Child Rescue System from Open Borewell

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Abstract: Open bore wells are a critical safety concern, particularly in rural areas, where children often fall into uncovered or abandoned wells. This project proposes a real-time, intelligent rescue mechanism utilizing IoT and embedded systems. The system comprises a camera-enabled robotic module that descends into the bore well to locate and rescue the child. The core components include the]Arduino Uno R4 Wi-Fi, ESP32 CAM, servo motor-driven robotic arm, and DC motor system. The goal is to minimize human risk and speed up the rescue process using remote monitoring and mechanical control. The Child Rescue System from open bore wells offers a promising solution to address the life-threatening situation of children falling into bore wells. The system effectively combines Arduino-based technology, real-time video monitoring, and automated actuators for safe and efficient rescue operations.

Keywords: *Open Borewell; Child Rescue; Borewell Rescue System ;IOT-Based Rescue System; Embedded System; Arduino Uno R3/R4 WIFI; ESP32-CAM; Robotic Arm; Servo Motor Control; DC Motor and L298 Driver Learning;*

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I. INTRODUCTION

Everyday, bore well accidents occur due to uncovered openings, posing a serious risk to children's lives. This project, titled 'Child Rescue System from Open Bore well' has been undertaken with the aim to save lives efficiently. With this in mind, the main objective of this project is to design and construct a portable system that is cost-effective, quick in action, and accurate. The Bore well Rescue System is capable of moving inside the well and performing operations based on user commands. The system is operated through a personal computer, with continuous observations made using a CCTV camera. The results of this project aim to provide an efficient and reliable solution to bore well rescue operations, ensuring the safety of children in such emergencies. Bore wells are commonly used for groundwater extraction, especially in rural and semi urban areas. How many bore wells are left uncovered after being abandoned, posing a significant hazard to children who may accidentally fall into them. Incidents of children getting trapped in bore wells have been reported frequently, and in most cases, traditional rescue operations involve digging parallel pits, which is time-consuming, labor-intensive, and often results in fatal consequences, The main objective of this project is to design and construct a portable system which is cost effective, quick in action and accurate. The Bore well Rescue System is capable of moving inside the well and performs operations according to the user commands. Once the system has reached proximity of child, it is stopped immediately and is given the commands by the controlling device to perform the closing of the systemic arms. Manually monitoring the child with the help of camera and controlling unit of system.

II. METHODOLOGY

The methodology for the Child Rescue System involves a structured approach that integrates hardware and software components to ensure an efficient and safe rescue operation. The following steps outline the process:

System Design & Component Integration of the project uses two Arduino boards an Arduino Uno R3 for the top cap module and an Arduino Uno R4 Wi-Fi for the disk-shaped module. These boards control the motor movements, sensor readings, and communication between modules. The ESP32-CAM is used for live video streaming, enabling real-time monitoring of the bore well interior. Deployment in Bore well: The disk-shaped rescue module is lowered into the bore well using a high-powered DC motor controlled by the Arduino Uno R3 and L298N motor driver. Once the module reaches the child, the servo motor and robotic arm (controlled by Arduino Uno R4 Wi-Fi) are activated to safely

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grab and lift the child using soft brushes. Real-Time Monitoring The ESP32-CAM streams live video from inside the bore well to the surface, allowing the operator to assess the child's condition and position. Temperature and humidity data from the DHT11 sensor are continuously monitored to ensure the child's safety during the rescue. Manual Intervention The operator can control the DC motor's movement through push buttons to precisely raise or lower the rescue module. The system's design allows for manual overrides in case adjustments are needed during the operation. Final Rescue After ensuring that the child is securely held by the robotic arm, the rescue module is raised back to the surface using the DC motor, bringing the child to safety. By combining manual control with automated systems, this methodology ensures both accuracy and efficiency during the rescue operation. It reduces human intervention, ensures live monitoring, and increases the likelihood of a successful rescue.

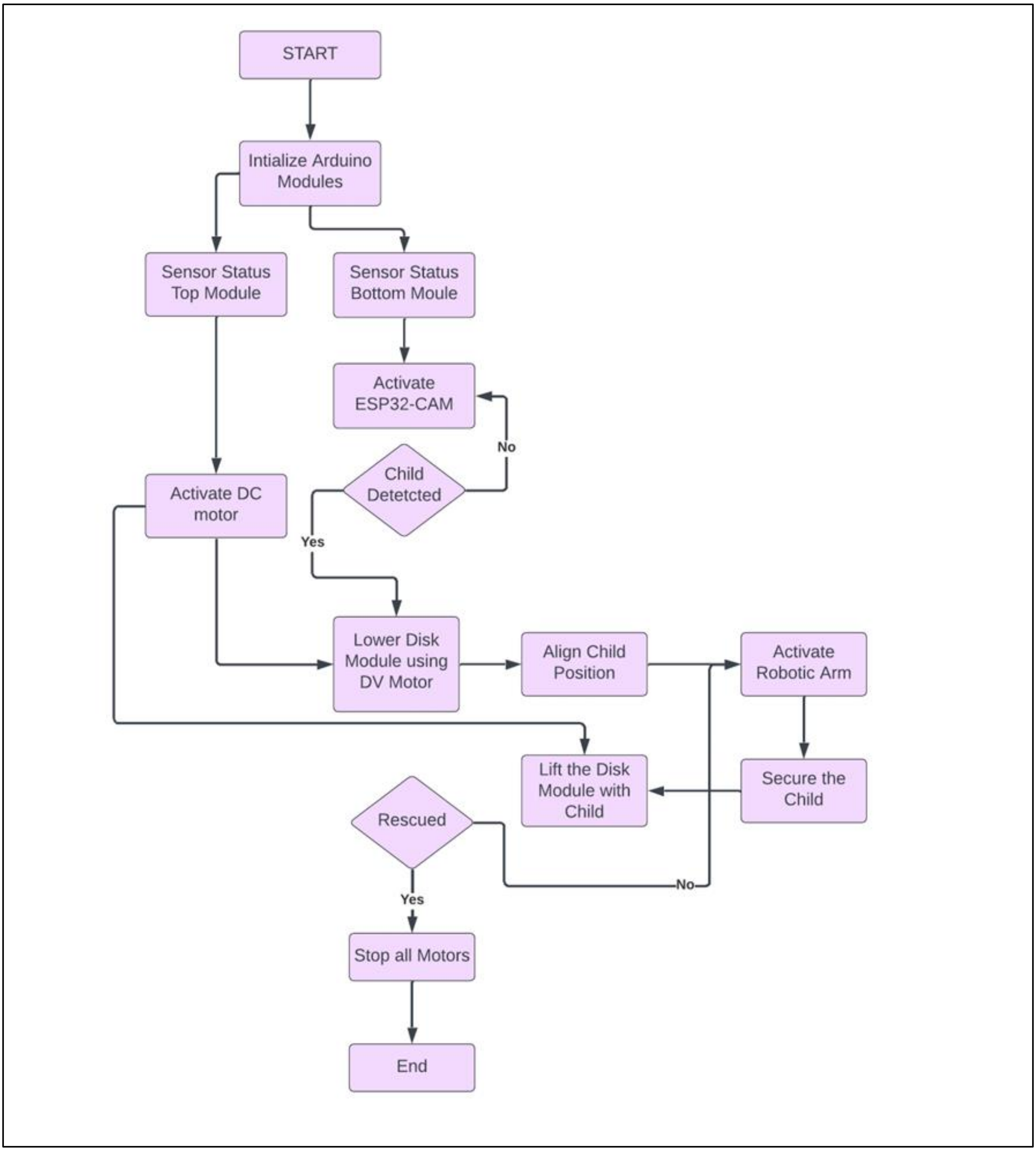

Fig 1. Flowchart

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- *Start and Initialization:*

The system begins by initializing all necessary hardware components, including the two Arduino boards (Uno R3 and Uno R4 Wi-Fi), ESP32-CAM, sensors, servo motor, DC motor, and manual control buttons. All connections and components are tested to ensure they are functioning properly before proceeding.

- *Establish Communication and Camera Feed:*

The bottom module activates the ESP32-CAM to start streaming real-time video from inside the bore well. At the same time, the top and bottom modules establish communication for coordinated actions during the rescue process.

- *Monitor Environment and Detect Child:*

The top module continuously reads data from the DHT11 sensor to monitor temperature and humidity inside the bore well. The video feed is used to detect the presence and position of the trapped child, either automatically using image processing or manually by a human observer.

- *Check for Emergency Conditions:*

If the temperature or humidity exceeds safe levels, the system triggers an alert using a buzzer or LED. These alerts help notify rescuers of potentially dangerous conditions that may affect the child or the rescue operation.

- *Lower Rescue Module (Disk-Shaped):*

Upon confirming the child's location, the DC motor is activated to slowly lower the Disk-Shaped Module containing the camera and robotic arm. The descent is carefully monitored to avoid any impact or instability during the operation.

- *Positioning and Arm Activation:*

Once the module reaches the level of the child, the robotic arm is controlled using the servo motor. The arm is positioned based on video feedback to reach and safely grip or guide the child into a secured position for lifting.

- *Secure the Child:*

The system ensures that the child is safely held using the robotic arm. Verification is done visually through the video feed or through sensors if present, confirming that the child is ready to be lifted.

- *Lift the Module:*

The DC motor is reversed to lift the entire Disk-Shaped Module with the child back to the surface. The ascent is smooth and controlled to ensure the child's safety during retrieval.

- *Manual Override and Safety:*

At any point during the process, manual controls can override the system in case of automation failure. Physical buttons on the top module allow operators to control the motor or the arm manually to handle emergencies.

- *Complete Rescue and Shutdown:*

Once the child is safely brought to the surface, all motors are stopped, and the system is reset. The rescue status is recorded, and the system is made ready for the next operation or powered off safely.

III. MODULES AND ITS IMPLEMENTATION

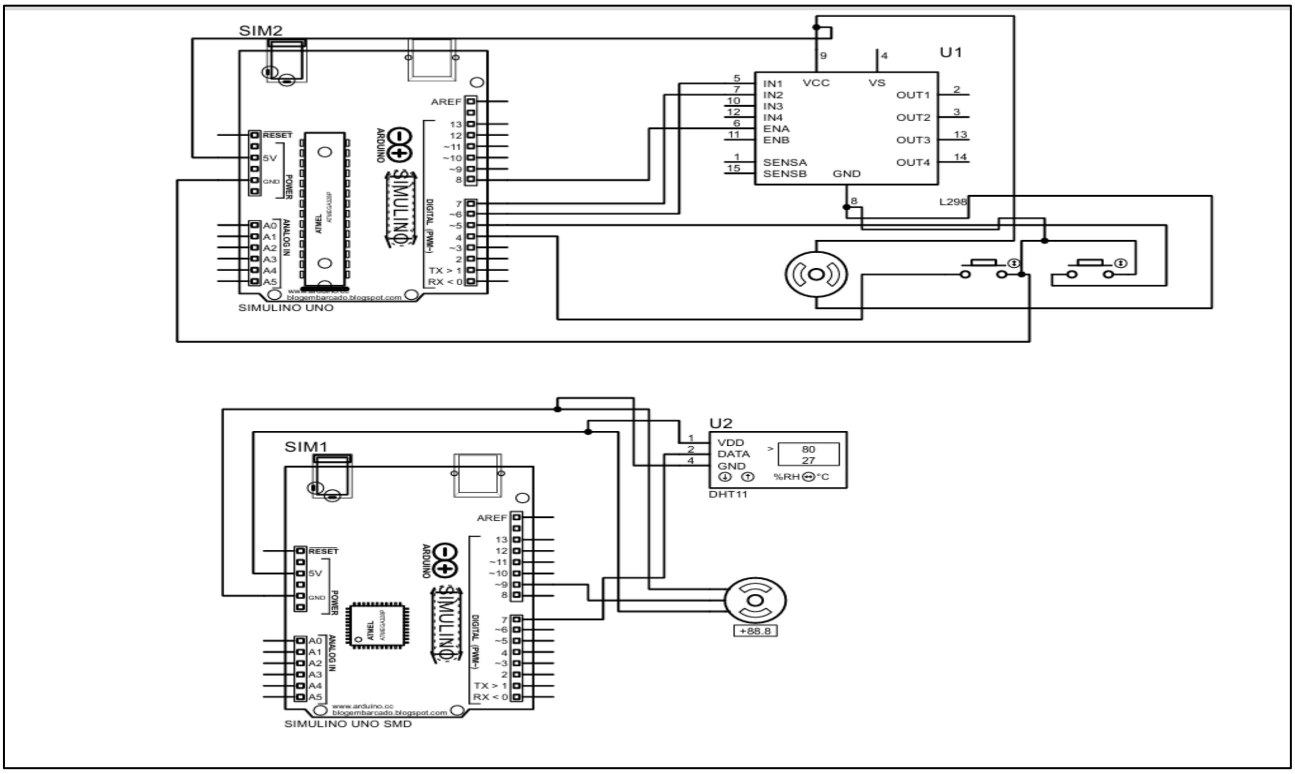

Fig 1 Modules

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A. System Operations:

- *Arduino UNO R4 WIFI:*

The Arduino Uno R4 Wi-Fi is a modern microcontroller board equipped with a 32-bit Renes as RA4M1 processor and integrated Wi-Fi connectivity, making it suitable for smart embedded applications. In this project, the R4 board is housed in the disk-shaped rescue module that is lowered into the bore well. Its main responsibility is to control the servo motor that drives the robotic arm designed for rescuing the trapped child. The robotic arm is equipped with soft gripping brushes to ensure a gentle and secure hold on the child during the rescue. The Arduino Uno R4 WiFi reads commands and precisely positions the servo motor to open or close the gripper based on real-time visual feedback provided by the ESP32-CAM. The board is either powered by a 5V battery or a wired connection from the top module. Its processing capability and wireless communication features make it ideal for managing critical actions in confined, remote conditions, increasing both efficiency and safety in life-saving operations.

- *Arduino UNO Development Board:*

I Arduino Uno is a popular open-source microcontroller board based on the Atmel AVR microcontroller chip. It is designed for use in a wide variety of electronic projects and is ideal for beginners and hobbyists due to its simplicity and ease of use. The board features 14 digital input/output pins, six analog inputs, a 16 MHz quartz crystal, a USB connection, a power jack, and an ICSP header for programming. It can be powered either through the USB connection or an external power source.

- *ESP32-CAM:*

The ESP32-CAM captures high-quality video of the bore well interior and streams it wirelessly to the surface, where the operator can monitor the trapped child’s position and condition through a web-based interface. This live video feed enables the operator to make informed decisions, ensuring that the robotic arm is aligned properly for a safe and successful rescue. Powered by a 5V battery or an external wire from the surface, the ESP32-CAM operates independently, requiring no additional infrastructure. Its integration with the Arduino Uno R4 Wi-Fi allows for seamless communication between the rescue module and the top cap module. The real-time monitoring capability provided by the ESP32-CAM enhances the precision and speed of the rescue operation, making it safer and more effective.

- *DHT11–Temperature and Humidity Sensor:*

Monitoring temperature and humidity allows the operator to assess whether the child is in a potentially harmful environment and make decisions regarding the speed of the rescue operation. The DHT11 sensor operates by sending digital signals that are easily read by the Arduino, enabling accurate readings of the bore well's internal conditions. The sensor’s low power consumption and easy integration make it an ideal choice for real-time applications.

- *Servo Motor SG-90:*

This system allows for automated rescue operations, with the servo motor adjusting the arm's position and strength as needed. By combining robotic precision with soft gripping technology, the servo motor and robotic arm work together to enhance the safety and effectiveness of the rescue process, minimizing human intervention while maximizing the chances of success.

- *DC Motor :*

The ESP32-CAM captures high-quality video of the bore well interior and streams it wirelessly to the surface, where the operator can monitor the trapped child’s position and condition through a web-based interface.

- *L298N Motor Driver:*

The L298N motor driver interfaces with the Arduino Uno R3, receiving control signals to drive the motor in either direction, based on the operator’s input from the manual push buttons. By controlling the direction and speed of the DC motor, the L298N motor driver ensures that the rescue module can be moved with high precision.

- *Robotic ARM:*

A robotic arm is a crucial component in modern automation systems, offering precise control over angular position, velocity, and acceleration. In robotics, servo motors act as actuators that enable robotic arms to perform complex and accurate movements required for tasks such as picking, placing, assembling, or even assisting in medical and industrial applications. The robotic arm typically consists of multiple joints, each powered by a servo motor. These motors receive control signals (PWM – Pulse Width Modulation) to rotate to a specific angle. The high precision and repeatability of servo motors make them ideal for applications where accuracy is essential.

- *Push Button :*

Push buttons serve as essential manual control inputs in the bore well child rescue system. They provide a simple and reliable interface for human operators to control different parts of the robotic setup.

IV. MODELING AND ANALYSIS:

Open bore wells, which are narrow and deep holes drilled for water extraction, have become a common hazard in rural and suburban areas. Due to negligence, these borewells are often left uncovered or inadequately sealed, leading to tragic incidents where children accidentally fall into them. Rescue operations in such scenarios are extremely challenging due to the limited space, lack of visibility, and urgency required to save lives. Traditional rescue techniques like parallel shaft digging are not only time-consuming but also pose significant risks to both the victim and the rescuers. Hence, a technological intervention is essential. This paper focuses on the modelling and analysis of an innovative robotic child rescue system

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designed specifically for open bore well emergencies, aiming to provide a faster, safer, and more reliable solution.

The primary objective of the proposed system is to create a compact and efficient robotic device capable of descending into narrow bore wells, locating the child, establishing communication, and safely retrieving the child. The system is modelled to include a cylindrical robotic unit equipped with visual and audio communication tools, robotic arms, oxygen supply, and a harness mechanism. This robot is designed to be tethered for power and communication and is operated remotely from the surface. The modelling phase uses computer-aided design (CAD) tools like Solid Works to construct an accurate 3D representation of the robot, considering real bore well dimensions typically ranging from 200 to 300 mm in diameter.

The robot consists of several modules, each with distinct functions. The upper section houses the control and communication unit, including a camera, microphone, and speakers for real-time interaction with the child. The middle section supports lighting and positioning sensors to navigate and stabilize the robot within the bore well. The lower section features two robotic arms with servo motors, capable of multi-directional movement to attach a safety harness to the child. An oxygen supply module is integrated with an extendable tube and mask to provide breathing support if necessary. The materials used in modelling are lightweight and corrosion-resistant, including aluminium alloy for the body and carbon fibres for the arms, ensuring structural integrity while maintaining mobility.

The robot's kinematic and dynamic behaviours are analysed using simulation tools such as MATLAB/Simulink and ANSYS. Forward and inverse kinematics are used to determine the exact positioning of the robotic arms, ensuring they can reach and operate within the tight confines of the bore well. Dynamic analysis ensures that the system maintains stability while descending and operating, even under the variable weight conditions of a trapped child. The descent speed, arm extension, and rotational motion are carefully modelled to balance precision and safety, avoiding jerky movements that might disturb the child or cause further injury.

Control of the robot is managed through a remote interface using a microcontroller such as Raspberry Pi or Arduino. The control system incorporates joystick input, video feedback, and sensor data to guide the robot's actions. A PID (Proportional-Integral-Derivative) control loop is implemented to ensure smooth and responsive motion of the robotic arms and descent mechanism. Real-time feedback from infrared and ultrasonic sensors helps detect obstacles and determine proximity to the child, enabling precise control even in visually obscured environments. The robot is tethered with a strong cable that doubles as a power and data link, eliminating the need for bulky on-board batteries.

Simulation of the complete rescue process is carried out in virtual environments using tools like Gazebo and ROS (Robot Operating System). A 3D simulation of a 30-meter-deep bore well is created, with a child mannequin placed at different depths and postures. The robot's performance is evaluated on parameters such as time taken to reach the child, success rate of harness attachment, and stability during lift. Results indicate that the robot can typically reach and secure a child within 10 to 15 minutes—drastically faster than traditional methods. The harness system is designed to adapt to different body sizes and postures, ensuring a firm yet gentle hold for lifting.

Safety is a key aspect of the system's design. The robot includes fail-safe mechanisms such as automatic brakes if power fails, temperature sensors to monitor bore well conditions, and emergency lighting. Stability during lifting is achieved through gyroscopic sensors that ensure the robot remains upright. The camera system provides continuous visuals to surface operators, while the speaker-microphone system allows operators to calm and instruct the child, reducing panic and improving cooperation. Additionally, the oxygen delivery system is capable of running independently for several hours, providing critical life support.

Despite the promising capabilities, the system faces certain limitations. Its effectiveness is reduced in bore wells that are extremely narrow, crooked, or partially collapsed. Operation still depends on the skill of the surface operator, and complex postures of the child may challenge the robotic arm's grip. Moreover, reliance on a tether limits manoeuvrability. Future work involves incorporating AI-based image processing to automate arm movements and harness placement, as well as developing wireless communication modules with signal repeaters to enhance mobility. Adding environmental control like temperature regulation or voice-responsive interaction can further improve the system’s utility and user-friendliness.

V. RESULT AND DISCUSSION AND CONCLUSION

This setup is a motor control system using an Arduino Uno, L298N motor driver, and DC motor, powered by 9V batteries. It's a key part of the child rescue robot, enabling vertical movement inside the bore well. This module features an Arduino-based sensor unit with a DHT11 sensor for temperature and humidity detection, crucial for monitoring a child’s condition inside the bore well. The structure includes supporting legs for stable placement during descent. Controlling a servo motor using an IP address typically involves connecting the servo motor to a network-enabled microcontroller. The ESP32-CAM, equipped with an OV2640 sensor, streams live video from inside the borewell to nearby devices via a local Wi-Fi network. Though it doesn’t control the robotic arm, its real-time feed is crucial for accurate rescue operation guidance.

Implementing the Child Rescue System from Open Borewell came with several technical and operational challenges. One of the most significant difficulties was designing a compact yet fully functional Disk-Shaped Module that could fit into narrow bore well shafts without

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getting stuck or causing additional damage. Ensuring smooth communication between the top and bottom modules, especially under real-time video streaming conditions using the ESP32-CAM, also required careful calibration and network stability. Another challenge was the reliable control of the robotic arm using servo motors to gently and precisely hold the child, which needed both software accuracy and mechanical stability. Power supply management, environmental interference such as dust or moisture, and ensuring complete insulation of electronic parts were other major considerations throughout the development phase.

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