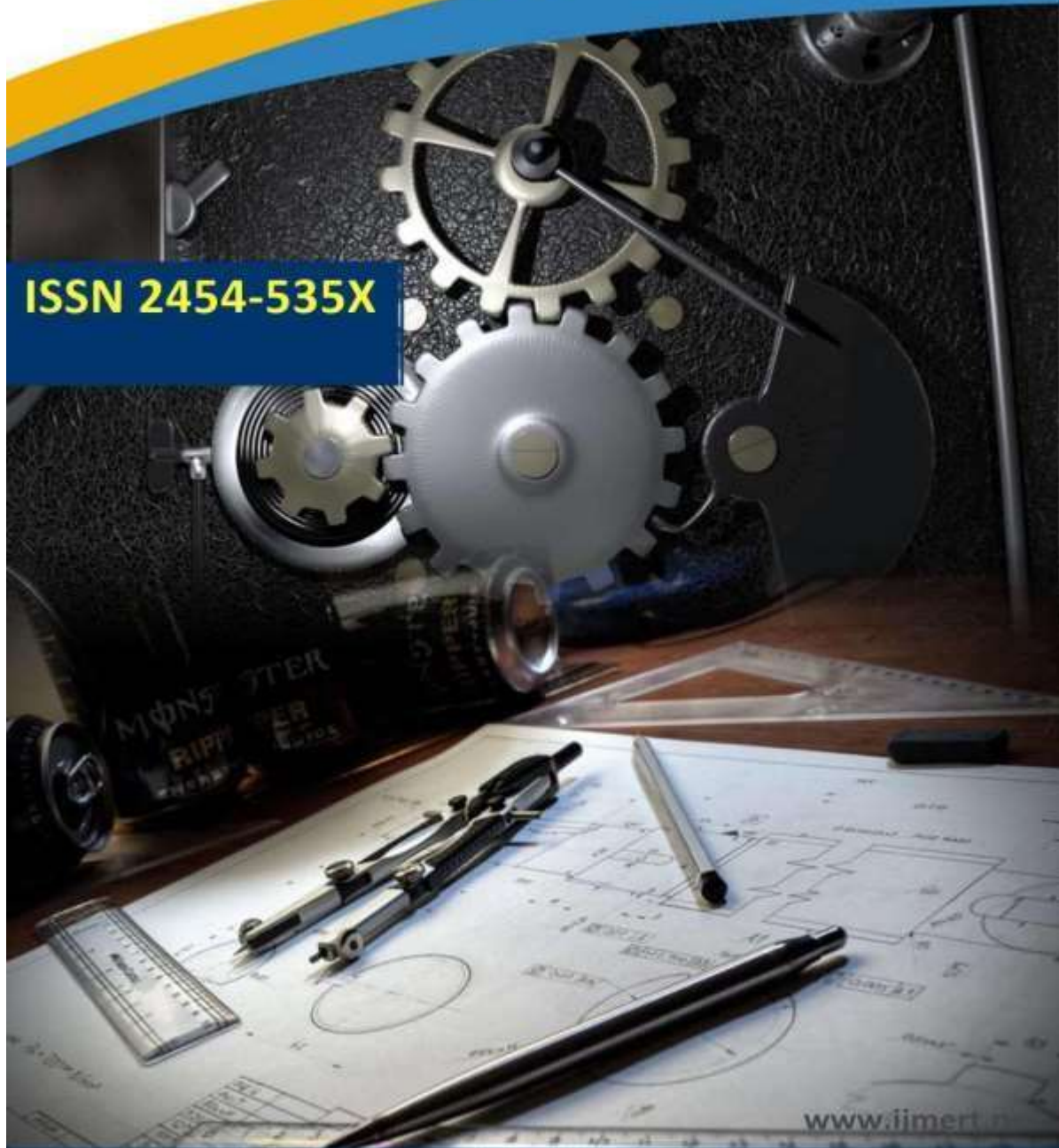




International Journal of
Mechanical Engineering Research and Technology

ISSN 2454-535X



www.ijmert.in

Email ID: info.ijmert@gmail.com or editor@ijmert.net



Design and Development of Gripper based Borewell Rescue Robot with Live Streaming

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ABSTRACT

Borewells are narrow and deep cylindrical excavations used for various purposes, such as water extraction or geological exploration. Accidental falls or entrapments in borewells pose significant challenges for rescue operations due to limited access and potential hazards. Therefore, developing a specialized robot for borewell rescue can enhance the efficiency and safety of such operations. This project presents the development of a borewell rescue robot equipped with an ESP32 microcontroller, high torque DC motors, a camera module, and a mechanical gripper. The robot is designed to navigate and perform rescue operations in narrow borewell environments, where human access is limited or hazardous. The objective is to create a robust and efficient robot capable of reaching and retrieving individuals trapped in borewells, thereby reducing the risks and time associated with manual rescue operations.

Keywords: Borewell Rescue Robot, Live Streaming, Mechanical Gripper, ESP232 Microcontroller.

1. INTRODUCTION

The historical context of the gripper-based borewell rescue robot can be traced back to various incidents worldwide, highlighting the urgency of finding a more effective approach. Notable examples include the 2006 incident in Kurukshetra, India, where a 5-year-old boy was trapped in a borewell for nearly 50 hours, and the 2019 case in Tamil Nadu, India, where a 2-year-old boy's rescue operation captured international attention. Such incidents motivated researchers, engineers, and organizations to develop a specialized robot to mitigate the risks associated with borewell accidents. Borewell accidents, where individuals, particularly children, get trapped in narrow borewells, have been a recurring problem in several parts of the world. These incidents often pose significant challenges to rescue teams due to the confined spaces and difficult access points. Traditional rescue

methods have limitations in effectively and safely retrieving trapped individuals from deep borewells. The development of advanced robotic technologies has revolutionized various industries, including search and rescue operations. One such innovation is the gripper-based borewell rescue robot with live streaming. This article aims to provide an overview of this remarkable robotic system, emphasizing its background, significance, need, and historical context. The development of advanced robotic technologies has revolutionized various industries, including search and rescue operations. One such innovation is the gripper-based borewell rescue robot with live streaming. This article aims to provide an overview of this remarkable robotic system, emphasizing its background, significance, need, and historical context.

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2. LITERATURE SURVEY

Rishab et al. (2023) presented a mechatronic puppet-based robotic hand system specifically designed for life-saving applications. The paper likely discusses the design and development of the robotic hand, including its mechanical structure, actuation mechanisms, and control system. The authors might have also explored the application of this robotic hand in scenarios such as search and rescue operations, where the dexterity and adaptability of the hand can be crucial in saving lives.

Ramkumar et al. (2022). proposed an IoT-based system for rescuing children who have fallen into borewells. The paper likely discusses the architecture of the system, which might involve sensors and communication devices connected through the Internet of Things (IoT). The authors might have also explored the integration of real-time monitoring, data analysis, and communication technologies to facilitate efficient and timely rescue operations.

Kavyasree et al. (2023) presented likely discuss a comprehensive system for rescuing children trapped in borewells using a robotic platform. The paper might cover the design, development, and functionalities of the rescue robot. This could include aspects such as mobility, sensing capabilities, manipulation mechanisms, and communication systems. The authors may also discuss the challenges associated with borewell rescue operations and how their proposed robotic system addresses those challenges.

Thota et al. (2023) likely discuss an innovative child rescue system that utilizes Arduino microcontrollers. The paper might cover the design and implementation of the system, highlighting the role of Arduino in controlling various components such as sensors, actuators, and communication modules. The authors may

also present experimental results and discuss the effectiveness of their proposed system in borewell rescue scenarios.

Karthik et al. (2020) published an investigation and analysis of child rescue systems specifically designed for open borewells. The paper might discuss different approaches and technologies employed in such systems, including sensing methods, communication systems, and robotic mechanisms. The authors may also present case studies or simulations to evaluate the effectiveness and limitations of existing rescue systems.

Akash et al. (2020) presented the design and development of a specialized robot for rescue operations targeting borewell victims. The paper might cover aspects such as the mechanical structure of the robot, its mobility mechanisms, sensing capabilities, and control system. The authors may also discuss the challenges faced in rescue operations and how their robot addresses those challenges.

Sui et al. (2021) focus on the design, characterization, and application of an enveloping soft gripper. The paper might discuss the unique features and advantages of the gripper design, its material properties, and its ability to handle high loads. The authors may also present experimental results and applications where the gripper demonstrates its effectiveness in various tasks, including robotic rescue operations.

RenugaDevi et al. (2021) published present an IoT-based system for detecting unclosed borewell holes using automated drone-operated cameras. The paper might cover the architecture of the system, including the deployment of drones equipped with cameras and IoT-enabled communication. The authors may discuss the image processing techniques employed to detect unclosed borewell holes

and how real-time alerts are generated to prevent accidents in remote areas.

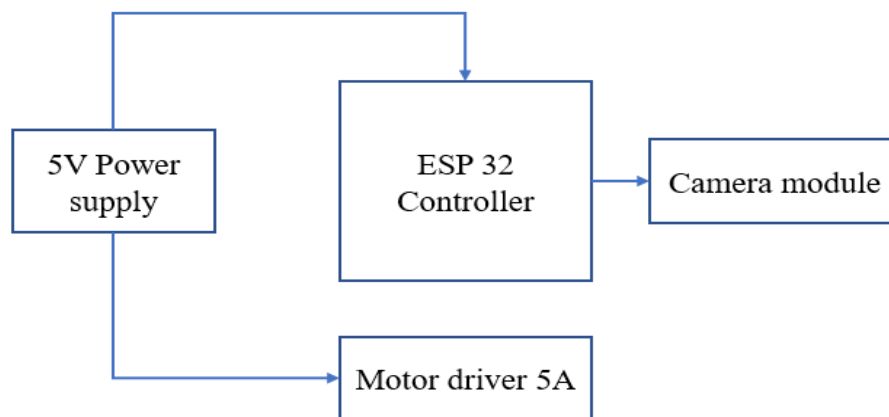
Rajesh et al. (2017) published discuss the design and development of a multi-purpose prosthetic borewell system, specifically focusing on an invincible arm. The paper might cover the mechanical design, actuation mechanisms, and control system of the invincible arm. The authors may also discuss its applications in borewell rescue operations, highlighting its versatility and ability to adapt

Certainly! Here's the continuation of the detailed explanations for the remaining papers:

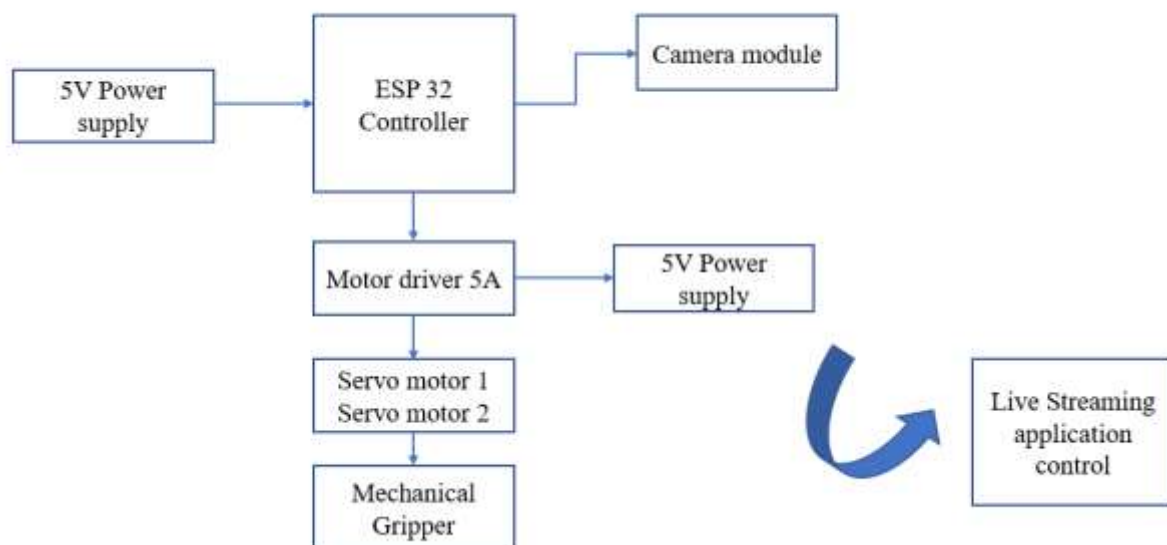
3. PROPOSED METHODOLOGY

3.1 Working operation

Figure 1 shows the proposed block diagram. The robot's working operation involves the operator remotely controlling its navigation, receiving live video feed, and utilizing the mechanical gripper to perform rescue operations.



(a)



(b)



Figure 1: Block diagram of proposed borewell rescue robot. (a) external hardware. (b) internal hardware.

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 centre, 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 modules

- CNC laser cutting
- CNC metal bending
- High torque DC motors
- ESP 32 controller
- 10A motor driver
- Camera Module
- Power supply
- Borewell casing pipe
- 3D printed brackets, clamps and slotted 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.

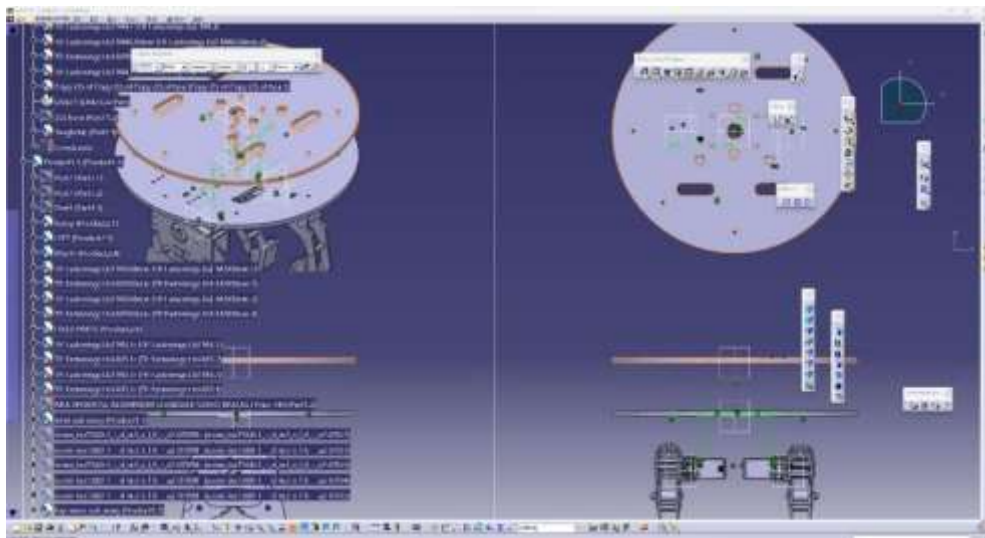
Mount the camera module onto the robot chassis, ensuring a clear and unobstructed view of the borewell environment. Connect the camera module to the ESP32 microcontroller,

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.

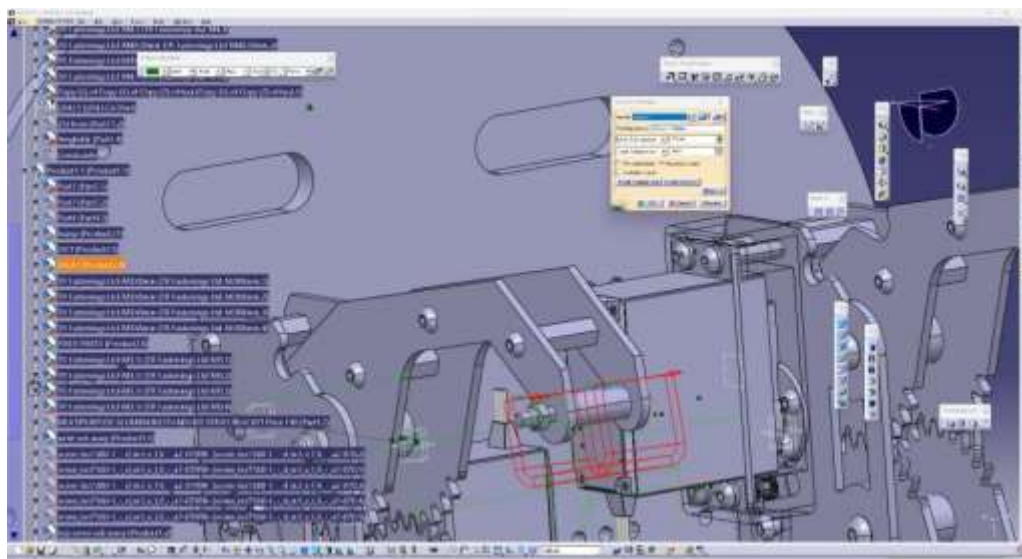
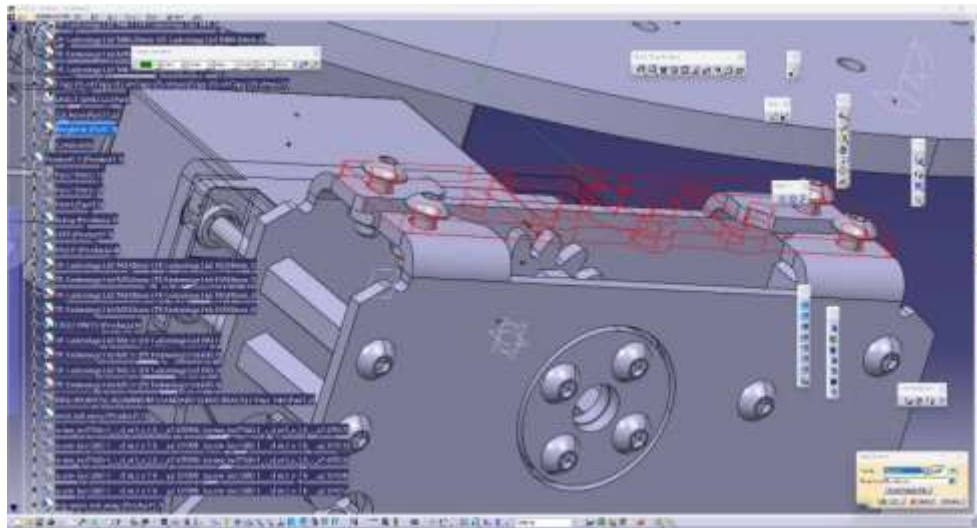
4. RESULTS AND DISCUSSION

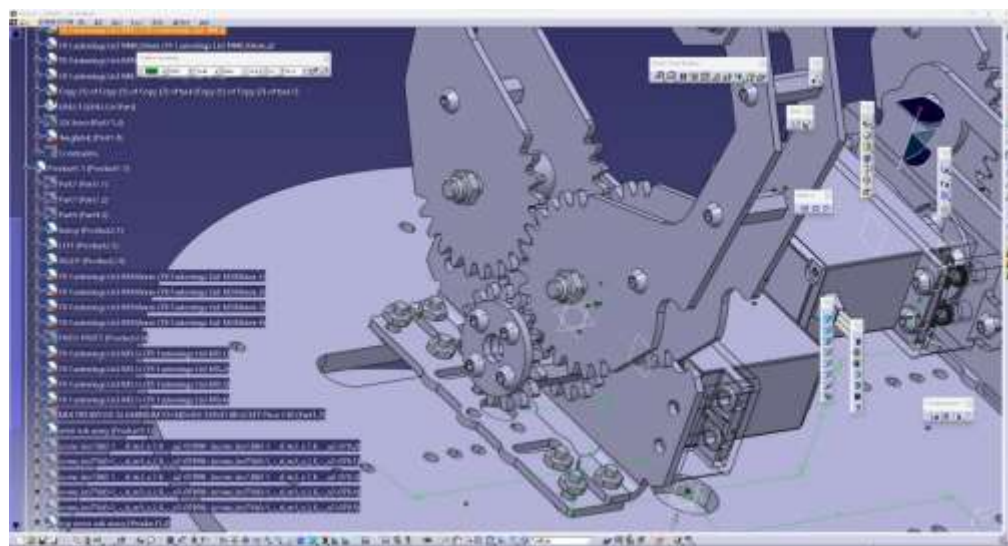
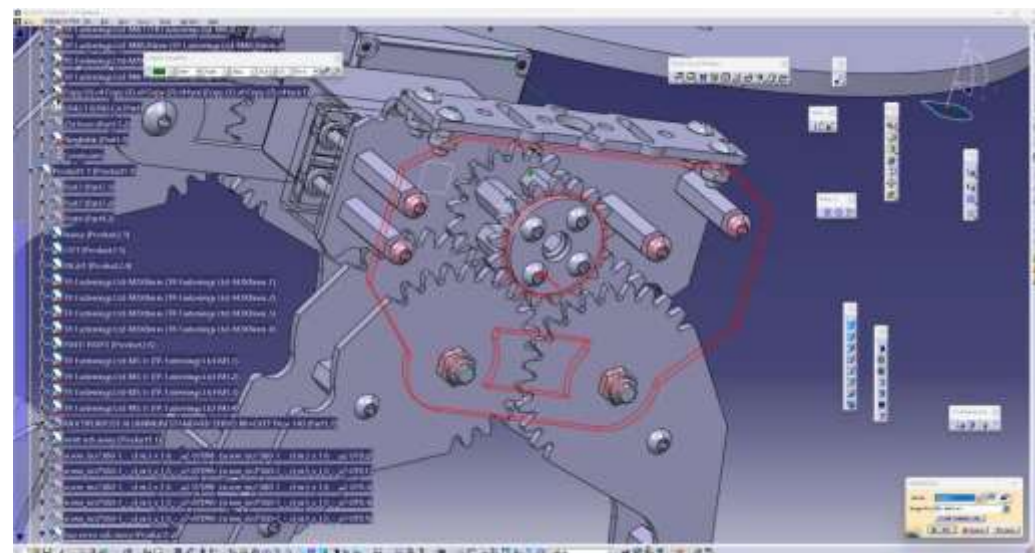
4.1 3D-Modelling Design

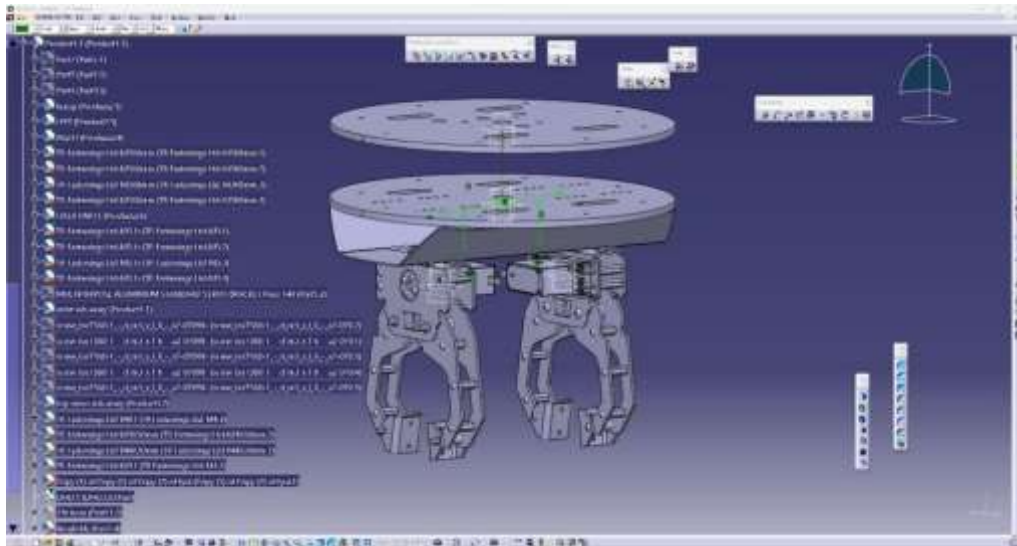


Cut the borewell casing pipe to the desired length, allowing it to fit through the borewell openings. Securely attach the robot structure, components, and modules onto the borewell casing pipe, ensuring structural stability and integrity. Test the overall assembly's robustness and stability, ensuring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

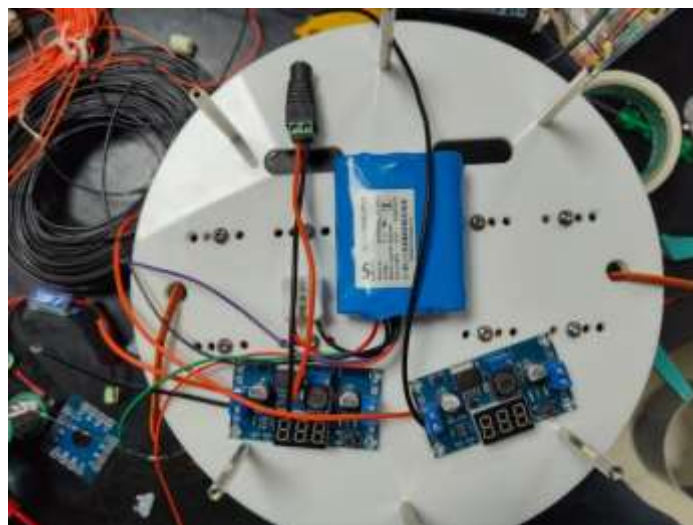
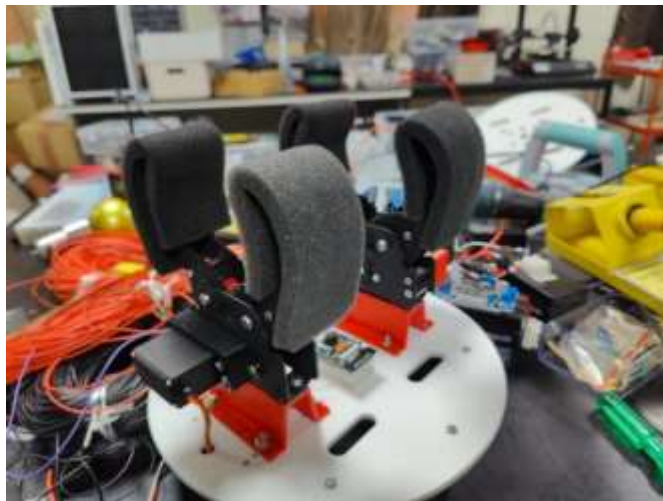
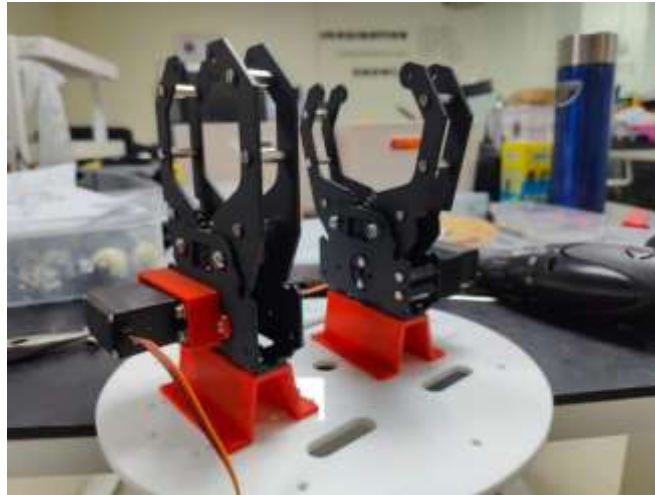






4.2 Hardware Implementation Outcomes







5. CONCLUSION

In conclusion, the development of a specialized borewell rescue robot equipped with an ESP32 microcontroller, high torque DC motors, a camera module, and a mechanical gripper offers a promising solution to enhance the efficiency and safety of rescue operations in narrow borewell environments. The robot's compact and sturdy design allows it to navigate through confined spaces, providing access where human intervention

may be limited or hazardous. The integration of high torque DC motors enables precise and powerful locomotion, allowing the robot to traverse challenging terrains within the borewell. The ESP32 microcontroller serves as the central control system, coordinating the various components and facilitating wireless communication with the remote-control device. The camera module provides real-time video transmission, allowing the rescue team



to have a visual understanding of the situation inside the borewell. The mechanical gripper system enables the secure retrieval of individuals trapped in the borewell, reducing risks and ensuring their safety during the rescue process. By developing such a specialized robot, the risks and time associated with manual rescue operations in borewells can be significantly reduced. The robot's ability to access narrow spaces and navigate through obstacles enhances the efficiency of rescue operations, potentially saving valuable time in critical situations. The real-time video feed and remote control capabilities empower the rescue team with accurate information and increased situational awareness, enabling better decision-making during the rescue process.

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