

Smart Borewell Rescue Robot: IOT-Driven Solution for Automated Detection and Recovery With ESP32 MCU Integration

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ABSTRACT

As of right now, there have been several reports of abandoned borewells turning into deadly risks. Many helpless children and animals are dying as a result of getting stuck in these open borewells. Rescue operations are frequently carried out using a significant amount of equipment and labor. This project's main goal is to design and build a portable robot that is accurate, quick to operate, and affordable. Thus, efficiency and safety can be increased by developing an intelligent rescue robot for borewells. Using an ESP32 microcontroller, servo motors, high-torque DC motors, a camera module, an H-Bridge motor driver, and a mechanical gripper, this project will build a borewell rescue robot. The robot is designed to navigate and carry out rescue operations in enclosed borewell environments where human access is limited or dangerous. The goal is to create a robust and efficient robot that can enter borewells and retrieve trapped people, reducing the risks and time associated with manned rescue operations.

Keywords: Smart Rescue Robot, Open Borewells, ESP32 MCU (Microcontroller Unit), Abandoned Borewells, Death Wells, Portable Robot, Cost-effective, High Torque DC Motors, H-Bridge Motor Driver, Mechanical Gripper, Rescue Operations

1. INTRODUCTION

In recent times water scarcity is getting evolved as a big crisis and this leads to the construction of borewells in many areas. After a period of time the borewells also gets dried up and left unnoticed. Although many awareness programs and strict rules

are forwarded by the government to close the open borewells people have converted the borewells as a death traps due to their lethargic behaviour. The borewell Rescue System is equipped for moving inside the well and performs tasks as indicated by the client directions. In this project we have used, ESP32 MCU, Servomotors, ESP32 cam module, LM2596 regulators, 12v battery, Bluetooth module, 8 ohm speaker, high torque DC motor, DC motor speed controller, DPDT switch, and an ON/OFF switch. The main heart of this process is an ESP32, in which an wifi module is already programmed think of it as the brain of the robot, responsible for processing information and controlling the robot's movements in real-time. Moreover, its robust communication modules facilitate seamless interaction with rescue teams, enabling coordinated efforts and enhancing overall operational efficiency. Real-time data transmission empowers decision-makers with critical insights, enabling swift and informed actions to maximize the likelihood of successful rescue operations. In conclusion, the Smart Rescue Robot represents a beacon of hope in the realm of emergency response, offering a potent blend of cutting-edge technology, efficiency, and safety. With its deployment, we embark on a journey towards a safer and more resilient future for all the victims.

PROBLEM STATEMENT

In numerous regions across the worldwide, open borewells have emerged as critical safety hazards, posing imminent threats to human lives, the environment, and community well-being. The absence of protective measures around these

borewells has led to numerous incidents of accidental falls, primarily involving children, resulting in injuries and fatalities.

The primary problem is the lack of an efficient and rapid response mechanism to address open borewell incidents. Traditional rescue operations rely heavily on manual intervention, often leading to delays that can exacerbate the severity of the situation. Additionally, the inherent dangers of sending human responders into these confined spaces present significant challenges, both in terms of safety and effectiveness.

Moreover, the existing methods for detecting open borewells lack the technological sophistication needed to provide real-time information and ensure swift responses. In many cases, communities and rescue teams rely on visual inspections, which are time-consuming, impractical for widespread coverage, and subject to human error. This inadequacy in detection methods amplifies the potential for accidents, hindering the overall safety of communities, especially in regions where open borewells are prevalent. The integration of the ESP32 Microcontroller Unit (MCU) and Internet of Things (IoT) technology aims to revolutionize the approach to borewell rescue operations. However, the current problem lies in the absence of a comprehensive and widely adopted solution that harnesses the power of these technologies to create a Smart Rescue Robot.

The Smart Rescue Robot is envisioned as a proactive and autonomous system capable of swiftly identifying open borewells, assessing environmental conditions, and providing real-time data to a central command station. By utilizing the ESP32 MCU, the robot can process information rapidly and make autonomous decisions, streamlining the rescue process. The integration with IoT ensures seamless communication with a central command station, enabling remote monitoring and control, thereby reducing the reliance on manual intervention and minimizing response times.

2. LITERATURE SURVEY

Bharathi et al. 2013 [1] describes about robotic system which can be controlled by a PC using ZigBee technology. The audio and video of the victim is displayed using a wireless camera. A high-power LED is attached to the robot as a light source. The proposed system does not include UDM sensor,

gas sensor, oxygen supply pipe and PIR sensor which has been incorporated in our work.

Manish Raj et al. 2014 [2] published a paper in which where it used mechanical system and two arms and camera to rescue the child. This system lacked with sensors such as temperature sensor, gas sensor, PIR sensor.

Palwinderkaur et al. 2014 [3] proposed a system which is designed to rescue children trapped inside non operative borewells within short time. This system works based on wireless communication concept and the commands are given by the user. This system has power supply, gear motors, camera and microcontroller as the components. Gear motors are connected to Robot which uses three wheels with Rubber grip which fit exactly to the walls of the hole so that the Robot moves down easily without sliding and the arm of Robot is used to Pick the child from the borewell. This system does not provide oxygen supply and does not use temperature sensor.

S.Gopinath , T.Devika et al., 2015 [4] The sensor systems are interfaced with the ARM8 processor. A camera along with an LED light is used to visualize the victim as well as it helps to operate the system by control unit. The vacuum cup is used to adjust the child position. The arm movement of the robot is controlled by stepper motor. Once child is perfectly picked by robot, BLDC motor is used to lift up the child from borewell.

Nish MohithKurukuti et al. 2016 [5] proposed a design to enlarge or adjusted as per the diameter of borewell. Ultrasonic Sensor used to measure the distance from Robot wheel to borewell Wall and Logitech C270 camera is used to provide visual information to operator. Servo motor is used to control Robot Arms and DC motors to actuate the wheels of the motor. The Robotic system would adjust to the borewell size with help of Rack and Pinion mechanism to grab and hold the child. This system lacks with gas sensor and oxygen supply.

Nish Mohith Kurukuti et al. 2016 [6] describes the rescue operations without human intervention. The system can adjust its legs according to the pipeline dimensions. The system consists of power supply, actuators, and dc motor, servo motor. The child position is captured from bore well with Camera module and monitored on PC. The ultrasonic sensor interfaced with arduino. The arduino uses a microcontroller not an application processor, so cannot run any operating system on it.

You cannot get a video output or Ethernet port on arduino.

Simi Simon et al. 2016 [7] published a paper on borewell rescue robot work presented in this paper describes the Robot used to rescue the children from unused borewells. This system monitors the trapped child through Infra-red water proof cameras and high-resolution TV monitor. This system uses Ultrasonic Sensors and temperature sensor. APR module is attached to Robot which is used to communicate with the child. This system lacks with gas sensor to monitor harmful gas and provide oxygen.

Kavianand et al. 2016 [8] published a paper on smart child rescue system which uses a PIR sensor to detect the motion of the child trapped in a borewell. The sensor is placed at the top of the borewell pipeline and the signals detected are sent to the raspberry pi controller. An alert message is sent to the nearby fire station and also the contractor in charge using the interfaced GSM module. This system lacks in measuring the distance of victim from borewell and temperature inside and does not use robot arm for immediate rescue of child.

Shivam Bajpai et al., 2017 [9] suggested an alternative method to save children who got trapped in borewell. The traditional way of digging parallel hole near the borewell is replaced by using robotic system in the borewell itself. The system is designed in such a manner that it gives pre-treatment for the child while rescue operation is being carried out. The setup consists of 3 mild steel rods positioned in triangular form with pulley, hanging disc operated by D.C motor, VGA camera and hanging balloon arrangement. Using this arrangement, the child will be safely rescued by the team without consuming long hours and large amount of manpower.

Lawrence daniela vino leer et al., 2017 [10] To assist in such rescue operations, we tend to propose a robotic system capable of moving underneath the bore well supported with user commands equipped with a robotic arm, high power LED, high-resolution camera, and sensors like ultrasonic, temperature and gas sensor. The device system is interfaced with the at mega 328 controllers. Robotic arm is designed uniquely where it operates with 4-point gripping system in which each pair is controlled separately in order to increase the precision of the grip.

3. PROPOSED METHODOLOGY

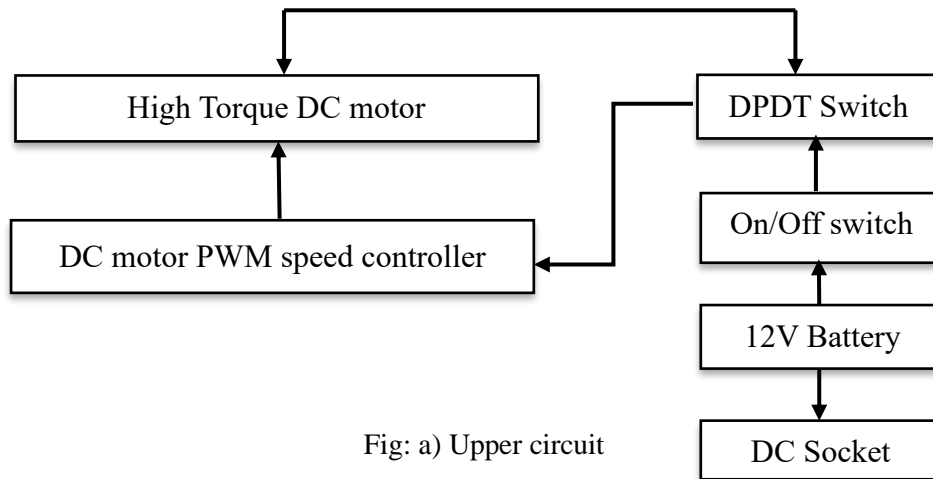
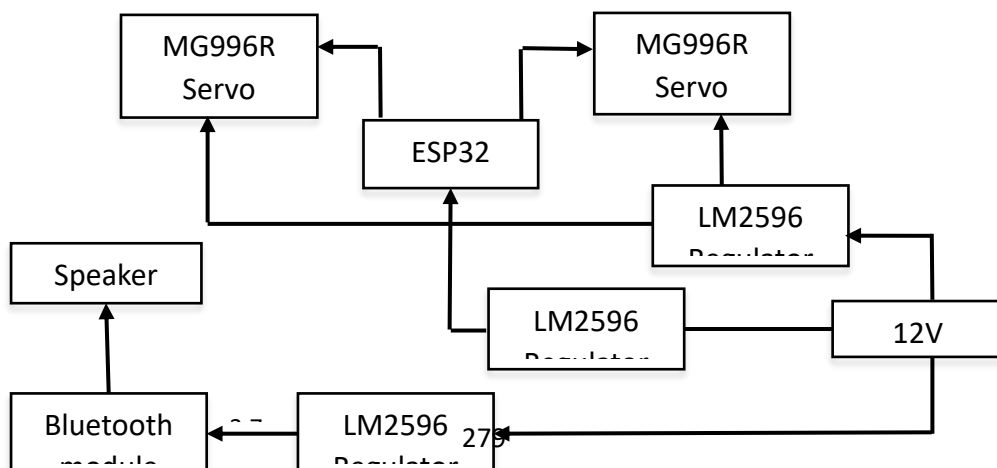


Fig: a) Upper circuit



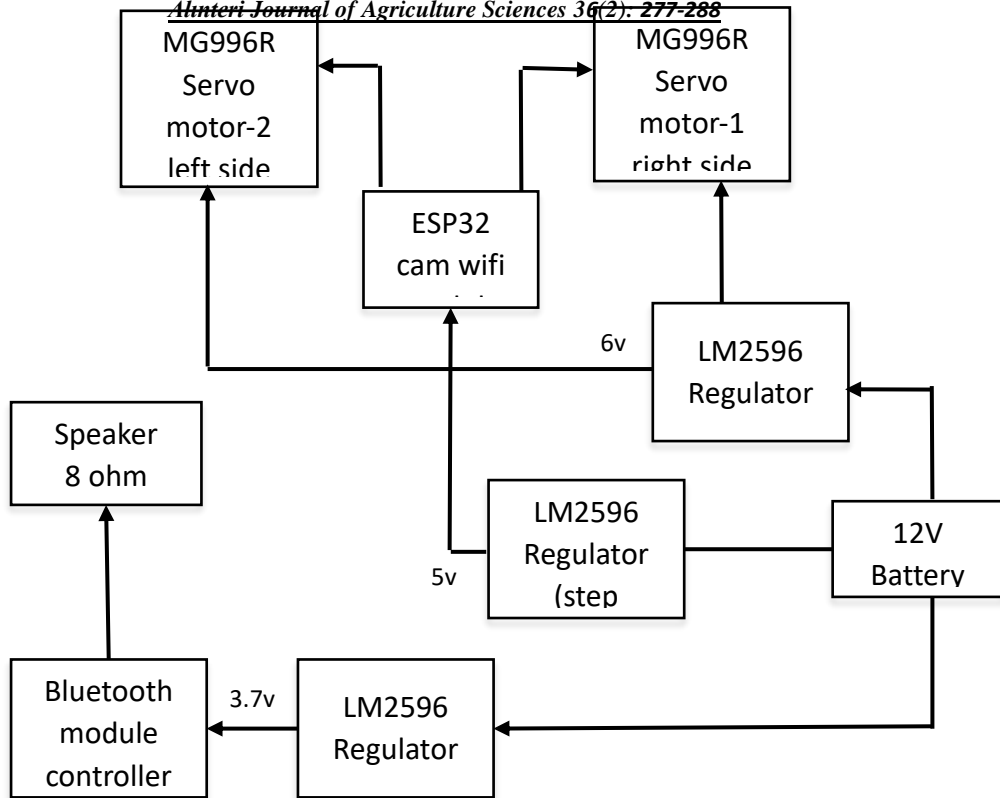


Fig: a) Bottom circuit

The ESP32 microcontroller acts as the central control system, coordinating all the components and facilitating wireless communication with the remote-control device. The integration of high torque DC motors, a camera module, and a mechanical gripper enhances the robot's capabilities for efficient and safe borewell rescue operations. The step wise analysis is illustrated as follows:

Step 1: Robot Navigation: The borewell rescue robot is designed to navigate through narrow and confined spaces, such as borewells, using its compact and sturdy structure. High torque DC motors are integrated into the robot to provide precise and powerful locomotion, enabling it to traverse challenging terrains. The ESP32 microcontroller acts as the control center, receiving input commands from the remote-control device and translating them into motor movements. The robot's movements are controlled based on the operator's commands, allowing it to navigate through the borewell while avoiding obstacles.

Step 2: Live Video Transmission: A camera module is attached to the robot chassis, capturing live video footage of the surrounding environment. The camera module is connected to the ESP32 microcontroller,

which processes and transmits the video feed to the remote-control device. The live video transmission enables the rescue team to have real-time visual feedback of the borewell interior, helping them assess the situation and make informed decisions.

Step 3: ESP32 Microcontroller and Control System: The ESP32 microcontroller serves as the central control system for the robot, coordinating its various components and functionalities. It establishes a wireless communication protocol, such as Wi-Fi or Bluetooth, to enable real-time control and data transmission between the robot and the remote-control device. The microcontroller receives commands from the operator through the remote-control device and sends corresponding signals to the motor drivers, controlling the robot's movement. It also receives and processes the video feed from the camera module, ensuring its transmission to the remote-control device.

Step 4: Mechanical Gripper Integration: A mechanical gripper system is designed and implemented to facilitate the safe retrieval of individuals trapped in the borewell. The gripper is integrated onto the robot chassis and connected to the ESP32 microcontroller for control. When a

trapped individual is located, the operator can remotely command the robot to position the gripper and securely grasp the person. The gripper's mechanism is designed to provide a firm and stable hold on the individual, enabling them to be lifted out of the borewell safely.

Hardware Components

- ESP 32 Controller
- Acrylic laser cutting
- 2mm mild steel metal
- High torque DC motors
- Casing pipe
- Grippers
- ESP 32 camera module
- 12V battery
- Servomotors(MG996R)
- DC Motor(12v)
- PWM DC motor speed controller
- Bluetooth module
- 8 Ohm speaker
- DPDT switch
- ON/OFF switch
- Regulators (LM2596)
- PLA 3D printed parts

Software modules

1. Catia V5
 - Mechanical design
 - Parts design
 - Sketcher
 - Assembly design
 - Drafting
 - Generative sheet metal design
2. Arduino IDE

Methodology

Utilize a CNC (Computer Numerical Control) laser cutting machine to precisely cut various components of the robot structure from metal sheets. Prepare the design files for the robot structure, ensuring proper dimensions and compatibility with the borewell openings. Load the metal sheets onto the CNC laser cutting machine and set up the cutting parameters, such as laser power and cutting speed. Execute the cutting process, allowing the CNC machine to accurately cut the desired shapes and structures for the robot components. After the cutting process, remove the cut metal pieces and perform any necessary finishing operations, such as deburring or sanding, to ensure smooth edges.

Utilize a CNC metal bending machine to shape and bend the metal components, such as brackets or clamps, required for the robot assembly. Prepare the design files with precise measurements and bending angles for the specific metal components. Load the metal pieces into the CNC metal bending machine and set up the bending parameters, including bend angle and bend radius. Initiate the bending process, allowing the CNC machine to accurately bend the metal pieces according to the specified design. After bending, remove the bent metal components from the machine and ensure their dimensional accuracy and structural integrity.

Mount the DC motors onto the robot chassis using brackets or mounting plates, ensuring secure and stable attachment. Connect the DC motors to the motor driver circuitry, providing power and control signals for their operation. Program the ESP32 microcontroller to control the DC motors, sending appropriate signals to the motor driver circuitry to control their speed and direction. Test the DC motors' functionality and ensure their proper integration with the overall robot control system.

Set up the ESP32 microcontroller as the central control unit of the robot. Develop the necessary software and firmware to program the ESP32, enabling it to receive commands from the remote-control device, control motor movements, and manage communication. Establish a wireless communication protocol, such as Wi-Fi or Bluetooth, to enable seamless communication between the robot and the remote-control device. Program the ESP32 to process incoming commands, translate them into motor movements or gripper actions, and send appropriate signals to the respective components. Test the ESP32 controller's functionality and ensure its integration with the other modules of the robot system.

Connect the motor driver module to the ESP32 microcontroller and the high torque DC motors. Ensure proper wiring and connections between the motor driver module, the ESP32, and the DC motors, following the manufacturer's guidelines. Program the ESP32 to send control signals to the motor driver module, enabling it to regulate the power supply and control the speed and direction of the DC motors. Test the motor driver's functionality, ensuring smooth and accurate motor control as per the commands received from the ESP32 microcontroller.

Mount the camera module onto the robot chassis, ensuring a clear and unobstructed view of the borewell environment. Connect the camera module to the ESP32 microcontroller, ensuring proper wiring and compatibility. Develop the software and firmware to capture and process video feed from the camera module. Program the ESP32 to receive video input from the camera module, process the captured frames, and compress them for transmission. Establish a wireless communication protocol between the ESP32 and the remote-control device to transmit the video feed in real-time. Test the camera module's functionality, ensuring the proper capture and transmission of live video feed from the borewell environment to the remote-control device.

Connect the 5v power supply unit to the robot's electrical system, ensuring proper wiring and polarity. Implement any necessary voltage regulation or current limiting mechanisms to protect the components from power fluctuations or overloading. Test the power supply system, ensuring stable and reliable power distribution to all modules of the robot.

Cut the borewell casing pipe to the desired length, allowing it to fit through the borewell openings. Securely attach the robot structure, components, and modules onto the borewell casing pipe, ensuring structural stability and integrity. Test the overall assembly's robustness and stability, ensuring that the robot can effectively navigate through the borewell using the borewell casing pipe as its guide.

Prepare the 3D printer by loading the appropriate filament material and configuring the printing parameters. Initiate the printing process, allowing the 3D printer to produce the desired components layer by layer. After printing, remove the 3D printed components from the printer, ensuring their dimensional accuracy and structural integrity. Assemble the 3D printed components onto the robot structure, ensuring proper fit and functionality. Test the 3D printed components, verifying their strength and compatibility with the overall robot system.

ADVANTAGES

1) Remote Operation: Allows rescuers to operate the robot remotely, reducing the need for direct human intervention in potentially hazardous environments, such as open borewells.

2) Real-time Monitoring: Provides real-time monitoring of the robot's location, sensor data, and operational status. This information aids rescuers in making timely and informed decisions.

3) Data Collection and Logging: Sensors on the robot collect valuable data during rescue operations, which can be logged for analysis. This data helps improve the robot's performance, optimize strategies, and enhance future rescue missions.

4) Quick Response: Enables a swift response to emergency situations, allowing rescuers to assess the situation promptly and deploy the robot for immediate action.

5) Enhanced Safety: Minimizes the risk to human rescuers by allowing them to operate the robot from a safe distance. The robot can navigate through confined spaces and potentially dangerous environments.

6) Adaptability: The ESP32 microcontroller's versatility enables the integration of various sensors and actuators, making the robot adaptable to different rescue scenarios and environmental conditions.

7) Cost-effective Solution: Compared to more complex robotic systems, a smart rescue robot with ESP32 is likely to be more cost-effective, making it a viable solution for organizations with budget constraints.

8) Communication Range: Utilizes Wi-Fi or Bluetooth for communication, providing a relatively broad range for rescuers to control the robot and receive real-time updates.

9) User-friendly Interface: Incorporates an intuitive user interface on the IoT platform, making it easier for rescuers to control the robot and interpret sensor data without extensive training.

10) Versatile Applications: The robot can be adapted for various applications beyond borewell rescues, such as search and rescue operations in confined spaces, infrastructure inspections, and environmental monitoring.

11) Rapid Deployment: The robot can be quickly deployed to the site, saving valuable time during emergency situations and potentially increasing the chances of successful rescues.

12) Efficient Navigation: Equipped with obstacle detection sensors, the robot can navigate through

challenging terrains and avoid obstacles autonomously, ensuring efficient movement.

13) Feedback Mechanism: Provides real-time feedback to rescuers, allowing them to assess the effectiveness of the robot's actions and make adjustments as needed.

14) Reduced Human Exposure to Hazards: Minimizes the exposure of human rescuers to hazardous conditions, chemicals, or dangerous environments, thereby enhancing overall safety during rescue operations.

15) Integration with Emergency Services: Can be integrated with emergency services and response systems, facilitating seamless collaboration between the robot and human responders.

APPLICATIONS

1) Borewell Rescue Operations: Primary application involves the deployment of the robot to navigate and inspect open borewells for potential rescue operations, helping in locating and assisting individuals trapped inside.

2) Search and Rescue in Confined Spaces: Utilized in various confined spaces, such as collapsed buildings, tunnels, or mines, where the robot can navigate and search for survivors more effectively than humans.

3) Emergency Response in Disaster Areas: Deployed as part of emergency response teams to navigate through disaster-stricken areas and assess the situation. The robot can provide real-time data to assist in decision-making.

4) Industrial Inspections: Used for inspecting and monitoring industrial spaces, especially in environments with potential hazards or where human access is difficult, ensuring safety during inspections.

5) Infrastructure Monitoring: Applied for inspecting and monitoring critical infrastructure like pipelines, sewer systems, and utility tunnels, helping identify issues and perform routine maintenance.

6) Environmental Monitoring: Equipped with environmental sensors, the robot can be deployed in hazardous areas to monitor air quality, temperature, and gas levels, providing valuable data for environmental assessments.

7) Remote Surveillance: Deployed for surveillance in areas that require continuous monitoring, such as border security, wildlife observation, or monitoring remote installations.

8) Search for Missing Persons: Utilized to search for missing persons in challenging terrains, including dense forests, mountainous regions, or areas with difficult accessibility.

9) Pipeline and Sewer Inspection: Navigates through pipelines and sewer systems to inspect for blockages, leaks, or structural issues, reducing the need for manual inspections.

10) Hazardous Material Handling: Used in situations involving hazardous materials, where the robot can navigate and handle materials without exposing humans to potential risks.

11) Education and Training: Applied as a tool for training emergency response teams, providing a realistic simulation of rescue scenarios and enhancing preparedness.

12) Surveillance and Security: Used for security purposes, patrolling and monitoring areas for potential threats, or providing an additional layer of security in public spaces.

13) Data Collection in Remote Areas: Deployed for scientific research or data collection in remote or challenging terrains, collecting valuable information without human intervention.

14) Assisting Emergency Responders: Assists emergency responders by providing real-time information, communication support, and performing preliminary assessments in hazardous environments.

15) Communication Relay: Acts as a communication relay in situations where regular communication infrastructure is disrupted, enabling communication between rescue teams and central command.

These applications highlight the versatility and potential impact of a smart rescue robot in various fields, contributing to improved safety, efficiency, and effectiveness in challenging environments

4. RESULTS

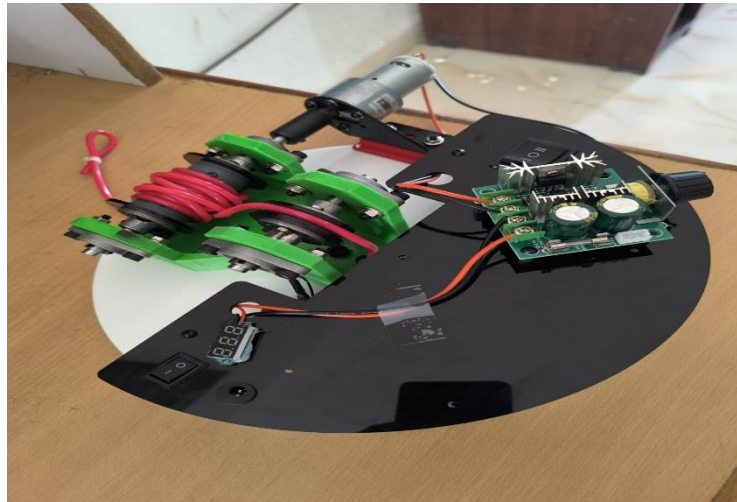


Figure 1: Upper part of the project

The above picture shows the hardware components of upper part of the kit. Activation of the kit is achieved by switching the ON/OFF switch on the battery. With the help of DPDT switch High torque dc motor and PWM speed controller is activated. A dc socket is present to charge the kit.

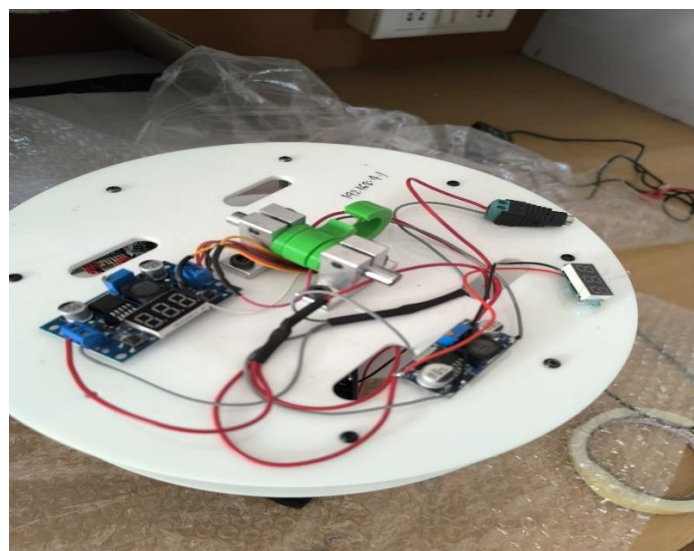


Figure 2: Lower part of project

The above picture shows the hardware components of lower part of the kit. A camera module and a speaker is connected at the bottom of the kit. The lower part is activated through a 12v Battery. When we turn on the lower section of the kit, three regulators are activated, each connected to various components.

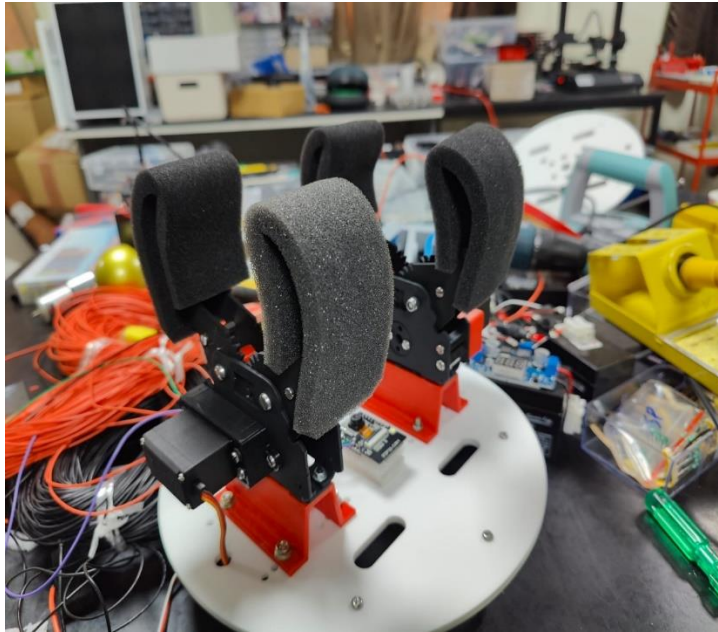


Figure 3: Grippers

Grippers are connected to lower section of the kit. Both the grippers are controlled by the servo motors. A 6v dc supply is given to servo motors through LM2596 regulator. The grippers are activated when the object is detected.

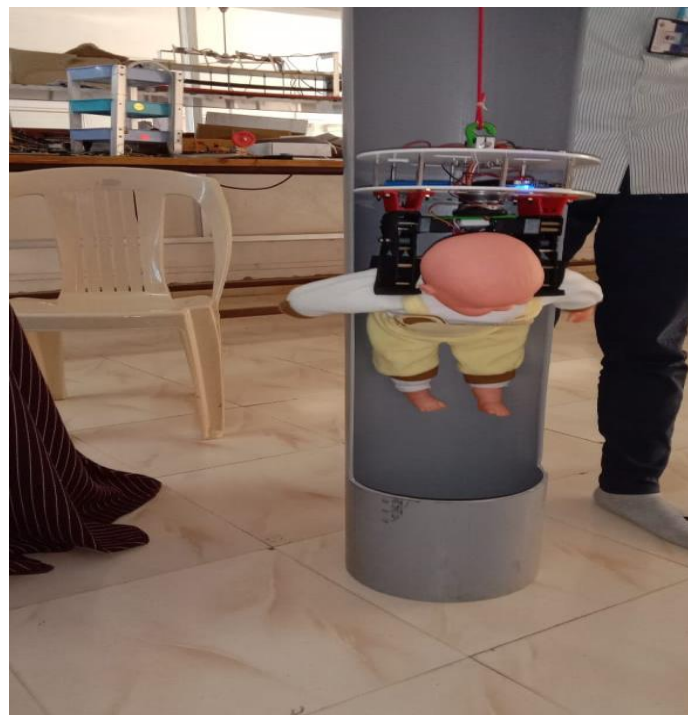


Figure 4: Victim being rescued

The borewell rescue kit is designed to save children who trapped in borewells by using grippers to securely hold the stuck baby and safely extracting them from the borewell. Compared to traditional

methods, this kit significantly reduces the time needed for rescue operations, ensuring a faster and more efficient response in critical situations.

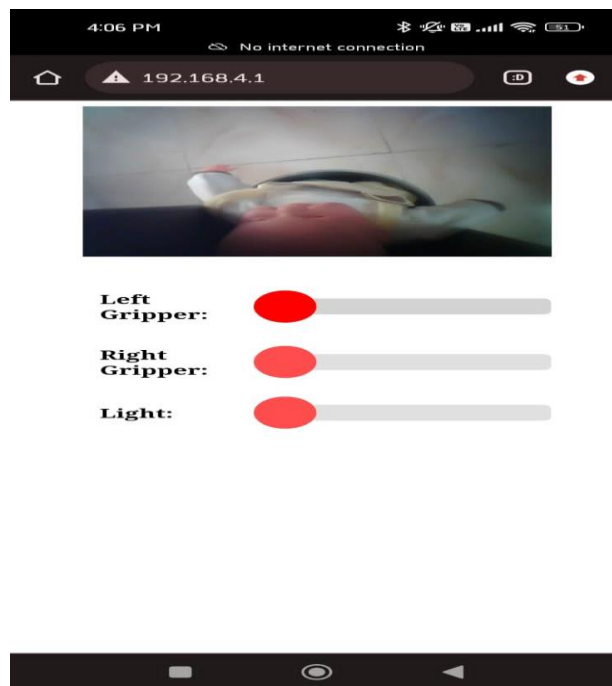


Figure 5: Web Interface for ESP32 CAM module

The rescue kit includes a camera to monitor the children trapped in the borewell, as seen in the above image. It displays the victim's condition. This camera is important for ongoing surveillance, for a successful rescue operation. It provides rescuers the real-time information, allowing them to take immediate action if needed and it also increases the efficiency.

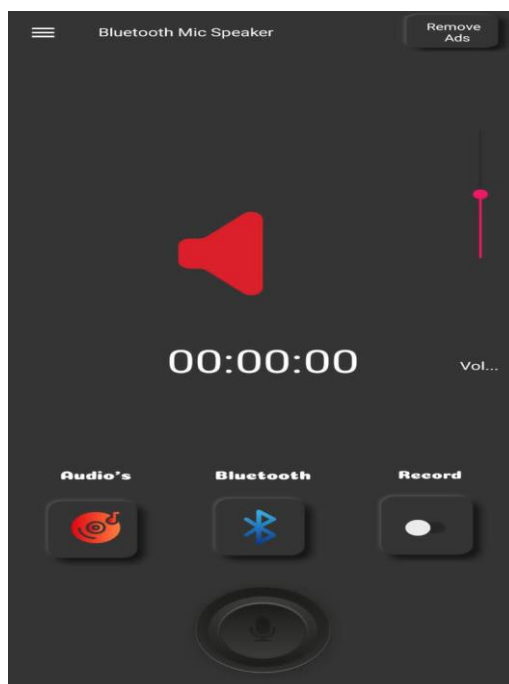


Figure 6: App interface for Bluetooth speaker

The application interface allows rescuers to communicate with the trapped victim inside the borewell. With a recording feature, the app can record the victim's voice. And with the presence of speaker the victim can listen our words. It helps the victim to get rid of stress and fear.

5. CONCLUSION

In simple words, the rescue robot for borewells is like a clever assistant that uses special technology called ESP32 and IoT. It's really good at quickly helping in emergencies, making rescue missions safer. The ESP32 is like the robot's brain, helping it talk and make smart decisions in real-time. What's nice is it's not complicated or expensive because it doesn't need extra sensors. This makes the robot easy to use and move around fast. Overall, this smart robot is a handy and clever way to deal with borewell rescues, showing that simple and smart ideas can solve big problems. Continuing to make the robot better and working together can improve its abilities. The straightforward design and clever performance also suggest that similar smart ideas could help solve other important problems. In the end, this rescue robot with its simple yet smart approach proves that technology can be a helpful friend in challenging situations.

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