

AUTONOMOUS BOREWELL RESCUE ROBOT WITH LIVE VIDEO SURVEILLANCE

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ABSTRACT

Children falling into open or abandoned borewells is a recurring tragedy in many parts of India. Borewells are drilled to depths of several hundred feet with a diameter that is often less than a foot, and when they are left uncovered a small child can slip inside and become trapped at a depth where no adult can reach. Conventional rescue involves digging a parallel pit with heavy machinery, which can take more than a day and exposes the child to lack of oxygen, low temperature, falling soil, and dehydration. This paper presents an autonomous borewell rescue robot with live video surveillance that is designed to reduce this delay.

The proposed robot is a compact cylindrical unit that is lowered into the borewell on a steel cable driven by a motorised winch at the surface. It carries a camera with infrared illumination, a temperature and humidity sensor, a gas sensor for oxygen depletion and harmful gases, an ultrasonic sensor for distance measurement, and a microphone for listening to the child. A Raspberry Pi on the robot handles video capture and streaming, while an Arduino or ESP32 controls the gripper motors, leg-type wall supports, and sensor sampling. Live video and sensor data are sent over a shielded cable or Wi-Fi link to a control station at the surface.

The robot descends autonomously under controlled speed, using the ultrasonic sensor and camera to stop at a safe distance above the child. Its wall-gripping legs expand against the borewell wall to stabilise the body, after which a set of padded arms is positioned around the child under the supervision of the operator. An oxygen supply tube can be guided down along the cable, and a two-way audio channel allows parents or rescuers to talk to the child and keep the child calm throughout the operation.

All sensor readings, including depth, temperature, gas levels, and the status of each actuator, are displayed on a laptop or tablet dashboard at the surface and are also pushed to a cloud server through a mobile network. District officials and remote experts can view the live stream and readings through a web page, which supports coordination between the fire department, disaster response teams, and medical staff. Automatic alerts are generated when oxygen falls below safe levels or when the gripper force exceeds a set limit.

The system is intended to support trained rescuers and not to act without human supervision during the critical lifting phase. Tests on a vertical PVC pipe model with a weighted dummy showed that the robot could reach a depth of several metres, hold its position steadily, and lift the dummy without slipping while the operator watched a

continuous video feed. Future work includes a narrower mechanical design for smaller borewells, depth rating for deeper shafts, and computer vision to assist in identifying the posture of the trapped child.

I. INTRODUCTION

Groundwater is the main source of irrigation and drinking water in large parts of rural India, and farmers often drill several borewells before finding one that yields enough water. Failed or dried borewells are frequently left open or covered only with a loose sack or stone. Over the years, many incidents have been reported in which young children playing near farms have fallen into such openings. Each incident draws national attention and a large rescue effort, yet the outcome is often tragic because of the time needed to reach the child.

The standard rescue procedure involves digging a parallel shaft with excavators and then cutting a horizontal tunnel to reach the child. This process depends on soil conditions, the depth of the trapped child, and the availability of heavy equipment, and it can take anywhere from several hours to a few days. During this time the child is trapped in a narrow space with little oxygen, no food or water, and no way to move. The vibrations from digging may also cause loose soil to fall further into the borewell, which adds to the danger.

Robotics and embedded systems offer a way to reach the child through the borewell itself rather than digging around it. A small robot that can travel down the shaft, see the child clearly, provide oxygen, and hold the child securely could shorten the rescue time considerably. The availability of compact single-board computers, low-cost cameras, reliable motor drivers, and wireless communication makes it possible to build such a robot with components that can be maintained and repaired by district-level teams.

This paper describes an autonomous borewell rescue robot with live video surveillance. The robot combines a controlled descent mechanism, environmental sensing, a stabilising leg system, a padded gripping mechanism, two-way audio, and live video streaming to a surface control station and cloud dashboard.

II. LITERATURE SURVEY

Early research on borewell rescue focused mainly on manual tools that could be lowered on ropes, such as hooks, loops, and simple claws operated from the surface. These tools were inexpensive and quick to deploy, but the rescuer had no direct view of the child and had to rely on sound and guesswork to position them. Several reports noted that such attempts sometimes pushed the child further down or caused injury, because the force applied could not be controlled accurately. Studies that reviewed past rescue operations concluded that visibility inside the borewell and controlled gripping force were the two most important missing capabilities. This led to later designs that attached a camera and lighting to the lowered tool so that the operator could see the position of the child, the diameter of the shaft, and any obstructions before attempting to hold the child. The addition of visual feedback was widely recognised as a necessary first step towards safer rescue methods.

Subsequent work proposed dedicated borewell rescue robots with motorised arms. Many of these designs used a central shaft with two or three arms driven by DC or servo motors through gear or lead-screw mechanisms, allowing the arms to close around the child from below the shoulders or under the arms. Researchers experimented with arm shapes, padding materials, and inflatable balloons that could be expanded under the child to form a supporting platform. A common concern in this literature is that the diameter of borewells varies from about six to twelve inches, so a robot must be narrow enough to pass down the shaft while still producing enough gripping force. Several prototypes addressed this through telescopic or foldable arms. Authors reported successful lifting of dummy weights in pipe models, but noted that uneven borewell walls, mud, and water accumulation create conditions that are harder to reproduce in laboratory tests.

Stabilisation of the robot inside the shaft has been treated as a separate research problem. A robot hanging freely on a cable tends to rotate and swing, which makes precise positioning of the gripper difficult. Studies borrowed ideas from pipe inspection robots and in-pipe climbing robots, which use wheels or legs pressed against the pipe wall by springs or linear actuators. Wall-pressing mechanisms allow the robot to hold its position and orientation while the gripper operates, and they also share the load when the child is lifted. Research on in-pipe robots has examined wheel-leg, screw-drive, and inchworm locomotion, each with different trade-offs in speed, grip, and complexity. For borewell rescue, most authors favoured simple radial legs with rubber pads because they keep the mechanism compact and can adapt to minor changes in diameter along the depth.

Environmental monitoring inside the borewell has received increasing attention because a child trapped for long periods may suffer from low oxygen, high carbon dioxide, and hypothermia. Researchers have mounted oxygen, carbon dioxide, methane, temperature, and humidity sensors on rescue robots and have transmitted readings to the surface to guide the rescue team. Some designs also included a flexible tube along the cable to deliver oxygen close to the child. Work on communication has compared wired links, which are reliable but add weight and drag, with wireless links, which are easier to handle but suffer attenuation in deep narrow shafts. Many prototypes use a hybrid approach, sending power and video over a thin cable while using wireless connectivity at the surface to share data with a wider team through cloud dashboards and mobile devices.

More recent studies have explored autonomy and intelligent assistance in rescue robots. Automatic descent control using distance sensors, depth encoders on the winch, and camera-based obstacle detection reduces the burden on the operator and prevents the robot from striking the child. Computer vision models have been suggested for detecting the head and limbs of the child in the video feed, so that the operator can be guided when positioning the arms. Researchers have also emphasised that fully autonomous gripping is not yet acceptable for such a sensitive task and that human confirmation should remain in the loop.

III. SYSTEM ANALYSIS

The borewell rescue robot is analysed as a mobile sensing and actuation unit connected to a surface control station and a cloud monitoring service. The robot body carries an infrared-capable camera, LED lighting, ultrasonic range sensors facing downward, a DHT22 temperature and humidity sensor, MQ-series gas sensors with an oxygen sensor, a microphone and speaker, and a depth encoder reading from the winch. A Raspberry Pi captures and compresses the video, and an ESP32 or Arduino drives the leg actuators, gripper motors, and sensor sampling through motor driver boards. The winch at the surface is controlled by a separate microcontroller that sets descent speed and stops automatically when the downward distance reaches a threshold. Video and sensor data travel through a shielded cable or a short-range Wi-Fi link to the control station, where a dashboard shows the stream, readings, and actuator status. The station forwards data over a mobile network to a cloud service so that officials and experts can monitor remotely and receive alerts.

Existing System

Borewell rescue in practice still relies mainly on the parallel pit method. Once a child is reported trapped, earth-moving machinery is brought to the site, a pit is dug alongside the borewell to a depth slightly below the child, and a horizontal tunnel is cut to reach the child from the side. This process is slow and depends on soil type, rock layers, groundwater, and weather. Meanwhile, rescuers usually lower a simple camera on a rope to observe the child and a pipe to supply oxygen, but these tools are not integrated and the camera image is often unclear. In some cases local innovators have lowered hand-made hooks or grippers, but these devices lack controlled force, stability, and sensor feedback. Information about the condition inside the borewell is passed verbally between teams, and district authorities have limited real-time visibility of progress. The overall result is a rescue that may take a long time and exposes the child to prolonged risk.

Disadvantages of Existing System

- Digging a parallel pit takes many hours or even days to reach the child.
- Heavy machinery may cause soil to collapse further into the borewell.
- Manual hooks and ropes give no control over gripping force.
- Rescuers have poor visibility of the child and the shaft conditions.
- Oxygen level and temperature inside the borewell are not measured continuously.
- Freely hanging tools swing and rotate, making positioning difficult.
- There is no reliable two-way communication with the trapped child.

Proposed System

The proposed system is an autonomous borewell rescue robot with live video surveillance that reaches the child directly through the borewell. A motorised winch lowers the cylindrical robot at a controlled speed while an encoder records depth and a downward ultrasonic sensor measures the distance to the child. The descent stops automatically at a safe distance, and radial legs driven by linear actuators press

against the borewell wall to stabilise the robot and prevent rotation. An infrared camera with LED lighting streams live video through a Raspberry Pi to the surface control station, while temperature, humidity, gas, and oxygen sensors report the conditions around the child. A flexible tube guided along the cable supplies oxygen, and a microphone and speaker allow the family to speak with the child. Padded gripper arms, controlled by the operator with current-limited motor drivers, close gently around the child before the winch lifts the robot and child together. Live video and readings are also sent to a cloud dashboard with automatic alerts for unsafe conditions.

Advantages of Proposed System

- Reaches the child through the borewell without digging a parallel pit.
- Provides a clear live video view of the child using infrared lighting.
- Stops descent automatically at a safe distance above the child.
- Stabilises itself against the borewell wall for precise gripper positioning.
- Limits gripping force to reduce the risk of injury during lifting.
- Monitors oxygen, gas, and temperature levels continuously near the child.
- Supports oxygen delivery and two-way audio to keep the child calm.
- Shares live video and readings with remote officials through the cloud.

IV. METHODOLOGY

The methodology begins with a study of typical borewell diameters and depths, which sets the outer dimensions of the robot and the lengths of its legs and arms. The mechanical body is designed as a cylindrical frame with three radial legs and three padded arms, and it is fabricated using aluminium and 3D-printed parts. Sensors and actuators are interfaced with an ESP32 for control and a Raspberry Pi for video, and each sensor is calibrated in a test pipe. The winch controller is programmed to lower the robot in steps, reading the encoder and ultrasonic distance, and to stop at a preset gap above the target. After stopping, the firmware extends the legs until motor current indicates firm wall contact. The operator watches the live stream and commands the arms, whose motor current is monitored to limit grip force. Sensor data is sent every second as MQTT messages from the control station to a cloud broker. Trials in a vertical PVC pipe with a weighted dummy measure descent accuracy, stability, lifting success, and video latency.

SYSTEM ARCHITECTURE

The architecture of the borewell rescue robot is arranged in layers from the sensing hardware inside the shaft to the people coordinating the rescue. The Sensing Layer includes the infrared camera, ultrasonic range sensors, gas and oxygen sensors, temperature and humidity sensor, microphone, and winch encoder. The Actuation Layer consists of the winch motor, leg actuators, gripper motors, and lighting, driven through motor driver boards with current sensing. The Embedded Control Layer uses an ESP32 for real-time control of descent, stabilisation, and gripping, and a Raspberry Pi for video capture and audio. The Communication Layer carries video, audio, and data from the robot to the surface through a shielded cable or short-range Wi-Fi link.

The Control Station Layer displays the live stream, sensor readings, and actuator status and accepts operator commands. The Cloud Layer receives data through MQTT over a mobile network, stores the rescue log, and applies alert rules. The Remote Monitoring Layer provides a web dashboard and mobile alerts for officials, medical staff, and experts.

Autonomous borewell rescue robot with live video surveillance

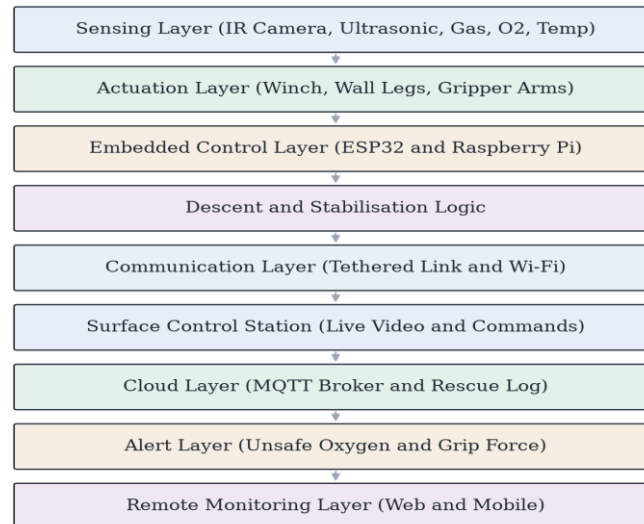


Fig. 1 System Architecture

V. RESULT AND OUTPUT



VI. CONCLUSION

This paper presented an autonomous borewell rescue robot with live video surveillance, intended to reduce the time needed to rescue children trapped in open

borewells. The robot travels down the borewell itself, stops at a safe distance from the child, stabilises against the wall, and lifts the child with padded arms, avoiding the slow and risky process of digging a parallel pit in most situations.

The integration of sensing and communication is central to the design. The infrared camera provides a clear view of the child and the shaft, while gas, oxygen, temperature, and humidity sensors report the conditions the child is experiencing. This information is shown at the surface control station and shared through the cloud, so that rescuers, medical staff, and officials work from the same live picture instead of relying on verbal updates passed between teams.

Tests on a pipe model with a weighted dummy showed that controlled descent, wall stabilisation, and current-limited gripping allowed the robot to hold and lift the dummy reliably while the operator watched the live stream. Keeping the operator in control during the gripping phase ensures that the most sensitive part of the rescue is guided by human judgement, while the robot handles repetitive and precise tasks such as descent control and position holding. The two-way audio channel also proved useful, since a familiar voice can keep a frightened child still while the arms are being positioned.

Future work will address smaller borewell diameters through a more compact mechanism, greater depth ratings with stronger cables and improved power delivery, and waterproofing for borewells that contain water. Computer vision models could be added to identify the posture of the child and suggest the best gripping position. Field trials in cooperation with disaster response agencies will be necessary to validate the robot under real soil and shaft conditions and to prepare operating procedures for district rescue teams.

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