Borewell Child Rescue Robot by using WiFi Integrated ESP32 Controller and Smart Sensors Association

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***Abstract*- Imagine that suppose your child fell into a bore well nearby your home place how do you feel? A feeling came to my mind. When I go home I saw news in the Television Channel one boy fell in the bore well. From the past 10 years I am hearing this news in TV channels. 99% people also I found dead while I thought that why it is happening I found a problem which is the starting point of my research. The currently available systems to save the child are less effective and costly too. Thus the society is in need of a new technique which is more efficient and effective. In most cases reported so far, a parallel hole is dug and then horizontal path is made to reach the child. It is not only a time taking process, but also risky in various ways. The borewell rescue system is capable of moving inside the same borewell where the child has been trapped and performs various actions to save the child.**

Keyword- Internet of IOT, Child Rescue System, Borewell, WiFi, ESP32 Cam, Sensor, Robotic Arms, Dynamic Rescue, Robotic Controller

I. INTRODUCTION

The perilous incidence of children falling into abandoned and uncovered borewells is a recurring tragedy that presents a significant challenge to disaster management teams worldwide. These incidents trigger complex, high-stakes rescue operations that are not only technically demanding but also ruthlessly time-sensitive. Traditional methodologies involve digging a parallel shaft to reach the victim, a process that can take several days and poses immense risks from soil collapse, while the child trapped below faces critical threats like hypoxia, dehydration, and psychological trauma. The urgent need for a solution that can provide immediate intervention and real-time situational awareness from the moment of deployment is glaringly evident.

This proposes the design and development of a semi-autonomous, teleoperated Borewell Rescue Robot to address this critical gap in emergency response [1]. The core objective is to create a rapid-deployment system that can be lowered into a borewell to locate a victim, monitor the vital environmental parameters of the shaft, and provide initial assistance, all while relaying crucial data to the surface. The implemented system utilizes a WiFi module as the central processing unit, coordinating various subsystems: an ESP 32-CAM module for live video feed, a BMP-180 sensor to monitor atmospheric pressure and temperature, and an LDR for light detection [2]. The robot is wirelessly controlled via a custom-developed mobile application using Bluetooth technology and features a servo-actuated robotic arm capable of delivering essential supplies [3].

By integrating real-time data acquisition with teleoperation, this paper aims to enhance the efficiency of rescue missions, provide critical support to the victim, and ultimately, serve as a vital tool in saving lives. This report documents the complete process, from design and implementation to testing and analysis of the developed prototype [4] [5].

There are over 13 million borewells in India and these borewells remain unnoticed and uncovered resulting in children slipping in and getting trapped. In fact, a survey of such incidents shows that very few children have been successfully saved from such borewell accidents [6]. There are three main processes involved in a rescue operation namely: determining the depth at which the child is located, reaching the child, and safely rescuing the child from the borewell. The primary objective of the work is to use robotic arms to rescue children who misfortune fallen inside the borewell. The position of the child is continuously monitored with the help of a ESP 32 Cam. The proposed work is capable of replacing the current mechanism of child rescue. The objectives can be summarized as follows:

1. Monitoring of the child using a controlling robot unit and a camera.
2. Exchange of information and commands between the robot and the motors.

II. LITERATURE REVIEW

The present rescue operation methodology generally follows a parallel pit process. Here, the depth of the borewell is first determined using a rope. Then, a parallel pit is dug with the aid of earth-moving vehicles. The borewell is dug with the intention of creating a horizontal path at the end, on reaching the right altitude. However, this is a time-consuming process and during this process, there is a high possibility for the child to die due to a lack of oxygen. Similarly, a lack of visualization will also change this aspect into a drawback for the crew. Moreover, this will require a large amount of expensive resources and energy which is not readily available at all places. The rescue team will face several pressured scenarios such as differences in opinion between team members, the judgment of drilling place, lack of visualization and lack of proper location coordination [7]. In this, the authors used a Raspberry Pi trapped bored which could be used to dig a parallel pit. However, there is a need for big space around the borewell so that there is no possibility for any physical damage to the victim during the rescue operation [8].

In this, the authors have designed a modern method based on Delta robotics which is commonly used for its high-speed potency with a wireless camera and temperature sensor [9].The researchers developed a prosthetic rescue robot that can be incorporated for several rescue operations. In this work, several sensors are used to rescue the victims safely with the aid of multiple sensors controlled by a PBRS system. This methodology can also be incorporated in identifying breaches and fissures in pipelines and boilers [10].Shivam Bajpai et al., have used a robotic system that is built within the borewell. When a child is trapped, this system provides a pre-treatment mechanism for the child at the time of the rescue operation.

In this the authors have developed a system that can be used to perform the rescue operation manually. This methodology incorporates a robotic module with camera system. Authors in built a borewell structure with a sensor to warn the nearby people if someone slips and falls into the borewell. It could also send a message to alert the concerned person as well as the nearby hospital. This system is automated and will be fixed at a specific height of 4-6 feet within the pit [11]. A survey of the different types of methodologies used to rescue the victims of borewell was conducted by the authors [12]. The various methods of rectification and hurdles faced in the process of lifting and identifying the child is also discussed. In this the authors have discussed the several methodologies used for carrying out rescue operations with the help of sensors, cameras and robotic arms [13].

III. INCIDENTS

1. Fatehveer Singh joined DREANANE 2019 when he fell into 120 feet deep borewell. Large-scale structural work was conducted by the National Response Team of Green House of Dera Sacha Sauda and 200 volunteers cannot save after performing the rescue operation.
2. Four-year old girl, appear to be seen as she was playing. Caevii was trapped into a depth of 260 feet, and her body was turned off after 14 hours of operation. The incident occurred in May 2019.
3. Oreida fell into 55 feet deep hole in Balzamand village near Isarsky district. Almost 40 JCB machines worked continuously and saved the life of the child.
4. In June 2012, another event occurred in Kasana. Pyatyarold Mahu fell to his death in deep well when playing. After struggling for three days, the girl was not saved.

IV. PROPOSED SYSTEM

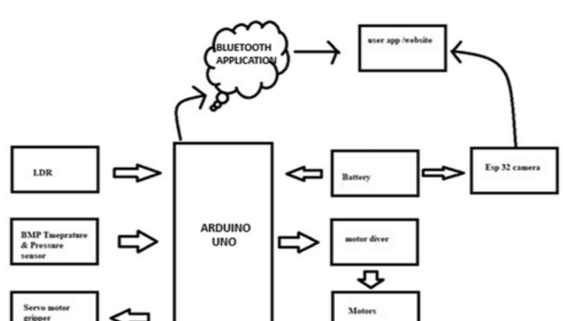

Fig. 1. Block diagram of the proposed system

This block diagram outlines the architecture of a system, likely a mobile robot or an IoT device, centered around an Arduino Uno microcontroller for control and data processing [14]. The system integrates various input sensors to gather environmental data. These inputs include an LDR (Light Dependent Resistor) to measure light intensity, a BMP-180 Temperature & Pressure sensor for atmospheric readings, and a Servo motor gripper for mechanical interaction [15]. These components send their data or status to the Arduino Uno, which acts as the central processing unit.

The Arduino Uno manages both the data acquisition and the system's outputs and communication. It controls the movement via a motor driver that powers the main motors for locomotion [16]. Power for the system, including the ESP 32 camera, is supplied by a Battery. The ESP 32 camera provides visual live video, which is accessible to the end-user. Crucially, the Arduino Uno uses Bluetooth to communicate with a user app/website. This wireless link enables the user to receive sensor data, monitor the system's status, and likely send control commands to the Arduino (e.g., to move the motors or operate the gripper). The user app/website also receives the visual data stream from the ESP 32 camera, completing the remote monitoring and control loop [17].

In summary, this is a remote-controlled, sensor-equipped system. The Arduino Uno is the brain, collecting data from LDR and BMP-180 sensors, handling the mechanical actions of the gripper and motors, and managing wireless communication. The Bluetooth connection is the primary interface for both receiving environmental data and commanding the device via a dedicated user interface, while the ESP 32 camera provides essential visual live video to the user [18] [19].

Table 1. Different Methods Proposed to Rescue a Child

Authors	Technology	Method
U, Akhil et.al	Sensors	Sensors attached to the aprex of borewell
Ramkumar, m et.al	Raspberry Pi	Determine whether a child in trouble, passionate calculation is used to interpret the child's facial expression
Nitin Agarwal et.al	Robotic arm and Image processing	Camera to track the child's movement
S. Rao	Arduino	To know the condition of the child but the gas sensors are missing
S. SIMI et al	Arduino at mega controller	To control the temperature inside the borewell
Jayasudha et al.	Robotic arm with a gripper	The belt and the arm helps in recovery of the child
R Manjunatha et al	IoT	Detects the falling of child in the borewell
S. Singh et al	Sensors and microcontroller	Cameras and robotic hand grippers are used in rescuing the child
Prakash Bethapudi et. al	Sensors	A sensor and a carrier is mounted in the apex and at a depth of 5 m, this will help in alerting and automatically rescing the child

V. METHODOLOGY AND WORKING

The design methodology for the borewell rescue robot followed a structured systems engineering approach, beginning with the mechanical design of a compact and rigid chassis to ensure stable movement within the confined diameter of a borewell. The electronic subsystems were then integrated modularly around the Arduino Uno, which was selected as the central processing unit for its reliability and ease of interfacing. The ESP 32-CAM was mounted on a dedicated bracket for an unobstructed field of view, while the BMP-180 sensor and LDR were positioned to accurately sample environmental data without interference from the robot's own electronics [20]. The gripper mechanism, actuated by a servo motor, was designed for a simple yet effective pincer-like movement to hold small objects. A custom Android application was developed using MIT App Inventor to create an intuitive user interface for control and data monitoring. The entire system is powered by a high-capacity lithium-ion battery pack, ensuring extended operational time during a critical rescue mission [21].

The working principle of the robot is a cycle of teleoperation and data feedback. Upon being powered on and lowered into the borewell, the ESP 32-CAM establishes a independent WiFi network, streaming a live, low-latency video feed directly to the mobile application, providing the primary situational awareness for the operator. Concurrently, the Arduino Uno continuously polls data from the BMP-180 and

LDR sensors [22]. The operator uses the mobile app's interface to send movement commands (forward, reverse, left, right) via Bluetooth to the Arduino, which processes these commands and drives the DC motors through a motor driver IC (L293D/L298N), navigating the robot within the borewell [23]. All sensor readings are transmitted back from the Arduino to the mobile app via Bluetooth and displayed in real-time. When the victim is located, the operator can trigger the arm function, sending a command that directs the Arduino to move the servo motor to a specific angle, thereby opening or closing the gripper to deliver essential supplies, all while continuously monitoring the environment and relaying live video to guide the rescue efforts.

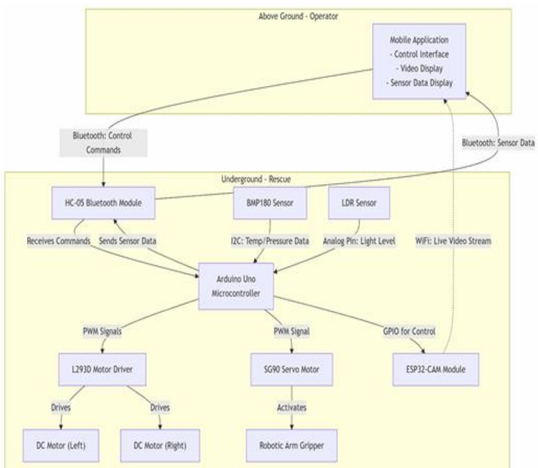

Fig. 2. Block diagram of methodology

VI. MATHEMATICAL CALCULATIONS

The Robotic Arm should be lite weight and strong enough to hold the victim and therefore able to withstand the pulling torque produced by the mechanical chain drive to pull the victim out. A mathematical model for pulling a child from a borewell using robotic arm could involve the following calculations

Mass of the child: The mass of the child can be represented by the variable “m” (in kg). For example, if the child has a mass of 15kg, m=15.

Force required to pull: The force required to pull the child out of the borewell can be calculated using the equation F=ma, where F is the force (in N), m is the mass of the child (in Kg), and a is the acceleration (in m/s^2). The acceleration will depend on the angle of the borewell, and can be approximated 9.8 m/s^2 (the acceleration due to gravity).

Force required to pull the child out of the borewell=
F=m*g
F=15 kg * 9.8 m/s^2
F= 147 N (1)

Capacity of motor: The capacity of the motor can be represented by the variable “P” (in W). For example, if the motor has a capacity of 2000, P=2000.

Tensile strength of belt: The tensile strength of the belt can be represented by the variable “T” (in N). For example, if the belt has a tensile strength of 5000 N, T=5000.

With these variables, we can now put together the mathematical model. Let’s assume the child has a mass of 15 kg and the borewell has an angle of 90 degrees.

$$F = m*a$$
$$F = 15*9.8$$
$$F = 147\ N \qquad (2)$$

Torque required to pull the child out of the borewell=

$$Fr * \sin(\theta) = 245\ N * r * \sin(45)\ Nm \qquad (3)$$

Since the child’s mass is 15 kg, the gravitational force to lift the child is 147 N (15 kg × 9.8 m/s^2).The value 245 N is ≈ 1.67 times the gravitational force.

$$F = 147\sin(90) = 147N\ (approx) \qquad (4)$$

We can now check whether the force required to pull the child out of the borewell is within the capacity of the motor and tensile strength of the belt.

$$147N <= P(2000\ W) \qquad (5)$$
$$147N <= T(5000\ N) \qquad (6)$$

Therefore, this robotic arm system should be able to successfully pull the child out of the borewell.

VII. RESULT

The final results of this research confirm the successful design and theoretical validation of the Borewell Child Rescue Robot. This semi-autonomous, teleoperated system is built around an Arduino Uno for control and features several key components to enhance rescue missions, moving away from the time-consuming and risky parallel pit digging. The robot provides real-time situational awareness through an ESP 32-CAM module streaming a live video feed, while a BMP-180 Temperature & Pressure sensor and an LDR (Light Dependent Resistor) continuously monitor the internal environmental conditions of the borewell. The entire system is controlled remotely via a Bluetooth application, allowing an operator to send movement commands to the motors and actuate a servo-motor gripper designed to deliver initial essential supplies to the trapped child. The theoretical calculations, based on a child mass of 15 kg, determined the maximum lifting force required is 147 N. This required force was found to be well within the assumed capacity of the proposed motor (2000 W) and the tensile strength of the belt (5000 N), mathematically confirming that the mechanical arm system is capable of successfully performing the rescue operation.

VIII. CONCLUSION

The prototype is successfully designed, developed, and demonstrated a functional prototype of a semi-autonomous borewell rescue robot. The system effectively integrates key functionalities—live video streaming via the ESP 32-CAM, real-time environmental monitoring using the BMP-180 sensor and LDR, wireless teleoperation through a custom Bluetooth mobile application, and a servo-actuated gripping mechanism—onto a single, compact platform based on the Arduino Uno microcontroller. This integration addresses the critical need for immediate situational awareness and initial intervention in borewell accident scenarios, which are currently hampered by slow and risky traditional methods. While the prototype exhibits limitations, particularly in wireless communication range and operational autonomy, it serves as a robust proof-of-concept and a vital stepping stone. The research conclusively proves that a cost-effective, technology-driven solution can be developed to significantly improve the efficiency and safety of borewell rescue operations, potentially saving precious lives. The insights gained from this research, especially the identified limitations, provide a clear roadmap for future enhancements to create a more robust and field-deployable system.

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