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Design and Development of Six-Wheeled Robot with Rocker Bogie Suspension System

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Abstract

This project presents the design and development of a six-wheeled robot equipped with a rocker bogie suspension system, Bluetooth-based control (voice and keys), and an ultrasonic sensor with a servo motor. The rocker bogie suspension, inspired by NASA's Mars rovers, enables the robot to traverse challenging terrains while maintaining stability and balance. The robot's control system utilizes Bluetooth technology, allowing users to operate it through voice commands or key inputs. The integration of ultrasonic sensing with a servo motor enhances the robot's ability to detect and avoid obstacles in its environment. The robot's mechanical design, control architecture, and sensor integration are discussed in detail, highlighting the key features and functionalities. Experimental results demonstrate the effectiveness of the proposed system, showcasing the robot's superior mobility, precise control, and obstacle avoidance capabilities. The developed robot presents a versatile platform with potential applications in exploration, surveillance, and other domains where robust and adaptable locomotion is required.

Keywords: Rocker bogie suspension system, Six wheeled robot, 10A motor driver, Ultrasonic sensor, HC-05 module.

1. INTRODUCTION

The development of the six-wheeled robot with a rocker bogie suspension system has its roots in the exploration of extraterrestrial environments. The concept was initially introduced by NASA in the 1960s as a solution for their Mars rovers, including the iconic Sojourner, Spirit, Opportunity, and Curiosity. The objective was to design a suspension system that could provide stability and traction on the rocky and uneven terrains of Mars, enabling the rovers to traverse the planet's surface effectively. Robotic exploration and reconnaissance missions often involve navigating challenging and rough terrains, both on Earth and in space. Traditional wheeled robots faced limitations in traversing uneven surfaces, climbing over obstacles, and maintaining stability. The rocker bogie suspension system emerged as an innovative solution to these challenges. Inspired by the mechanisms found in six-wheeled military vehicles, the system offers enhanced mobility, stability, and adaptability to varying terrain conditions.

Need

The need for a six-wheeled robot with a rocker bogie suspension system arises from the demand for versatile and robust robotic platforms capable of operating in challenging environments. Applications that require such capabilities include planetary exploration, where robots need to traverse uneven and rocky surfaces on other planets or moons. Additionally, the system finds utility in search and rescue missions, hazardous environment inspection, military operations, and off-road exploration in industries such as mining and agriculture. The need for enhanced mobility and stability in these scenarios drives the development of robots with the rocker bogie suspension system.

Significance

The significance of a six-wheeled robot with a rocker bogie suspension system lies in its ability to traverse rough and uneven terrains with agility, stability, and precision. The system enhances the robot's mobility and maneuverability, allowing it to navigate obstacles, climb over rocks, and cross gaps that would be challenging or impossible for conventional wheeled robots. This capability is particularly vital in applications such as planetary exploration, where the robot must gather scientific data, capture images, and perform experiments in various terrains. The significance also extends to other domains, including search and rescue operations, where the robot can access disaster-stricken areas with debris and uneven surfaces. In industries such as mining and agriculture, the robot can operate effectively in rugged landscapes, improving efficiency, productivity, and safety.

Problem Statement

The problem addressed by the development of a six-wheeled robot with a rocker bogie suspension system is the limited mobility and stability of conventional wheeled robots in rough and uneven terrains. The goal is to design and implement a robust suspension system that allows the robot to traverse obstacles, maintain stability, and distribute weight effectively across its wheels. The challenge lies in creating a suspension system that can articulate the wheels independently, adapt to varying terrain conditions, and withstand the harsh environments encountered during missions. Additionally, integrating the suspension system with the robot's overall control and navigation systems is essential, ensuring seamless operation and optimal performance in challenging environments.

2. LITERATURE SURVEY

Arunkumar, A., S. Ramabalan, and D. Elayaraja (2023) focused on the optimum design of stair-climbing robots using the Taguchi method. Their work aimed to enhance the performance of robots when navigating stairs. The Taguchi method was employed to identify the optimal design parameters that would result in improved stair-climbing capabilities. However, the paper did not specify any drawbacks or limitations associated with their proposed design. Gao, Haibo, et al. (2023) investigated a necessary condition for passive all-wheel attachment of a wheeled planetary rover. They explored the mechanical constraints and kinematic conditions required for effective wheel-terrain interactions in challenging planetary environments. The study aimed to improve the mobility and stability of wheeled rovers. However, the paper did not discuss any specific drawbacks or limitations associated with their findings.

Bouton, Arthur, and Yang Gao (2023) presented the MARCEL (Mobile Active Rover Chassis for Enhanced Locomotion), a rover chassis design focused on improving locomotion capabilities. The design incorporated active suspension systems and adaptable wheels to enhance mobility over various terrains. The paper highlighted the advantages of the MARCEL system but did not explicitly mention any drawbacks or limitations. Jeon, Haneul, and Donghun Lee (2023) proposed an explicit method for identifying pointwise terrain gradients to compensate for speed in four driving tracks of a passively articulated tracked mobile robot. The study aimed to improve the robot's motion control and maneuverability over uneven terrain. However, the paper did not discuss any specific drawbacks or limitations associated with their proposed method.

Nicolella, Armando, et al. (2022) provided an overview of the kinematic analysis of the rocker-bogie suspension system for six-wheeled rovers when approaching obstacles. The study aimed to analyze the system's performance and identify limitations in obstacle negotiation. However, the paper did not delve into specific drawbacks or limitations associated with the rocker-bogie suspension system. Cosenza, Chiara, et al. (2022) presented a spring-loaded rocker-bogie suspension design for six-wheeled rovers. Their work focused on improving the mobility and stability of rovers in rough terrains. The paper highlighted the advantages of the proposed suspension system but did not explicitly mention any drawbacks or limitations.

Cosenza, C., Niola, V., Pagano, S., & Savino, S. (2023) conducted a theoretical study on a modified rocker-bogie suspension system for robotic rovers. They aimed to enhance the mobility and terrain adaptability of the rovers. The paper provided theoretical analysis and simulations but did not specify any drawbacks or limitations associated with the proposed modification. Pandey, A., Kumar, A., Diwan, T. D., Hasan, M. E., Mohanty, R. L., & Gour, S. S. (2022) presented a new concept-based six-wheeled rocker-bogie robot and conducted its design and analysis. The study focused on improving the performance and stability of the rocker-bogie mechanism for planetary rovers. Lim, Kyeongtae, et al. (2022) proposed a modified rocker-bogie mechanism with fewer actuators and high mobility. Their design aimed to reduce the complexity and increase the mobility of the rover. The paper highlighted the advantages of the modified mechanism, but specific drawbacks or limitations were not mentioned.

Arunkumar, A., S. Ramabalan, and D. Elayaraja (2023): This paper, previously mentioned, focuses on the optimum design of stair-climbing robots using the Taguchi method. The authors aimed to improve the robot's ability to navigate stairs by optimizing the design parameters. Lim, Kyeongtae, et al. (2022) presented a modified rocker-bogie mechanism with fewer actuators and high mobility. Their design aimed to reduce the number of actuators required for the mechanism while maintaining high mobility. The paper discussed the advantages of the modified mechanism, such as improved maneuverability and reduced complexity.

3. EXISTING SYSTEM

The four-wheeled robot is a mobile robotic system designed to traverse various terrains and perform tasks such as exploration, surveillance, or transportation. Unlike the rocker bogie suspension system commonly used in robots, this particular robot does not incorporate such a mechanism. The robot should be able to move in different directions (forward, backward, left, right) to navigate its environment. The robot should be capable of traversing diverse terrains, including flat surfaces, uneven ground, and obstacles The robot should have the ability to carry a certain payload, such as equipment or objects, depending on its intended application. The robot should maintain stability while moving or when stationary to prevent tipping or loss of balance. The robot should have a reliable control system to facilitate user commands and autonomous operations. The robot should efficiently manage its power source, ensuring optimal battery life and recharging capabilities.

Drawbacks of a Four-Wheeled Robot without Rocker Bogie Suspension System:

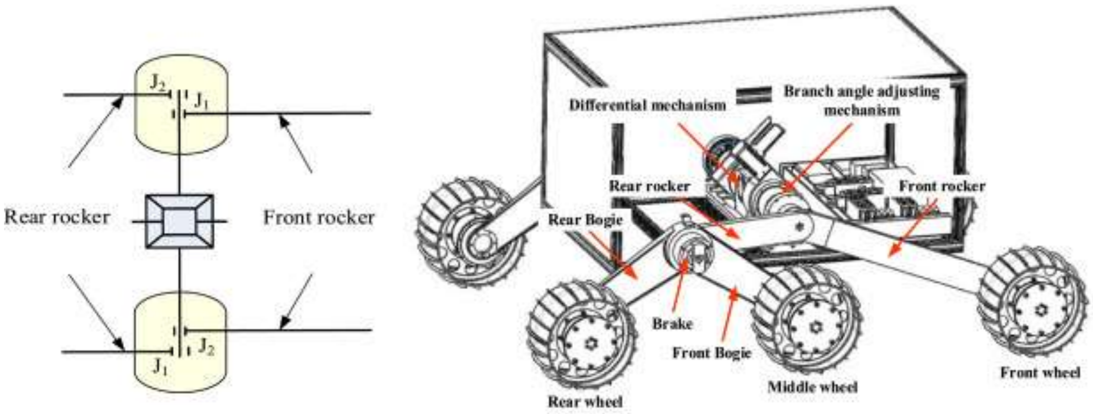
- Limited Terrain Adaptability: One major drawback of a four-wheeled robot without a rocker bogie suspension system is its reduced capability to traverse uneven terrains. Without a suspension mechanism, the robot may struggle to maintain traction, especially on rough or rocky surfaces, which can limit its overall mobility and application range.
- Reduced Stability: The absence of a rocker bogie suspension system can compromise the robot's stability, particularly when encountering obstacles or navigating challenging terrains. The lack of independent wheel movement and articulation increases the risk of tipping or losing balance, impacting the robot's overall safety and reliability.
- Impact on Payload: The limited suspension capabilities can negatively affect the robot's ability to carry a payload. Vibrations and shocks experienced due to uneven terrains may result in increased stress on the payload, potentially causing damage or affecting the robot's overall performance.
- Decreased Comfort: Without a proper suspension system, the robot's movements may become jarring and uncomfortable, affecting the user experience in applications where human interaction is involved.
- Reduced Traction: The absence of a suspension system can lead to reduced traction, especially on challenging terrains. This can result in wheel slippage, decreased maneuverability, and compromised overall performance.

4. PROPOSED METHODOLOGY

The 6-wheel robot utilizes a rocker bogie suspension system, which consists of six wheels arranged in a pattern that enables smooth traversal over uneven surfaces. Figure 1 shows the rocker bogie suspension system. This suspension configuration ensures that at least four wheels are in contact with the ground at all times, providing stability and preventing tipping. The robot's control mechanism is based on Bluetooth technology, enabling wireless communication between the robot and a remote-control device. The control device can be operated via voice commands or traditional key-based input. Voice commands are converted into corresponding control signals, allowing for intuitive and hands-free operation. Key-based control provides a manual alternative for precise movements and navigation.

To facilitate obstacle detection and avoidance, ultrasonic sensors are integrated into the robot. These sensors emit ultrasonic waves and measure the time it takes for the waves to bounce back after hitting an object. By analyzing these measurements, the robot can estimate the distance between itself and the obstacle. This information is then used to make decisions regarding navigation and path planning.

The robot's servo motors are responsible for actuating the movement of the ultrasonic sensors and other mechanical components. By utilizing servo motors, the robot can precisely position the sensors in different directions, enhancing its ability to detect obstacles and adjust its path accordingly.



(a) Simple model. (b) Design model.

Fig. 1: Rocker bogie suspension system.

Figure 2 shows the proposed system block diagram of Rocker bogie suspension-based robot. Throughout the system analysis and development process, it is important to consider factors such as power management, safety features (e.g., emergency stop mechanisms), and robustness testing to ensure reliable and efficient operation of the four-wheeled robot with the proposed subsystems.

Design and Fabrication: Determine the specific requirements for the robot chassis, considering factors such as size, weight, and structural stability. Create a detailed design for the chassis, incorporating provisions for mounting the rocker bogie suspension system. Select appropriate materials for the chassis and suspension components, considering factors such as strength, weight, and cost. Use fabrication techniques such as welding, cutting, or 3D printing to construct the chassis and suspension components according to the design specifications.

Wheel and Motor Integration: Select suitable wheels based on the desired terrain adaptability, traction, and load-bearing capacity. Determine the required motor specifications, such as torque, speed, and power consumption, to meet the robot's mobility requirements. Integrate the wheels into the chassis, ensuring proper alignment and attachment mechanisms. Connect each wheel to an individual motor, considering the motor control interfaces and wiring requirements. Implement motor control circuitry, such as motor drivers or motor control boards, to regulate motor speed and direction.

Bluetooth Communication: Select a Bluetooth module that is compatible with the robot's control system and offers the desired range and data transmission capabilities. Design the hardware and software interfaces to establish a Bluetooth connection between the robot and a control device (e.g., smartphone, computer). Implement Bluetooth communication protocols, such as Bluetooth Low Energy (BLE) or Serial Port Profile (SPP), to facilitate data transmission and control commands. Develop software algorithms to handle Bluetooth data reception, interpretation, and response in the robot's control system.

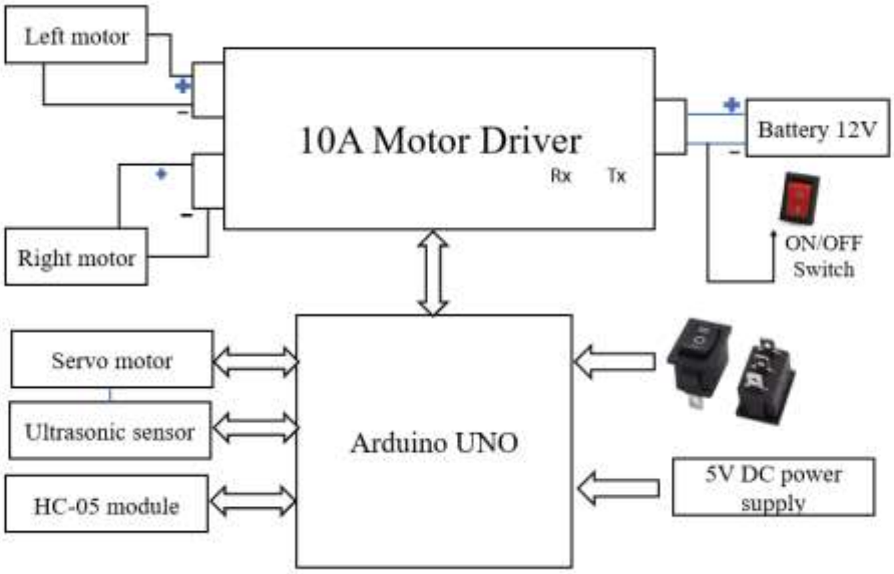


Fig. 2: Proposed system block diagram of Rocker bogie suspension-based robot.

Ultrasonic Sensor Integration: Determine the number and placement of ultrasonic sensors based on the desired field of view and obstacle detection requirements. Select suitable ultrasonic sensors that offer the necessary range, accuracy, and reliability. Develop sensor interfaces to connect the ultrasonic sensors to the robot's control system, considering factors such as power supply, data communication, and signal conditioning. Implement appropriate signal processing algorithms to interpret the ultrasonic sensor data and calculate obstacle distances. Integrate the ultrasonic sensor outputs with the overall control system to enable obstacle detection and avoidance capabilities.

Servo Motor Integration: Select servo motors that meet the required specifications for angular positioning, torque, and speed control. Design and implement mechanical linkages or mounts to attach the ultrasonic sensors to the servo motors, allowing for adjustable positioning. Develop control algorithms to precisely position the servo motors and adjust the direction of the ultrasonic sensors based on control inputs. Implement servo motor control interfaces in the robot's control system, allowing for real-time adjustments of the ultrasonic sensor orientations.

Control System Development: Design the control software architecture, considering modularization and separation of concerns for different subsystems (motor control, sensor integration, Bluetooth communication). Develop algorithms to interpret control commands received via Bluetooth, enabling both voice and key-based control options. Implement motor control algorithms to regulate motor speed, direction, and coordination for smooth robot movement. Integrate the ultrasonic sensor data processing algorithms to enable obstacle detection and avoidance behaviors. Develop user-friendly interfaces (e.g., graphical user interface or command-line interface) for controlling and monitoring the robot's functionalities.

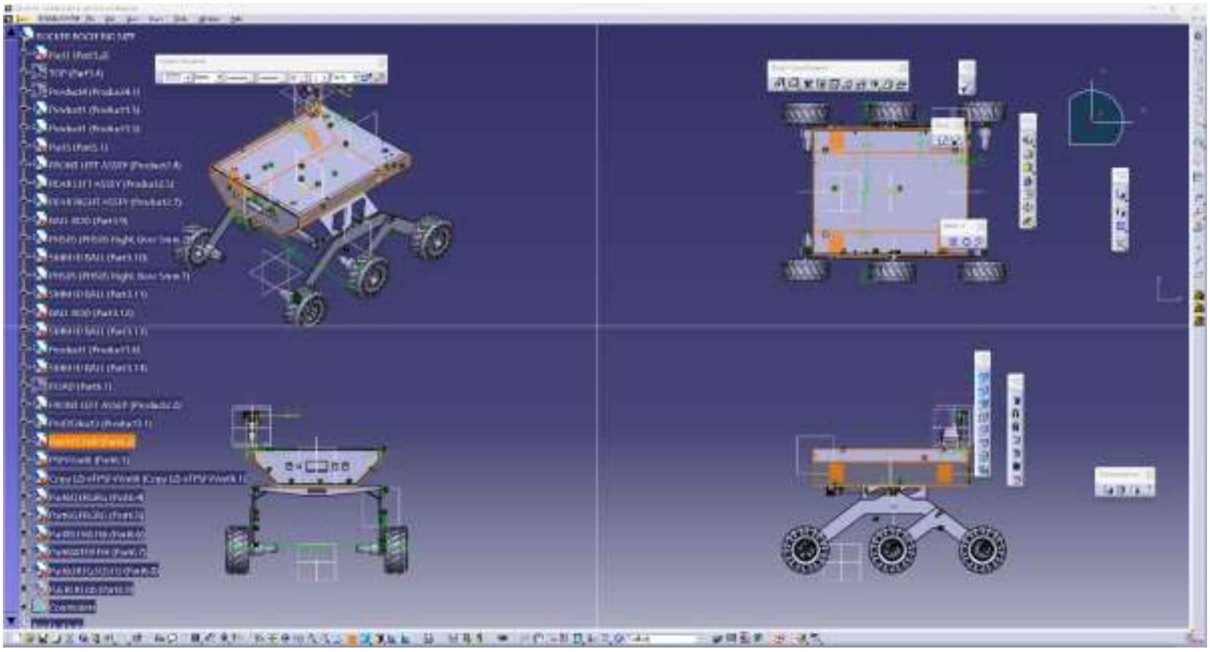
Working

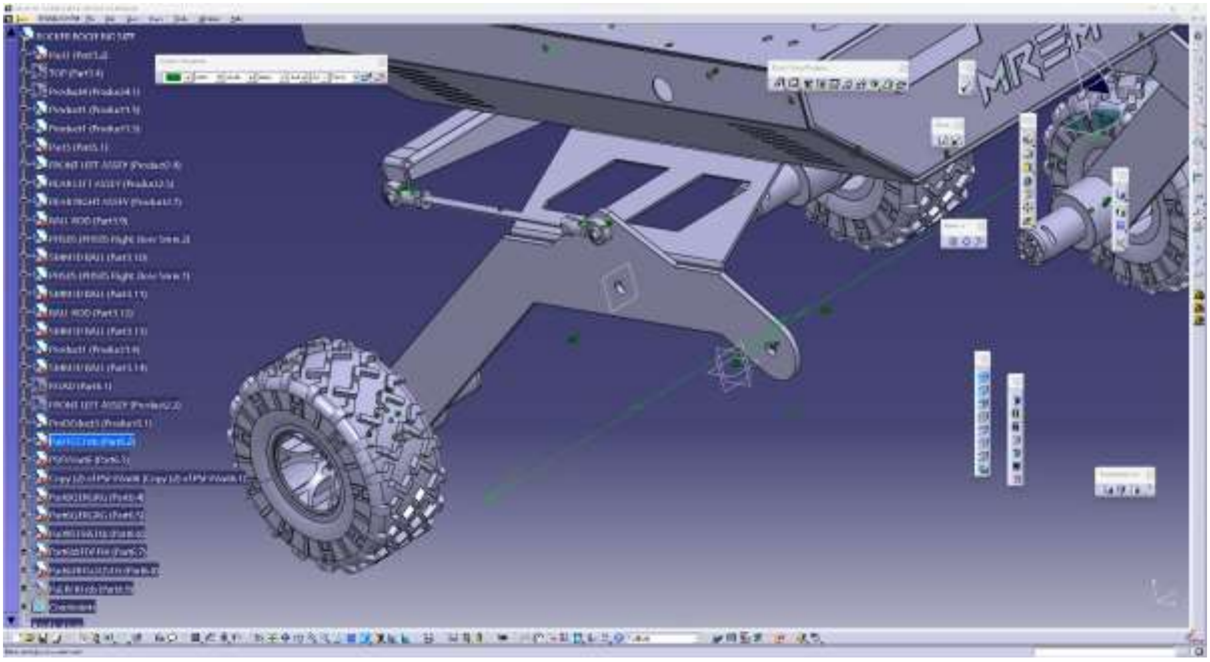
The CNC laser cutting module is used to precisely cut the chassis and suspension components of the robot from selected materials, ensuring accurate dimensions and structural integrity. The CNC metal bending module is employed to shape and bend the metal components of the robot's chassis and suspension system, allowing for the creation of desired angles and contours. The powder coating module is utilized to apply a protective and visually appealing finish to the robot's chassis and metal parts, enhancing their durability and aesthetic appeal. The Arduino UNO microcontroller serves as the central control unit of the robot, receiving and processing inputs from various sensors and modules, and controlling the motor movements and other functionalities. The HC-05 module enables wireless Bluetooth communication between the robot and a control device, facilitating remote control and data transmission for seamless user interaction. Ultrasonic sensors are integrated into the robot to detect obstacles and measure distances, providing essential information for obstacle avoidance and navigation.

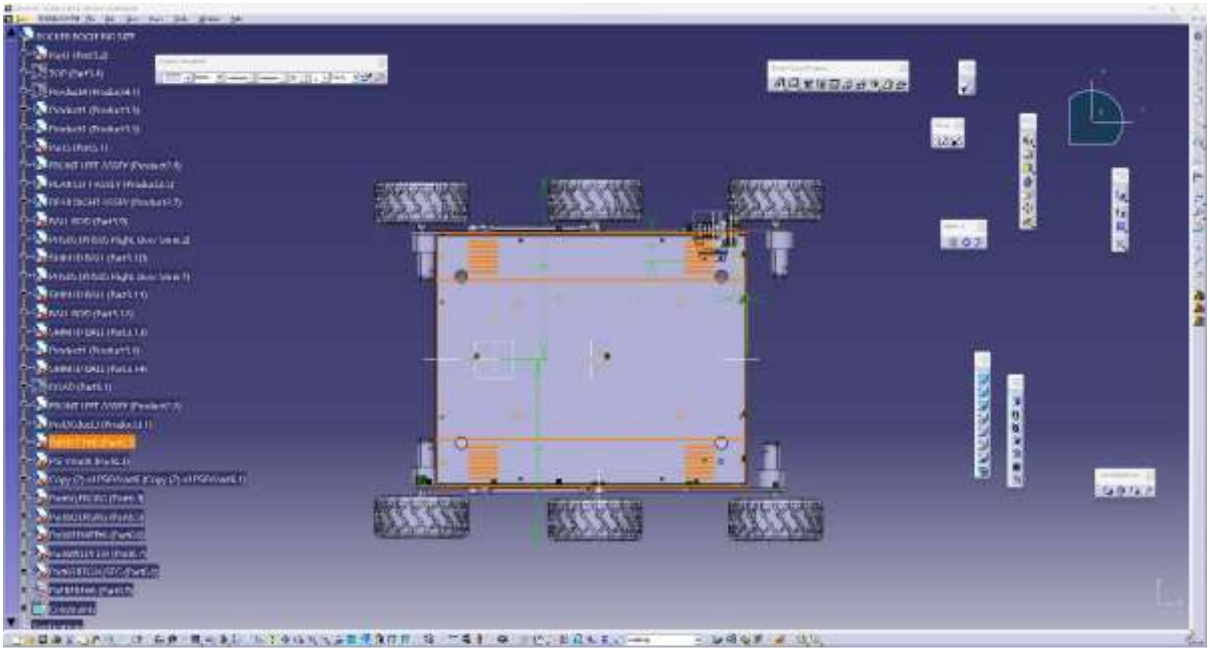
The servo motors, powered by a 6V power source, are responsible for precisely controlling the movement and positioning of the ultrasonic sensors, allowing for adjustable direction and accurate obstacle detection. The 10A motor driver regulates the power and direction of the high torque DC motors that drive the wheels, ensuring smooth and coordinated movement of the robot. A 12V battery serves as the power source for the robot, supplying the necessary electrical energy to the motors, control system, and other components. SPST and SPDT switches are used for various purposes, such as power control, mode selection, or emergency stop functionality, providing manual control options and safety features. 3D printed brackets, clamps, and solid parts are used to create customized and lightweight components, offering flexibility and versatility in the robot's design and assembly process.

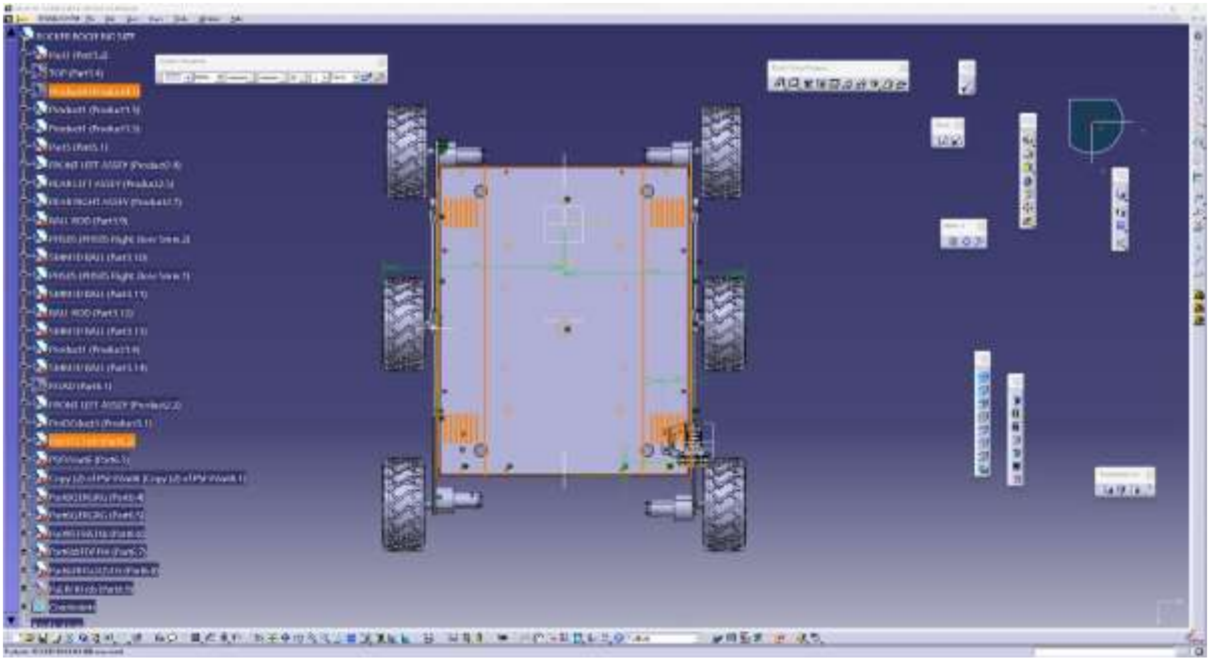
4. RESULTS AND DISCUSSION

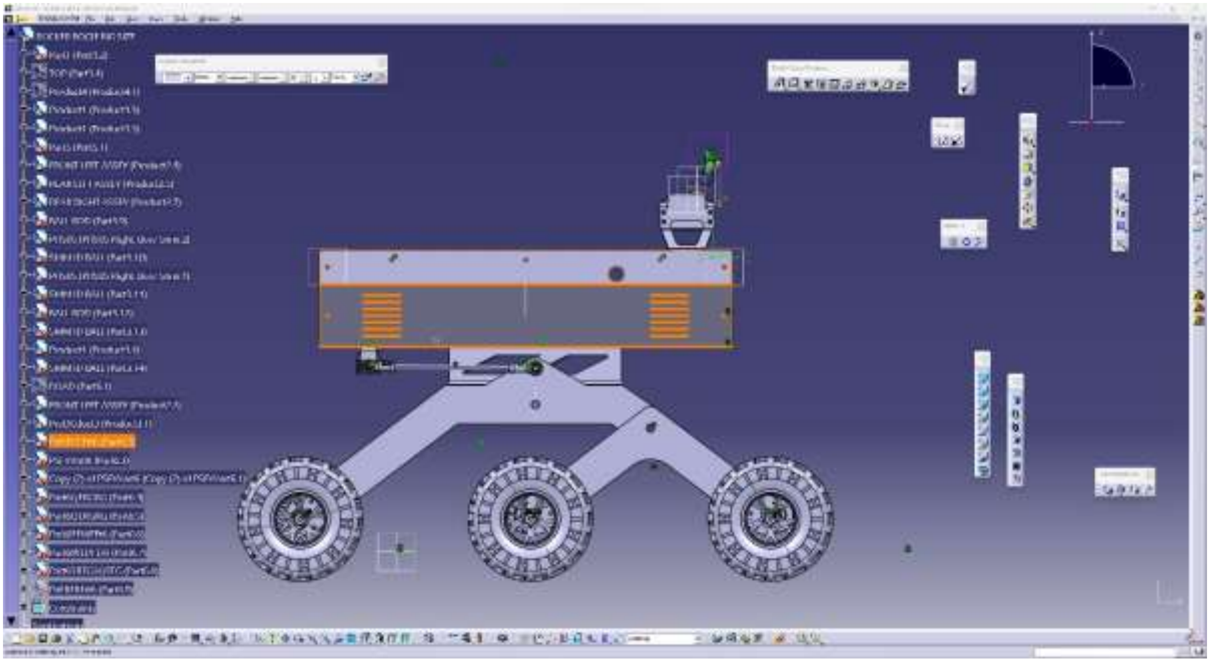
4.1 3D-Design Modelling

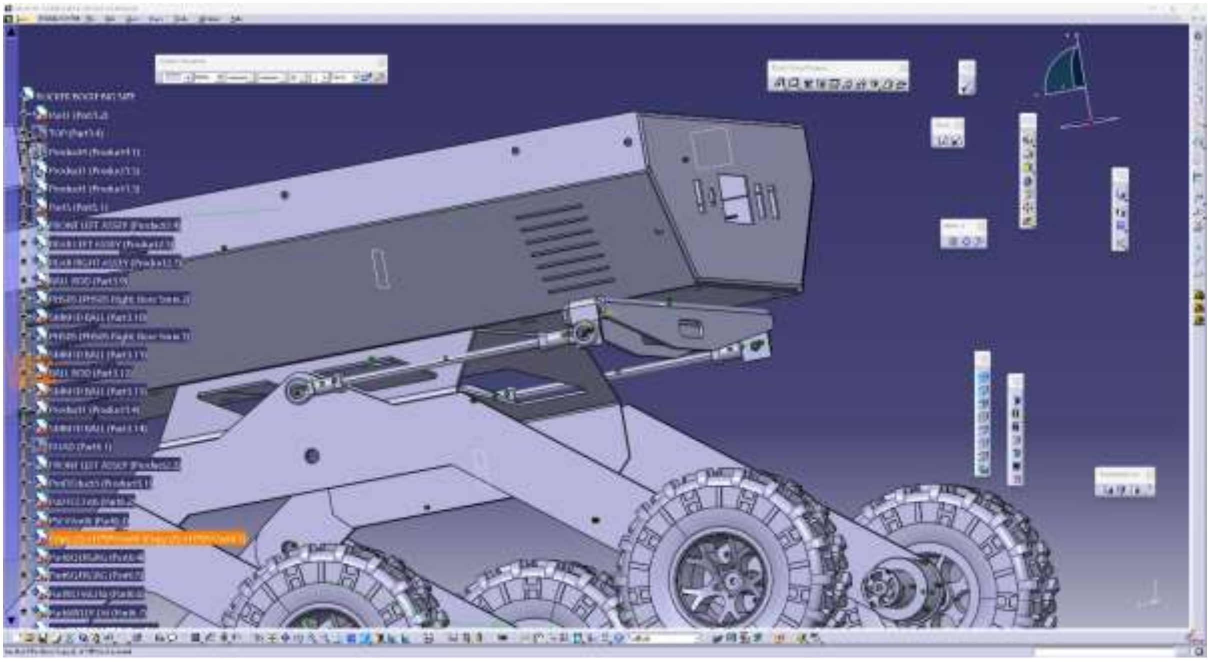


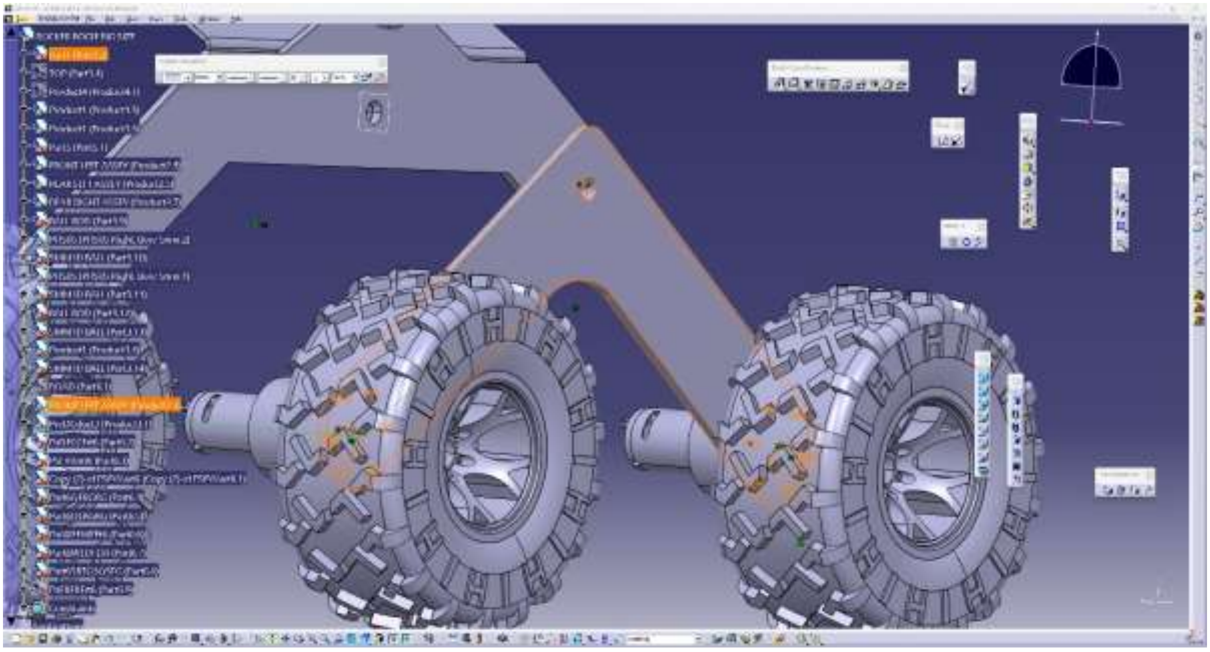


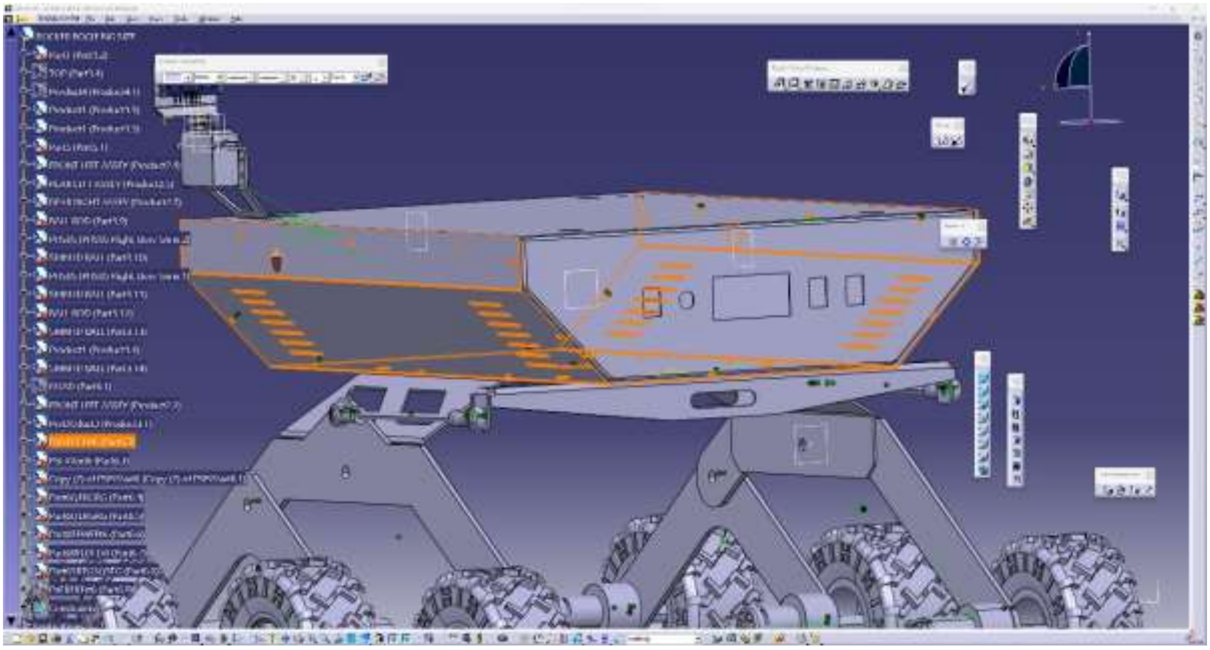


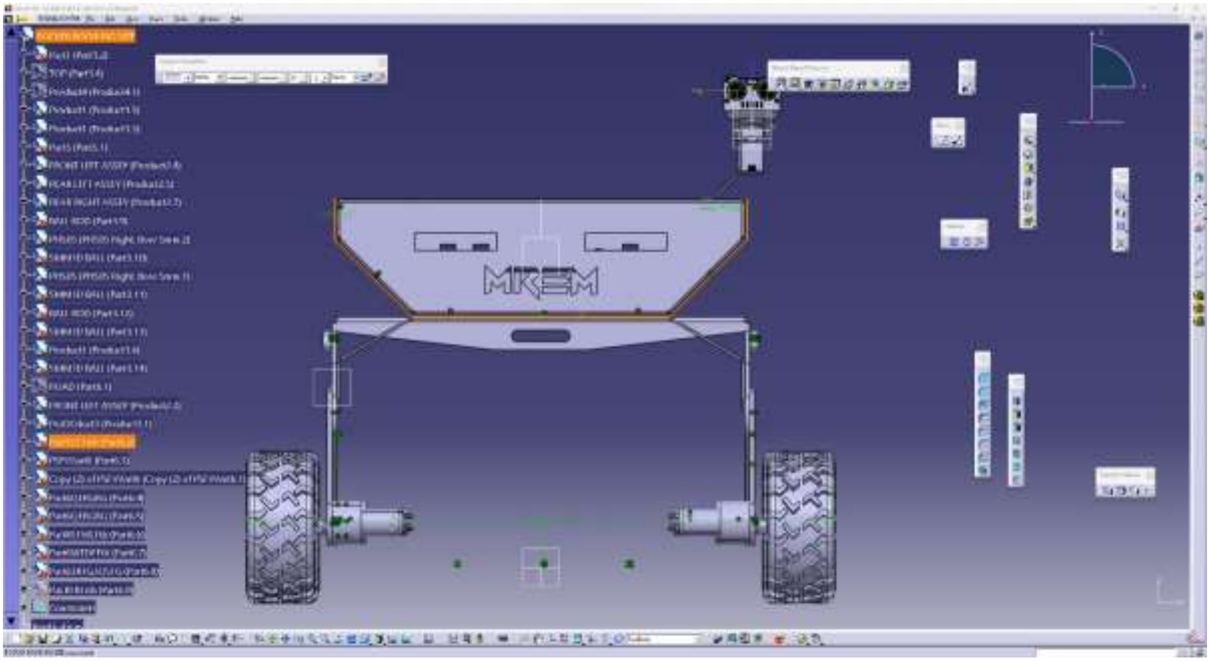












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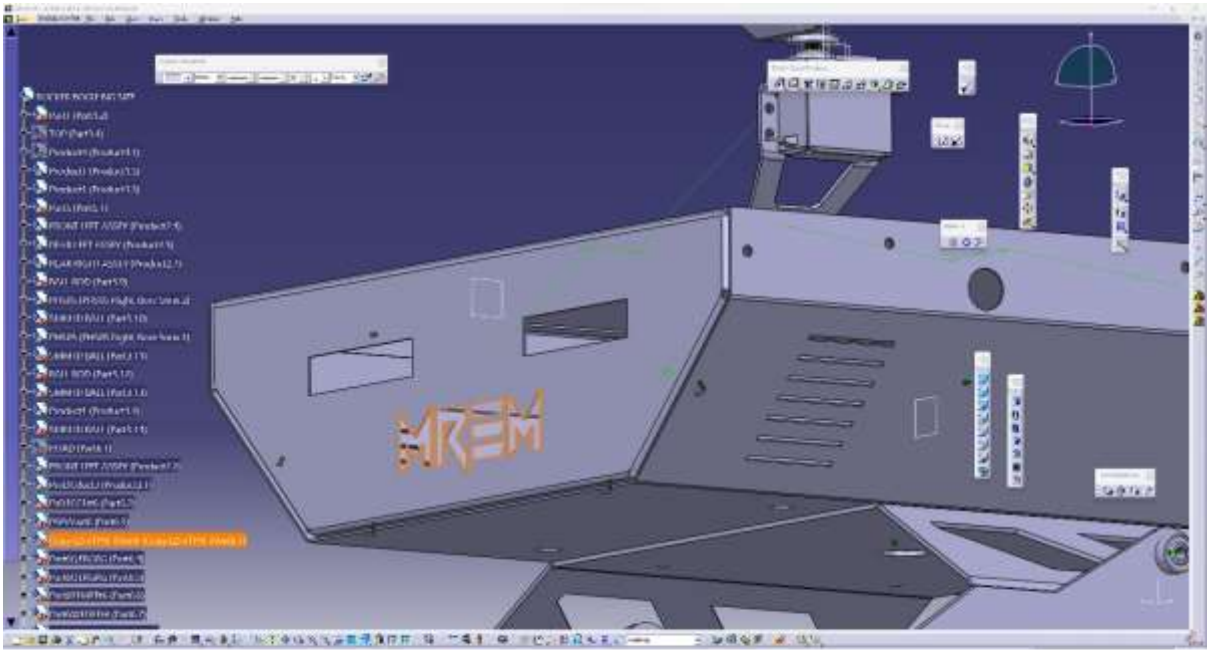

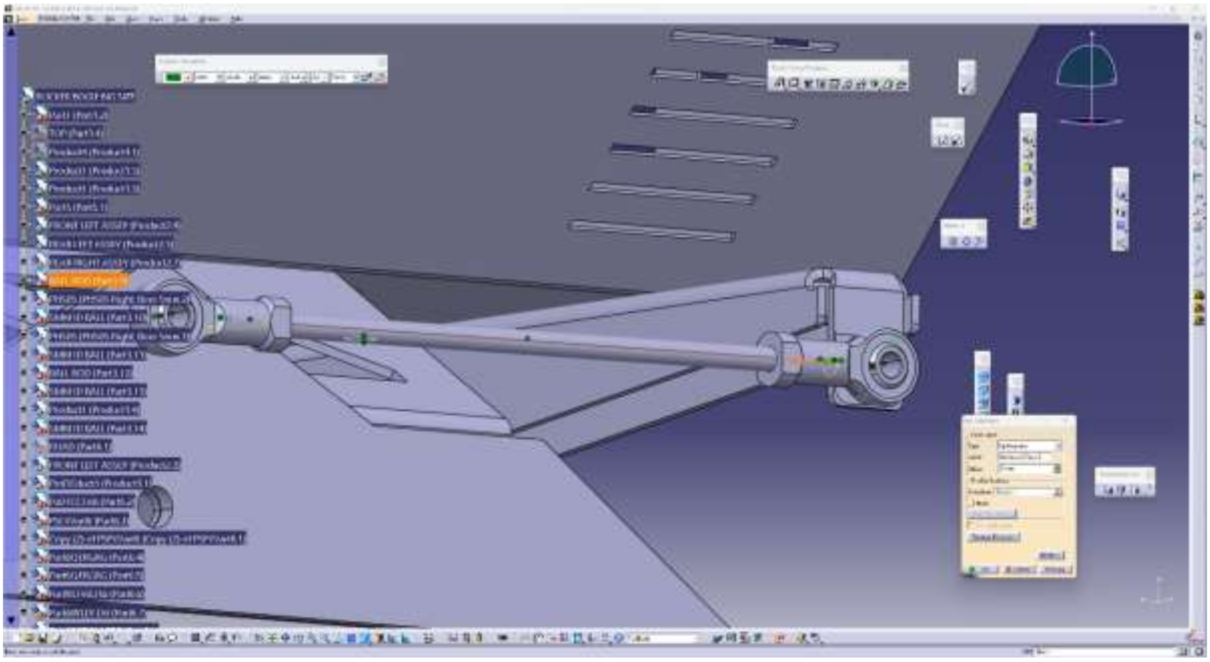

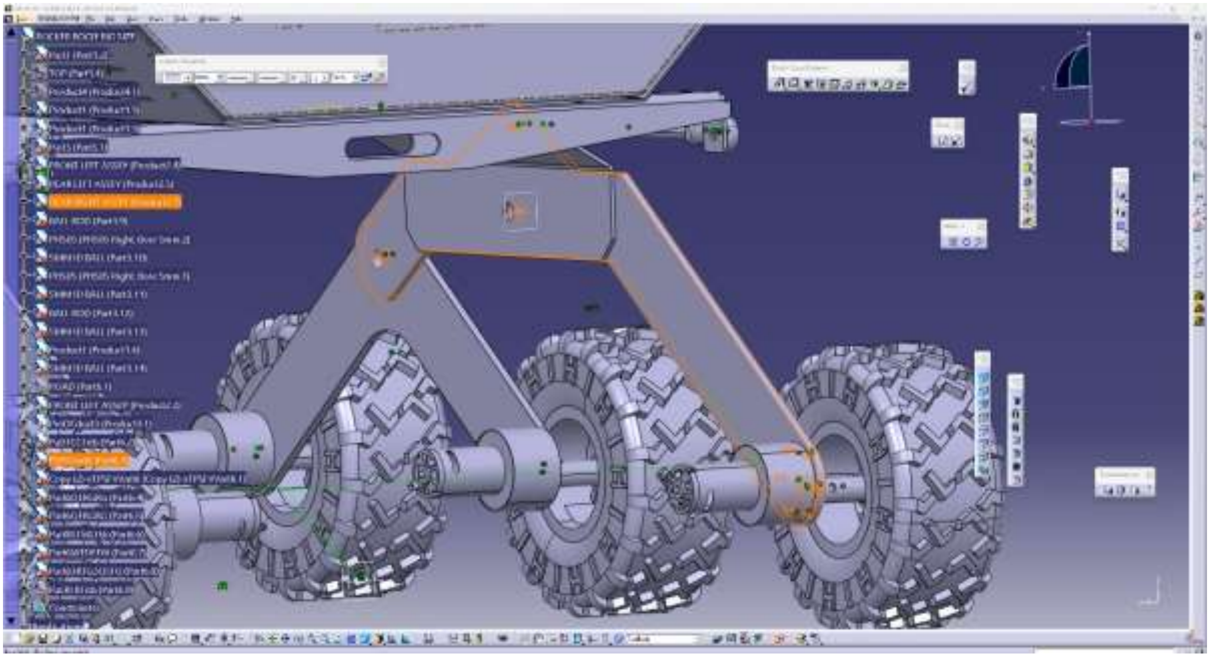

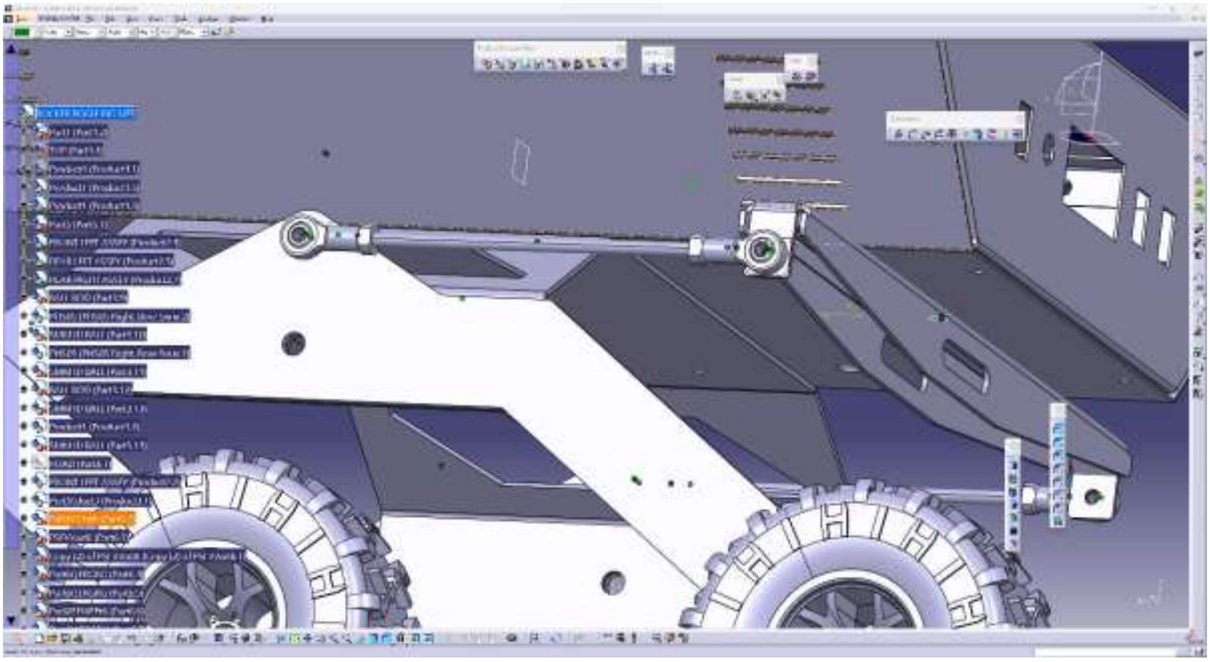

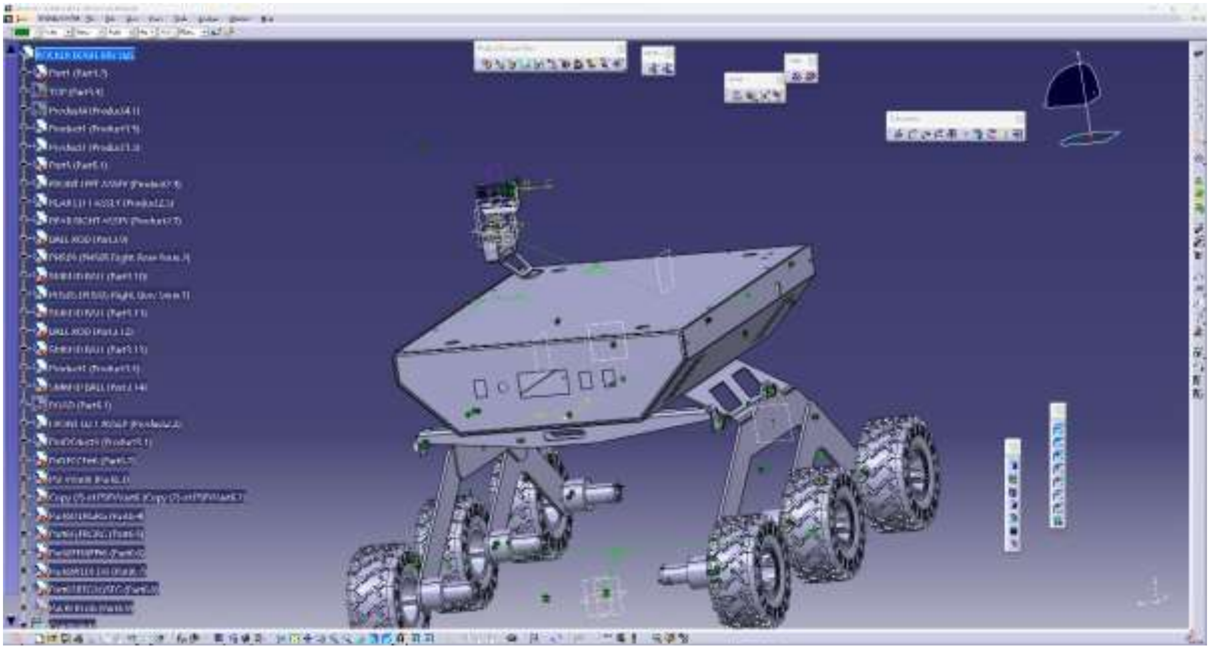

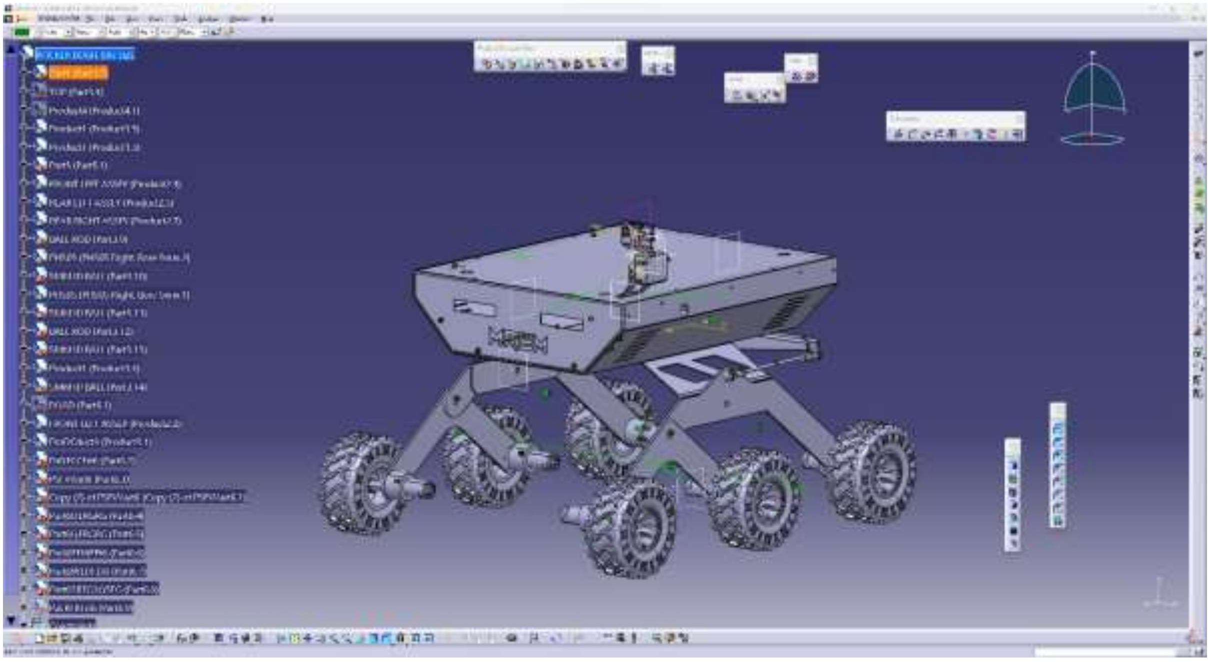

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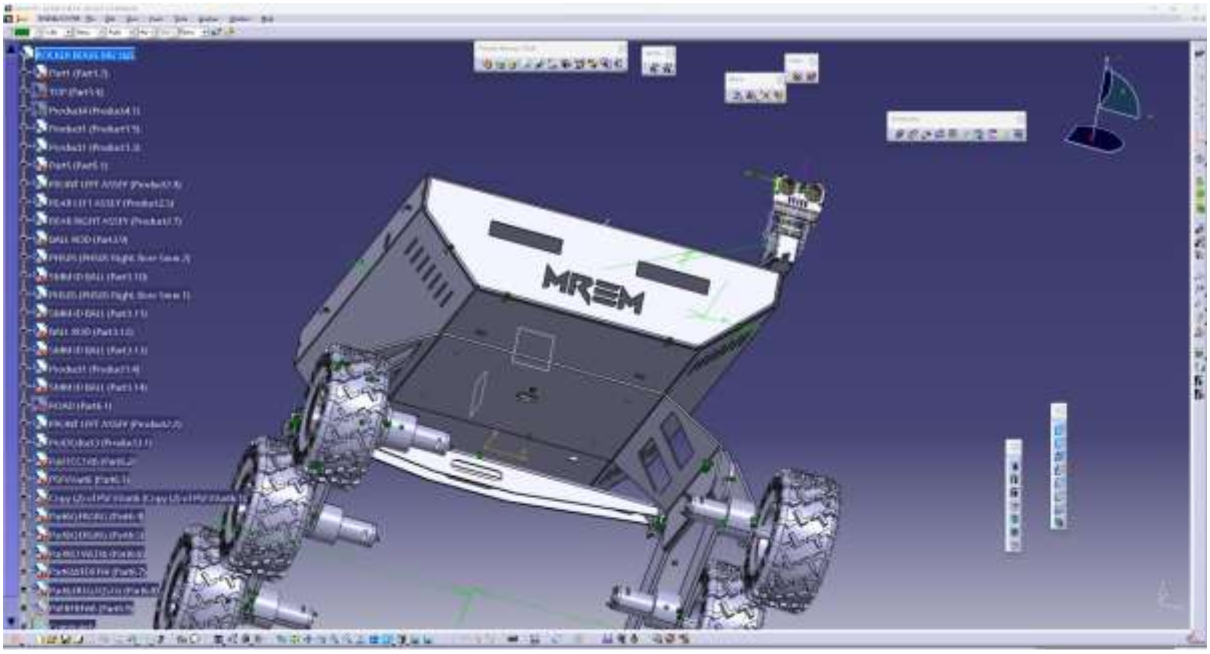

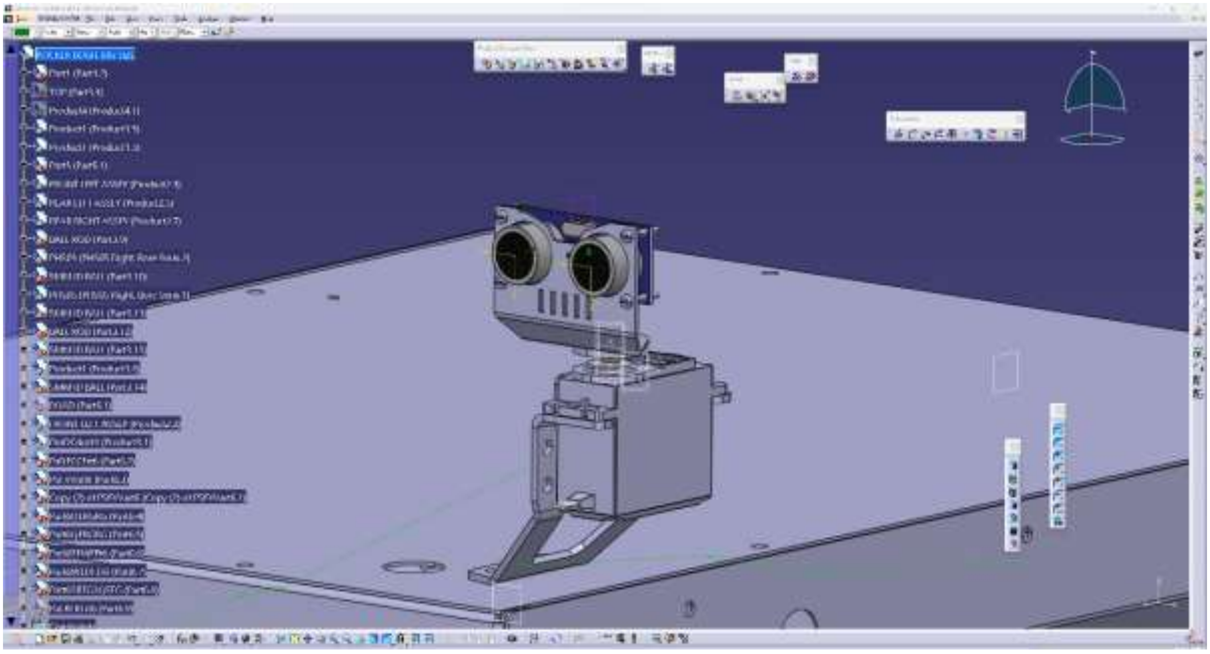

5. CONLUSION AND FUTURE SCOPE

In conclusion, the design and development of the six-wheeled robot with a rocker bogie suspension system, Bluetooth-based control, and integrated ultrasonic sensing have resulted in a versatile and capable robotic platform. The rocker bogie suspension system, inspired by NASA's Mars rovers, provides the robot with exceptional stability and terrain adaptability, allowing it to traverse challenging landscapes with ease. The Bluetooth-based control system offers convenient and flexible operation through both voice commands and key inputs, enhancing the user experience and enabling remote control capabilities. The integration of the ultrasonic sensor with a servo motor further enhances the robot's perception abilities, enabling it to detect and avoid obstacles in real-time. The combination of these features provides the robot with superior mobility, precise control, and obstacle avoidance capabilities.

The developed robot opens up several possibilities for future improvements and extensions. Some potential areas for further exploration and development include: Integrating additional sensors such as cameras, LIDAR, or infrared sensors can expand the robot's perception capabilities, enabling advanced mapping, object recognition, and navigation in complex environments. Implementing algorithms and machine learning techniques to enable autonomous navigation and path planning would enhance the robot's autonomy and make it suitable for applications such as autonomous exploration or surveillance missions. Upgrading the mechanical design and components to increase the robot's payload capacity would allow it to carry and manipulate heavier objects, expanding its range of applications. Investigating the coordination and collaboration between multiple robots could enable the development of swarm robotics systems for tasks requiring collective intelligence and distributed sensing.

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