system capable of rescuing children trapped inside narrow borewells. The robot is powered by an Arduino Uno microcontroller and is controlled remotely through a web-based interface. It utilises an ESP32-CAM module for live video streaming, enabling rescuers to monitor the borehole in real-time. The robot is equipped with several infrared (IR) and ultrasonic sensors to accurately detect the child's position and movements. Additionally, it features a robotic arm with grippers designed to gently lift the child. The system also includes a mechanism for supplying oxygen to maintain the trapped child's air quality. The focus of this project is on affordability, ease of deployment, and remote-controlled operation [1].

Padhmaloshani P. et al. introduce an IoT-based child rescue system from Open Borewell. This project integrates Internet of Things (IoT) technologies with mechanical systems to develop an automated child-rescue device. The setup includes an ultrasonic sensor to measure the child's distance and position, a motor driver IC to control the motors, and a NodeMCU microcontroller with a Wi-Fi module for cloud connectivity. The live data, including position and environmental parameters, is transmitted to a remote monitoring dashboard. The mechanical system features an adjustable harness designed to secure and lift the child safely. The objective is to reduce human risk during rescues and accelerate response time through continuous data transmission and cloud-based control [2].

Ashish Shantaram Bhagat et al. introduce the Fall Detection and Rescue System from Borewell. The paper presents a fall-detection and rescue system using a robot equipped with a video-surveillance module and a robotic gripper. The system detects falls through motion sensors and then activates the robotic unit. The robot is equipped with a servo-based gripper that can firmly but gently hold the child. The entire rescue operation is remotely monitored, allowing operators to guide the robot precisely. The solution significantly reduces the time required for rescue and ensures minimal manual intervention, making it safer for both the trapped child and the rescue team [3].

Dr U. Penchalaiah et al. introduce the Design and Fabrication of Borewell Child Rescue System. This work focuses on the design and fabrication of a specialised robotic system to rescue children from borewells. The robot, powered by an ESP32 microcontroller, is designed to descend vertically into the borehole. It features DC motors for controlled motion, a camera for visual guidance, and a mechanical gripper to latch onto the child. The system is operated remotely and provides live video feedback to ensure proper gripper positioning. Special attention was given to system stability and weight distribution to prevent the robot from swinging, which could cause injury to the trapped child [4].

Hai-bo Tian et al. introduce the Stability Analysis and Control Method of a Variable-Structure Detection Robot for Underground Rescue. This paper presents a highly advanced detection robot with **a** variable-structure design specifically for underground rescues, such as borewell incidents. The robot can change its configuration based on the borehole dimensions to maintain optimal stability. A back-propagation neural network (BPNN) model is used for adaptive stability control, meaning the robot adjusts itself automatically based on sensor feedback. The study provides a new stability criterion based on contact force, ensuring that the robot does not topple or cause additional risk while descending into confined spaces. The system is validated using simulation experiments [5].

Mutturaj et al. introduce. Smart Robot for Child Rescue System from Borewells. This research proposes a pneumatically assisted robotic system to rescue children trapped in borewells. The robot features **a** pneumatic robotic arm that can securely attach a harness to the child. A teleconferencing system is included to enable the trapped child to communicate with rescuers and relatives, providing emotional comfort. The robot also includes an inflatable airbag at the bottom to prevent the child from sliding deeper. The design focuses on reducing psychological trauma and accelerating rescue by establishing both physical and emotional support systems during operations [6].

P. Sukanya et al. introduce Design and Development of Gripper-Based Borewell Rescue Robot with Live Streaming. This work proposes a robotic system that streams live video from the borehole while performing rescue operations. Using an ESP32 microcontroller**,** high-torque motors, and a gripper with flexible motion, the robot can navigate narrow, irregular borewells. The gripper is designed to adjust its grip pressure based on feedback, reducing the chance of harming the child. An onboard camera with infrared (IR**) Sensors ensure** visibility even in low-light conditions. The robot's

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actions are remotely controlled, enabling rescue teams to manage operations safely from above [7].

Dr Ashwinee Barbadekar et al. introduce the design of a Gripper for Borewell Rescue Operations. This paper primarily focuses on the design and optimisation of a mechanical gripper for borewell rescues. The gripper has four degrees of freedom, enabling more flexible movements in tight spaces. It can adjust its position both horizontally and vertically to grip the trapped child securely. A combination of camera modules and proximity sensors helps correctly position the gripper without harming the victim. This design focuses on ease of operation, safety, and lightweight construction, making it easier to deploy the system quickly in emergencies [8].

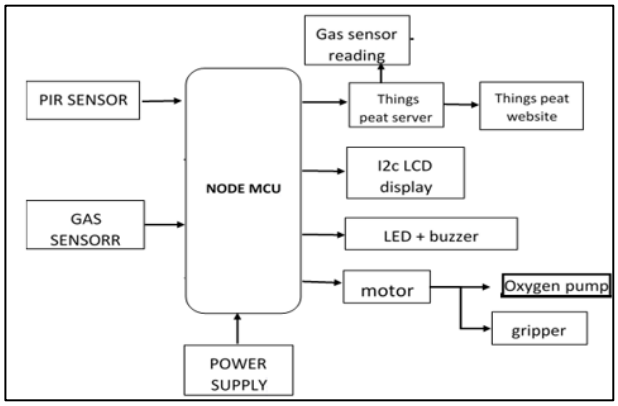
Melvin Paul, Miki V, and colleagues have developed an Arduino-based borewell child rescue system. This compact robotic setup includes a four-legged metal stand with a gripper that allows for vertical and slight horizontal adjustments of a child's position. It is controlled via a user-friendly smartphone app using wireless Bluetooth modules. Designed for portability and cost-effectiveness, this robot is ideal for rural areas with limited technical expertise [9].

Vyavahare V. A et al. introduce a semi-automatic Child Rescuing Robot for deep borewell rescues. The robot uses a rocker-bogie mechanism for smooth navigation and is controlled via Bluetooth from a mobile device. It features a padded gripping mechanism to safely lift the child, along with live video transmission and sensors to monitor air quality and temperature inside the borewell during the rescue [10].

III. SYSTEM DEVELOPMENT

A. Hardware Architecture

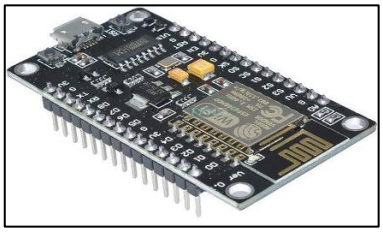
Figure 1 shows the system diagram for the rescue operation, with the NodeMCU as the main control unit. The process starts with a Passive Infrared (PIR) sensor inside the bore well that detects motion or heat, confirming the presence of a trapped individual. Upon **detection**, a gas sensor monitors air quality; if hazardous gases such as methane or carbon monoxide are present, the NodeMCU activates an air pump to deliver fresh, oxygen-rich air. A mechanical gripper on a robotic arm is then deployed to gently grasp and lift the trapped person to safety, minimising the risk of injury. Throughout this operation, sensor data on motion, gas levels, and device status is transmitted to a cloud-based IoT platform, allowing emergency responders to monitor conditions and control the system remotely.



[Fig.1: Block Diagram]

B. NodeMCU/ESP8266-12E

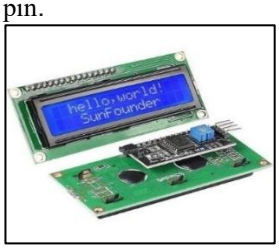
NodeMCU (Node Micro Controller Unit) is an open-source platform for Internet of Things (IoT) projects, built on the affordable ESP8266-12E System-on-a-Chip (SoC). Developed by Espressif Systems, it includes essential components such as a CPU, Wi-Fi networking, RAM, and an SDK, making it ideal for IoT prototyping. Similar to an Arduino, the NodeMCU features built-in Wi-Fi and can be programmed in Lua or C in the Arduino IDE. It also provides 10 General Purpose Input/Output (GPIO) pins for device interfacing.



[Fig.2: Node MCU Board]

C. I2C LCD Display

An I2C LCD, or Liquid Crystal Display, is an alphanumeric display module commonly used with microcontrollers and embedded systems. The "I2C" refers to the communication protocol that allows the microcontroller to control the display using only two wires: SDA for data and SCL for the clock. This setup simplifies wiring and reduces the number of pins required. The I2C LCD consists of four pins. GND is the ground pin and should be connected to the Arduino's ground. VCC supplies power to both the module and the LCD, so it should be connected to the Arduino's 5V output or to a separate power supply. SDA is the Serial Data pin, which is used for both transmitting and receiving data, while SCL is the Serial Clock pin.



[Fig.3: I2C LCD Display]

D. Buzzer

A buzzer is an electronic device that produces a buzzing or beeping sound when an electrical current passes through it. Typically consists of a coil of wire and a vibrating diaphragm or a piezoelectric element. Buzzer is commonly used in alarm systems, timers, doorbells, and electronic games to provide auditory alerts or notifications.



[Fig.4: Buzzer]

E. PIR Sensor

A PIR (Passive Infrared) sensor detects motion by

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measuring changes in infrared radiation emitted by objects, such as the human body. Widely used in security systems, lighting, and robotics, it is affordable, reliable, and easy to integrate. It has pins for power (VCC), output (OUT), and ground (GND), with adjustable sensitivity and delay settings.



[Fig.5: PIR Sensor]

F. Servo Motor

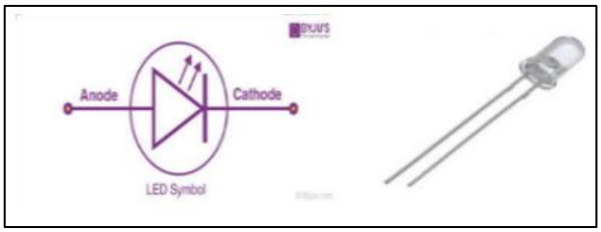
A servo motor is a type of rotary actuator that allows for precise control of angular position. It consists of a motor, a feedback sensor (typically a potentiometer), and a control circuit. The control circuit compares the desired position with the motor shaft's actual position and adjusts the motor's speed and direction accordingly to reach and maintain the desired position.



[Fig.6: Servo Motor]

G. LED

An LED (Light Emitting Diode) is a semiconductor device that emits light when current flows through it. It works like a PN junction diode, allowing current only in the forward direction. Common materials used include Gallium Arsenide and Gallium Phosphide, which produce different colours. LEDs have two leads: the anode (longer, positive) and the cathode (shorter, negative). When powered, the crystal inside emits light as electrical energy is converted into light energy.



[Fig.7: LED]

H. Gas Sensor

A gas sensor is a device designed to detect the presence and concentration of gases in the environment. It plays a crucial role in monitoring air quality, ensuring safety, and detecting hazardous gases. Gas sensors operate by measuring changes in electrical resistance or voltage caused by interactions between gas molecules and the sensor's sensing material. Gas sensors typically have four pins: VCC for power supply, GND for grounding, AO (Analog Output) for variable voltage based on gas concentration, and DO (Digital Output) that triggers when gas levels exceed a set threshold.



[Fig.8 Gas Sensor]

I. Oxygen Pump

An oxygen pump is a device that supplies concentrated oxygen for various purposes. It functions by drawing in air, separating oxygen from other gases through filtration, and then releasing the purified oxygen. These pumps are widely utilised in medical devices, industrial operations, and environmental applications.



[Fig.9: Oxygen Pump]

J. Gripper

A gripper is a mechanical device used in robotics and automation to grasp and manipulate objects, playing a key role in tasks such as picking and assembling parts. Grippers operate using pneumatic, hydraulic, or electric systems, typically featuring two or more jaws to securely hold objects. The choice of gripper depends on the object's characteristics. They are commonly used in industries such as automotive and electronics, with advanced models incorporating sensors for improved precision and flexibility.



[Fig.10: Gripper]

IV. EXPERIMENTAL SETUP AND RESULT DISCUSSION

A. Circuit Diagram

The circuit diagram of the cloud-based smart child rescue system for open borewell safety is shown in the figure below.

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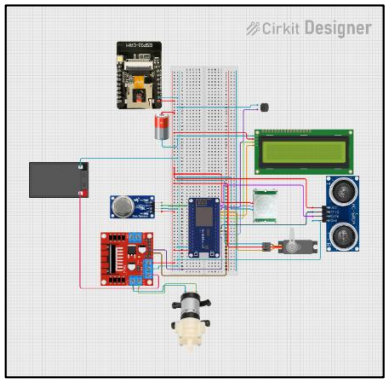


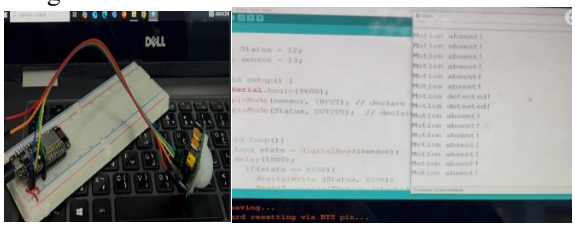
[Fig.11: Circuit Diagram]

B. Results and Discussion

The rescue system starts with a PIR sensor detecting motion or heat to confirm the presence of a trapped individual in the borewell, triggering a buzzer alert. A gas sensor then monitors air quality, and if toxic gases are detected, the NodeMCU activates an air pump to supply fresh oxygen. A robotic arm equipped with a mechanical gripper is deployed to carefully lift the victim. Real-time data, including motion, gas levels, and system status, is transmitted to a cloud-based IoT platform and displayed on an I2C LCD. This allows remote monitoring and control by emergency personnel, improving rescue speed, safety, and coordination.

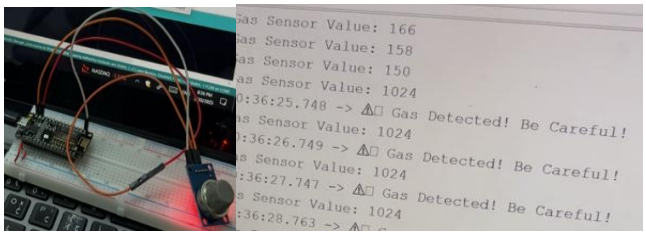
C. Testing of Circuit

Each sensor is tested, and the result is shown in the serial monitor. The PIR sensor was tested, and the result is shown in the figure below.



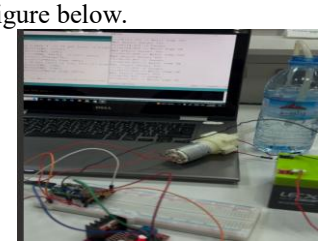
[Fig.12: Testing of PIR Sensor]

The gas sensor is connected to the NodeMCU and has been tested. The result is shown below. The result is also shown in the Serial monitor.



[Fig.13: Testing of Gas Sensor]

If the gas sensor value exceeds a threshold, the air pump will turn on to supply oxygen. The testing and the results are shown in the figure below.



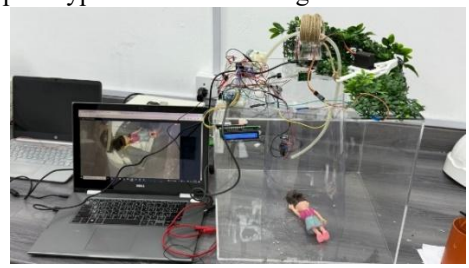
[Fig.14: Testing of the Air Pump]

If the motion is detected, the servomotor holding the gripper will catch the child. The connections and the result are shown in the figure below.



[Fig.15: Testing of Servomotor]

Connect all the components and test the result. The final product prototype is shown in the figure below.

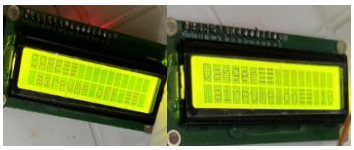


[Fig.16: Final Product Prototype]

The result from the gas sensor is also available on ThingSpeak and on the I2C LCD. The figure below shows the ThingSpeak output and the I2C LCD output from the gas sensor, in safe and danger modes.



[Fig.17: Thingspeak Result]



[Fig.18: I2C LCD Display]

D. AI-Based Real-Time Risk Prediction and Monitoring

To implement the machine learning component, essential Python libraries such as Pandas, Scikit-learn, and Matplotlib are installed in the Google Colab environment for efficient data processing, model training, and performance evaluation. The gas sensor dataset, collected from ThingSpeak, is manually uploaded as a CSV file and verified for accuracy. The sensor readings are preprocessed by converting them to floating-point values, and a threshold-based method classifies them into risk categories, labelling values above the threshold as “High” risk and those below as “Low” risk. This labelled dataset is used for supervised learning with a Random Forest Classifier with 100 decision trees, trained on

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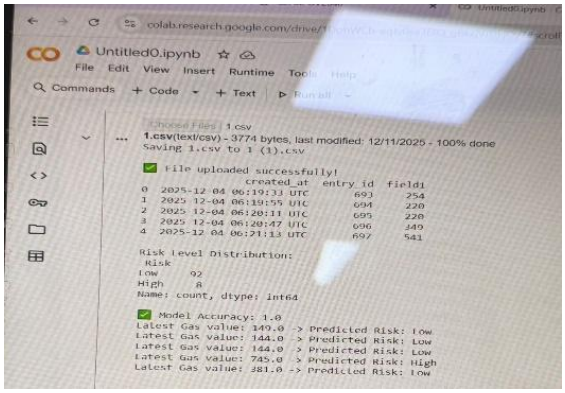
80% of the data and tested on the remaining 20% to ensure robust, reliable classification. Model performance is assessed using accuracy metrics, along with the confusion matrix and classification report, to validate its effectiveness. For real-time operation, the latest gas readings are continuously fetched from ThingSpeak and processed by the trained model, which predicts the current risk level. The system updates every 30 seconds, displaying the latest gas value along with its predicted risk, enabling immediate detection of dangerous conditions and prompt safety actions to protect the bore well victim. The result is shown below.



[Fig.19: AI-Based Gas Risk Prediction and Monitoring]

V. CONCLUSION

The proposed cloud-based smart rescue system provides an automated solution for borewell emergencies using motion and gas sensors, a robotic gripper, and controlled ventilation. IoT and cloud connectivity enable real-time monitoring and faster decision-making, significantly improving rescue speed, safety, and success rates.

DECLARATION STATEMENT

As the article's author, I must verify the accuracy of the following information after aggregating input from all authors.

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- **Funding Support:** This article has not been funded by any organizations or agencies. This independence ensures that the research is conducted objectively and without external influence.
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- **Author's Contributions:** The authorship of this article is contributed equally to all participating individuals.

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