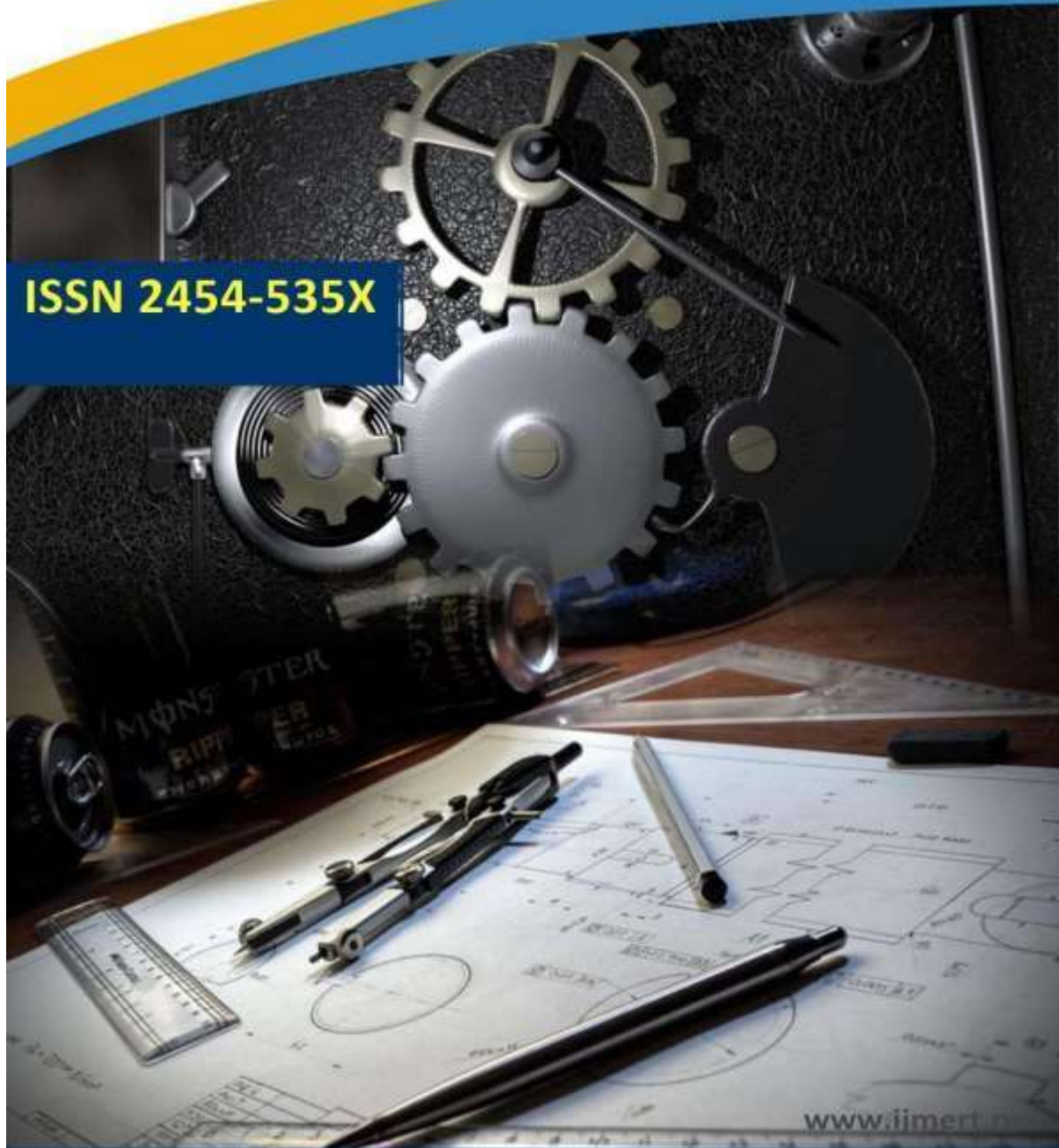




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Modelling and Implementation of Rover with Robotic Arm-based Soil Moisture Sensor and Live Camera

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Abstract

In the field of agriculture, it is crucial to monitor the health and moisture levels of soil and plants in order to maximize crop yields and detect diseases at an early stage. However, the traditional methods of monitoring often involve manual labour and are time-consuming, making it challenging to collect real-time data. To overcome these limitations, a solution has been proposed: the use of a rover equipped with advanced technologies. The rover incorporates a robotic arm-based soil moisture sensor and a live camera for capturing images of plants. The robotic arm is a mechanical arm that can be controlled remotely and is specifically designed to interact with the environment. In this case, the robotic arm is equipped with a soil moisture sensor, which measures the moisture content of the soil by analyzing parameters such as electrical conductivity. By utilizing the capabilities of the robotic arm, the rover can navigate different locations within the agricultural field, enabling efficient and accurate measurement of soil moisture levels. In addition to the soil moisture sensor, the rover is equipped with a live camera capable of capturing high-resolution images of plants in real-time. The camera can be mounted on the rover and positioned at various angles to capture comprehensive images. These images provide valuable visual information about the health and condition of the plants, allowing for the detection of diseases, nutrient deficiencies, and other abnormalities. By combining the robotic arm-based soil moisture sensor and the live camera, the rover system aims to automate and streamline the process of monitoring soil moisture levels and detecting plant diseases. This technology significantly improves agricultural practices by providing real-time data, optimizing resource utilization, and enhancing crop productivity. With the rover system, farmers and agricultural professionals can benefit from efficient and accurate monitoring of soil moisture levels and plant health without the need for manual labor or time-consuming processes. The real-time data provided by the rover enables timely interventions, such as adjusting irrigation or applying treatments, leading to better crop management and increased yields. This advancement in agricultural technology holds great potential for transforming farming practices and ensuring sustainable and productive agriculture.

Keywords: Robotic Arm, Soil Moisture, Live Camera, Rover System.

1. Introduction

The agricultural sector faces numerous challenges, including the need for improved water management and precise monitoring of soil conditions. Soil moisture plays a critical role in crop growth and health, as it directly

influences the availability of water to plant roots. Traditional methods of soil moisture measurement involve manual labour and time-consuming processes, which often

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yield imprecise results. Additionally, visual monitoring of crops is vital for identifying growth patterns, detecting diseases, and optimizing resource allocation. In the realm of agriculture, the constant need to optimize crop productivity and efficiently manage resources has led to the development of advanced technologies. One such innovation is the integration of rovers equipped with robotic arm-based soil moisture sensors and live cameras. This cutting-edge solution combines the capabilities of robotics, sensing, and imaging to provide real-time data on soil moisture levels and visual insights for precision agriculture. The integration of robotic technologies into agricultural practices has gained significant momentum in recent years. Researchers and engineers have explored various solutions to automate data collection and enhance decision-making processes for farmers. Early attempts to develop robotic systems for agriculture primarily focused on autonomous navigation and crop harvesting. However, as the importance of soil moisture management and real-time monitoring became apparent, the inclusion of soil moisture sensors and live cameras in rovers emerged as a logical progression. The need for a Rover with a robotic arm-based soil moisture sensor and live camera arises from the limitations of conventional agricultural practices. Manual soil moisture measurement methods are labour-intensive and time-consuming, rendering them inefficient for large-scale farming operations. Moreover, relying solely on visual inspection by farmers often results in missed opportunities for early disease detection or timely intervention. By combining the functionality of a rover, a robotic arm, soil moisture sensors, and live cameras, farmers can obtain accurate data and visual information remotely, allowing them to make informed decisions promptly.

2. Literature Survey

Tian, Yongding, et al. (2022) proposed intelligent robotic systems for structural health

monitoring in the construction industry. They discussed the various applications of these systems, such as damage detection, condition assessment, and real-time monitoring. The authors also highlighted future trends in the field, including the integration of artificial intelligence and machine learning techniques. However, the paper did not explicitly mention any drawbacks or limitations of their proposed work.

Bej, Gopinath, et al. (2022) presented a real-time robotic vision application for health monitoring of paddy plants. Their work aimed to enhance the monitoring and management of agricultural crops. The system utilized robotics and computer vision techniques to analyze visual information from the plants, enabling early detection of diseases and nutrient deficiencies. However, the paper did not specify any drawbacks or limitations associated with their approach, such as accuracy issues or challenges in practical implementation.

Devanna, Rosa Pia, et al. (2022) developed an in-field automatic identification system using a farmer robot for pomegranates. Their work aimed to improve efficiency and reduce labor costs in the agricultural sector. The robot employed sensors and computer vision algorithms to identify and locate ripe pomegranates, facilitating selective harvesting. However, the paper did not discuss any potential drawbacks or limitations of their proposed system, such as the performance in different lighting conditions or the adaptability to different varieties of pomegranates.

Basri, Mohd Ariffanan Mohd, and Muhamad Azizi Adnan (2022) presented an autonomous agriculture robot for plant monitoring using the Internet of Things (IoT). Their work focused on integrating IoT technologies to enable real-time data collection from sensors placed on the robot, allowing farmers to monitor the health and growth of crops remotely. However, the paper did not mention any specific drawbacks or limitations of their



proposed system, such as the scalability of the IoT infrastructure or the robustness of the robot's navigation algorithms.

Sankarananth, S., and R. S. Arun (2022) introduced a smart cable-driven parallel robot assistant for individual plant care in farming. Their work focused on developing a robotic system capable of precise and controlled movements for tasks such as pruning, watering, and fertilization. However, the paper did not discuss specific drawbacks or limitations associated with their proposed robot assistant.

Ummadi, Vinay, Aravind Gundlapalle, and Althaf Shaik (2022) presented an autonomous agriculture robot for smart farming. Their work aimed to improve agricultural practices by integrating robotic technologies for various tasks, including crop monitoring, irrigation, and pesticide application. However, the paper did not explicitly mention any drawbacks or limitations of their proposed robot for smart farming.

Poojari, Mohan, et al. (2023) focused on computational modeling for the manufacturing of a solar-powered multifunctional agricultural robot. Their work aimed to optimize the design and manufacturing processes of the robot, considering factors such as energy efficiency and operational capabilities. However, specific drawbacks or limitations of their computational modeling approach were not discussed in the paper.

Khan, Arfat Ahmad, et al. (2022) presented a cost-efficient environment monitoring robotic vehicle for smart industries. Their work aimed to develop a robotic vehicle capable of monitoring various environmental parameters in industrial settings. However, the paper did not explicitly mention any drawbacks or limitations associated with their proposed robotic vehicle.

Chen, Gerry, et al. (2022) proposed a hybrid cable-driven robot for non-destructive leafy plant monitoring and mass estimation using structure from motion. Their work focused on developing a robotic system capable of estimating plant mass and monitoring plant health without causing damage. However, the paper did not discuss specific drawbacks or limitations associated with their proposed hybrid cable-driven robot.

Vulpi, Fabio, et al. (2022) explored the use of RGB-D multi-view perspectives for autonomous agricultural robots. They investigated the integration of RGB-D cameras and multi-view techniques to enhance the perception capabilities of agricultural robots. However, the paper did not explicitly mention any drawbacks or limitations of their proposed approach.

3. Proposed Method

Figure 1 shows the proposed block diagram of rover with live camera and soil moisture sensor system. The robotic arm with soil moisture sensor, live camera for plant image capturing, disease detection and classification algorithms, left and right motors with a motor driver, and the 6-channel transmitter and receiver work together to enable remote-controlled movement, soil moisture measurement, plant imaging, disease detection, and classification for agricultural or scientific purposes.

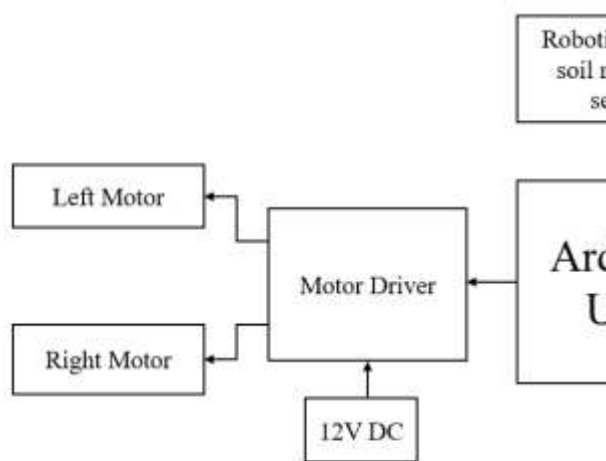


Fig. 1: Proposed block diagram of rover with live camera and soil moisture sensor system.

Step 1: Operational Methodology of the Robotic Arm with Soil Moisture Sensor:

Positioning the Robotic Arm: The operator uses the control system, either through the transmitter or a pre-programmed sequence, to position the robotic arm in the desired location. The actuators or motors of the arm are controlled to move it to the target area where soil moisture measurements are required.

Inserting the Soil Moisture Sensor: Once the robotic arm is positioned, the operator commands the arm to lower or extend the sensor towards the soil. The arm's actuators or motors adjust the position of the sensor and carefully insert it into the ground to a suitable depth, ensuring proper contact with the soil.

Soil Moisture Measurement: With the sensor inserted into the soil, it starts measuring the moisture content. The sensor may utilize various technologies such as capacitive or resistive sensors to detect the moisture levels. It provides feedback in the form of electrical signals, which are transmitted to the control system for further processing.

Interpretation of Moisture Levels: The control system receives the feedback from the soil moisture sensor and interprets the data to determine the moisture status of the soil. It analyzes the electrical signals and applies predefined thresholds or calibration curves to classify the moisture levels as dry, moist, or saturated. This information can be displayed on a user interface or used for further decision-making.

Step 2: Operational Methodology of the Live Camera for Plant Image Capturing:

Camera Orientation: The operator controls the orientation of the camera using the control system. If the camera is mounted on a pan-tilt mechanism, the operator can adjust its position remotely using the transmitter or pre-programmed commands. This allows for capturing images from different angles and perspectives.

Image Capture: Once the camera is properly positioned, the operator triggers the image capture process. The camera captures high-resolution images of plants or specific plant parts, such as leaves or stems. The captured images are then transmitted or stored for further processing.

Step 3: Operational Methodology of Disease Detection and Classification:

Image Processing: The captured plant images are processed using computer vision techniques. The images are fed into the control system, which applies machine learning or image processing algorithms to analyze the images.

Feature Extraction: The algorithms extract relevant features or visual markers from the images that are indicative of plant diseases. These features can include color variations, texture patterns, lesion formations, or any other distinguishing characteristics associated with diseases.



Disease Detection and Classification using DLCNN: The control system compares the extracted features with a pre-trained dataset of healthy and diseased plants. The dataset contains labelled images that serve as references for disease identification. By matching the extracted features with the dataset, the system can classify the plant as healthy or identify the specific disease affecting it.

Step 4: Operational Methodology of Left and Right Motor with Motor Driver:

Motor Control Signals: The operator sends commands through the transmitter to the rover's control system. These commands specify the desired movement or maneuver, such as moving forward, backward, turning left, or turning right.

Signal Processing: The control system receives the commands and processes them to generate appropriate signals for the motor driver. The signals determine the power, direction, and duration of the motor's operation.

Motor Driver Operation: The motor driver acts as an interface between the control system and the left and right motors. It receives the signals from the control system and regulates the power and direction supplied to the motors accordingly. By adjusting the power and direction of the motors, the rover achieves the desired movement and maneuverability.

Step 5: Operational Methodology of the 6-CH Transmitter and Receiver for Robot Controlling:

Command Transmission: The operator uses the 6-channel transmitter to send commands or instructions to the rover. The transmitter provides various controls or buttons corresponding to the different functions and movements of the rover, such as forward, backward, left turn, right turn, robotic arm control, and camera control.

Signal Transmission: When the operator activates a specific control or button on the transmitter, it sends corresponding signals through radio frequency (RF) communication to the receiver on the rover. These signals carry the information about the desired action or movement of the rover.

Signal Reception: The receiver on the rover receives the signals transmitted by the transmitter. It captures and decodes the signals to extract the commands or instructions sent by the operator.

Command Processing: The control system of the rover processes the received commands or instructions. It interprets the signals and determines the appropriate actions to be taken based on the specific command received.

Motor Control: Once the control system processes the commands, it sends control signals to the motor driver. These signals regulate the power, direction, and duration of the motor's operation, enabling the rover to move in the desired manner as commanded by the operator.

Robotic Arm and Camera Control: In addition to motor control, the control system also handles the commands related to the robotic arm and camera. It sends signals to the robotic arm actuators or motors for positioning the soil moisture sensor or adjusting the camera orientation based on the operator's commands.

Feedback and Response: The control system continuously monitors the status and feedback from various components of the rover, such as the sensors, motors, and cameras. It provides real-time feedback to the operator through the user interface, indicating the rover's movement, sensor readings, captured images, and any detected diseases or abnormalities in the plants.

Iterative Control: The operator can continue to send commands and instructions using the

transmitter, allowing iterative control over the rover's movements, sensor operations, and image capturing. The control system receives and processes each command, updating the rover's actions accordingly.

3.1 Methodology

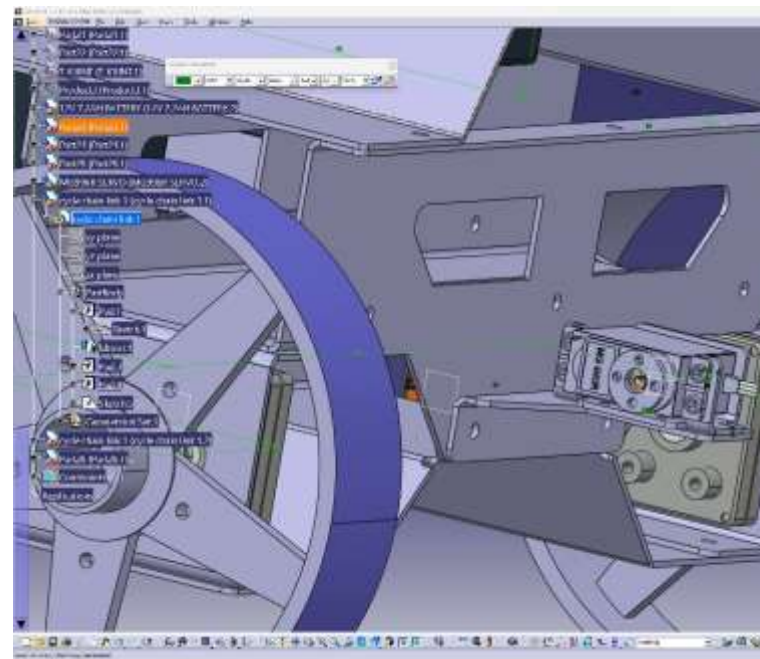
The Arduino UNO is a microcontroller board that serves as the brain of the rover. It controls and coordinates the actions of different modules and processes the sensor data. It provides the necessary input/output interfaces and programming capabilities. High torque DC motors are used to drive the wheels of the rover, allowing it to move in different directions and navigate the terrain. These motors provide sufficient power and torque to overcome obstacles and move the rover effectively. 10A Motor Driver with 12V DC Supply: The motor driver is a circuit module that controls the operation of the DC motors. It receives signals from the Arduino UNO and provides the necessary power and control to drive the motors. The 10A motor driver is capable of handling the high current requirements of the DC motors.

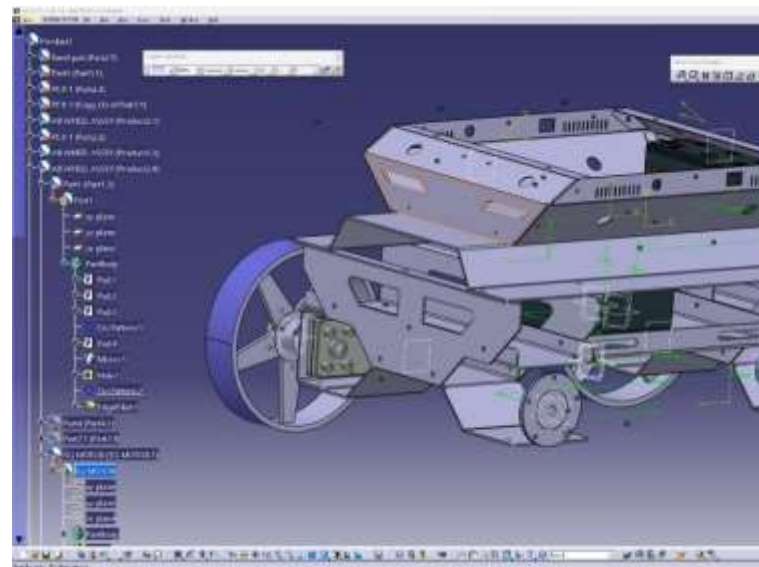
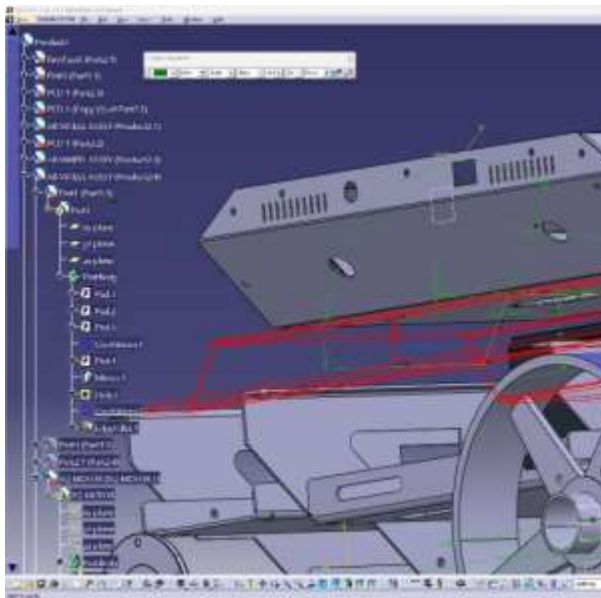
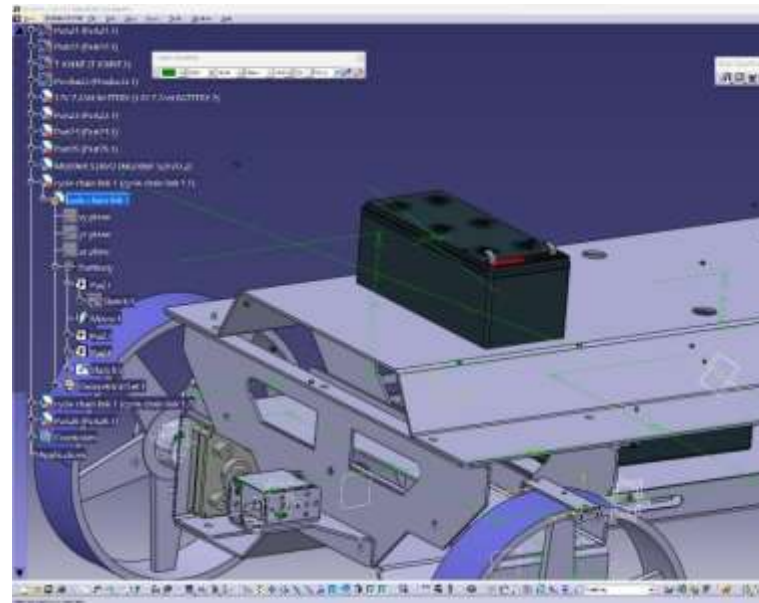
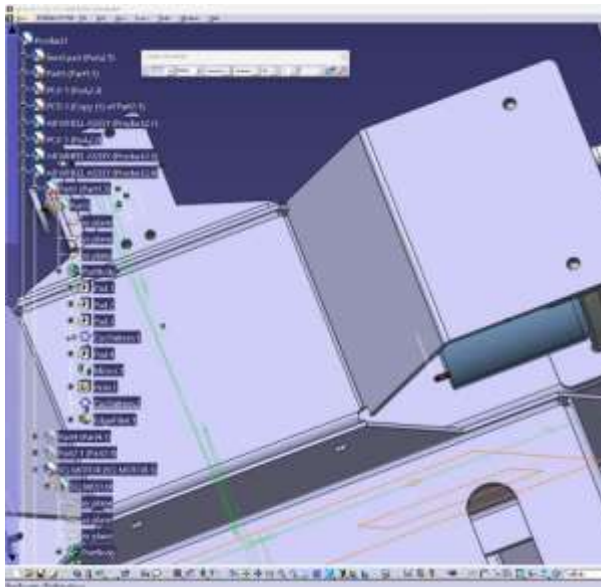
6-CH Transmitter and Receiver: The 6-CH transmitter and receiver are used for remote control of the rover. The transmitter is used to send control signals from the user to the rover, and the receiver on the rover side receives these signals and forwards them to the Arduino UNO for processing. This allows the user to control the movement and actions of the rover wirelessly. The robotic arm is equipped with a soil moisture sensor at its end. The arm is responsible for positioning the sensor at different locations to measure soil moisture levels. It can be controlled by the Arduino UNO, which sends commands to move the arm and collect data from the sensor. The soil moisture sensor measures the moisture content in the soil and provides the data for analysis.

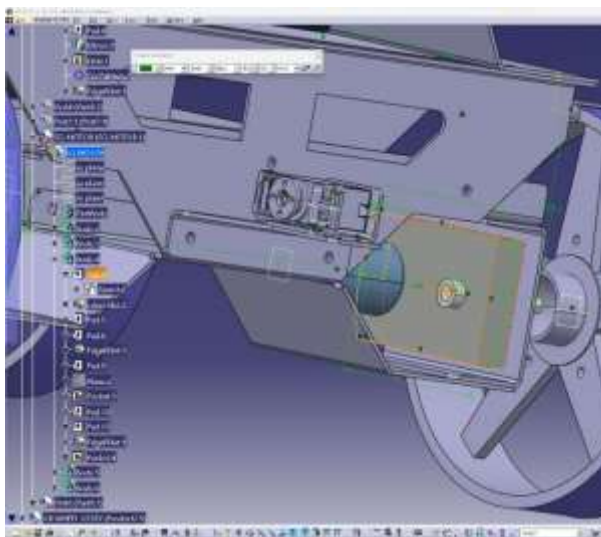
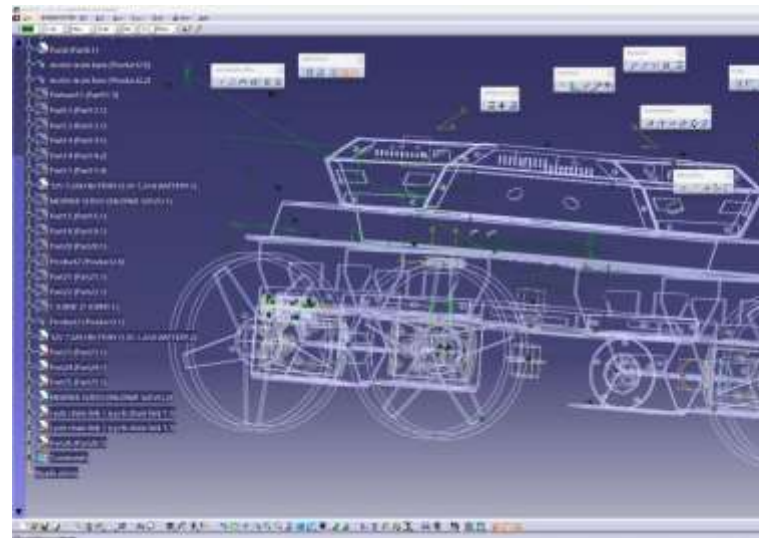
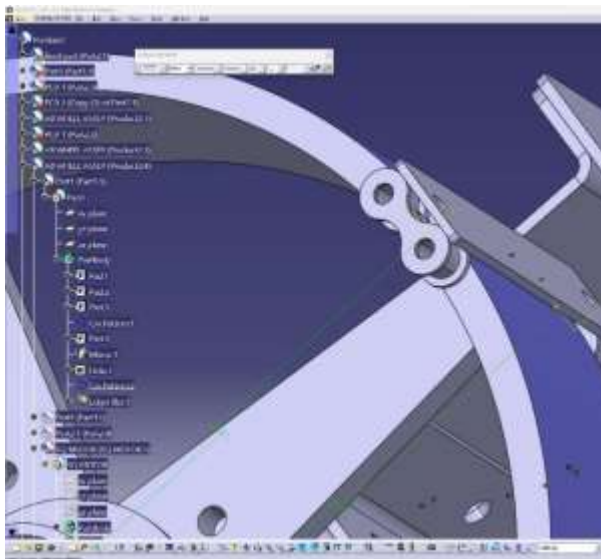
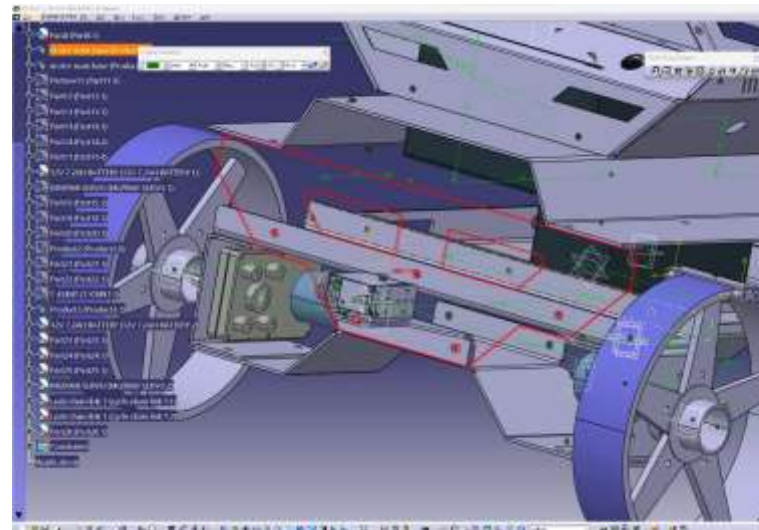
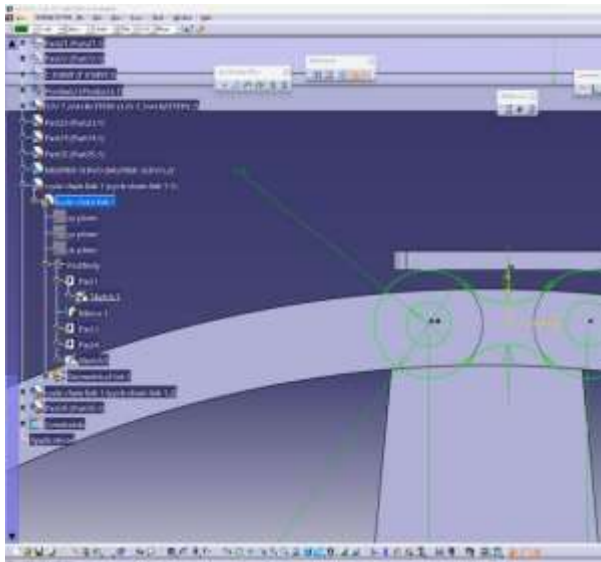
The live camera is used for capturing images of plants for disease detection and classification. It is connected to the Arduino UNO and powered by a 5V DC supply. The camera can be controlled by the Arduino UNO to capture images at specific intervals or upon user command. The captured images can be processed and analyzed for disease detection using image processing techniques or machine learning algorithms. The streaming application is a software component that runs on a computer or mobile device. It receives the live video feed from the camera on the rover and displays it in real-time. This allows the user to monitor the rover's surroundings and observe the captured images for disease detection and classification.

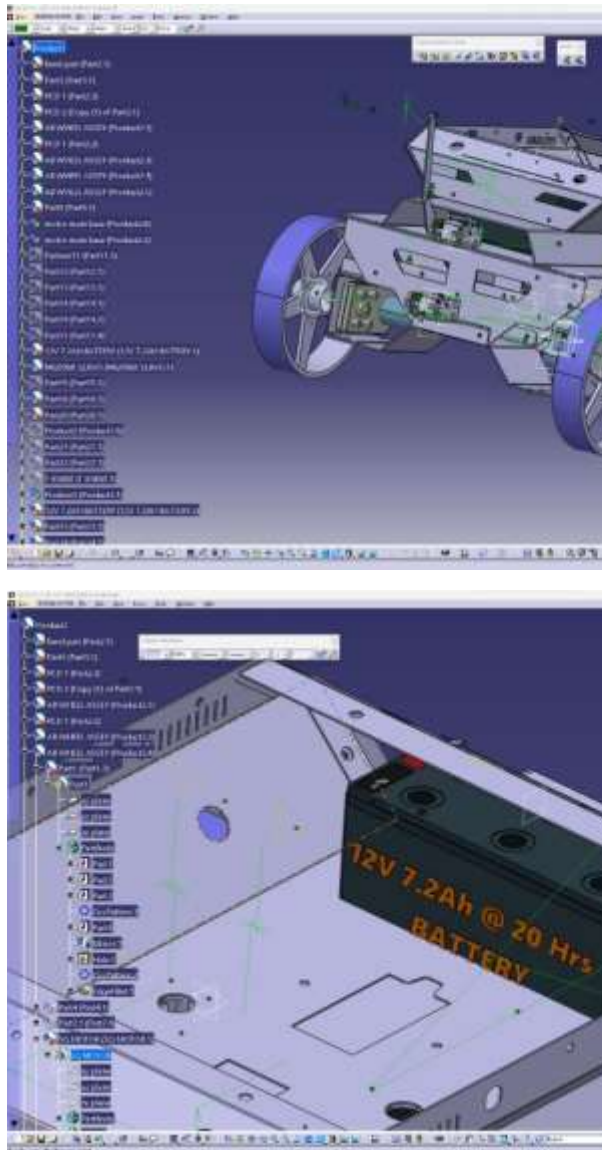
4. RESULTS AND DISCUSSION

4.1 3D-Design Modelling









5. CONCLUSION AND FUTURE SCOPE

In conclusion, the development of a rover equipped with a robotic arm-based soil moisture sensor and a live camera offers a promising solution for efficient and accurate monitoring of soil and plant health in agriculture. By automating the data collection process, the rover system eliminates the need for manual labor and provides real-time information that can optimize resource utilization and enhance crop productivity. The integration of the robotic arm-based soil moisture sensor enables the rover to navigate

different areas within the field and precisely measure soil moisture levels. This information is crucial for determining irrigation requirements and ensuring optimal water management practices. Additionally, the live camera captures high-resolution images of plants, allowing for early detection of diseases, nutrient deficiencies, and other abnormalities. This visual data empowers farmers to take timely actions to mitigate crop health issues and improve overall yields.

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