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Design and Development of Fire Fighting Robot with Live Streaming

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Abstract

This project presents the design and development of a firefighting robot equipped with a camera and pump system. The robot is specifically designed to assist in firefighting operations, providing remote surveillance and firefighting capabilities in hazardous environments. The integration of a camera allows for real-time video streaming, enabling firefighters to assess the situation and make informed decisions from a safe distance. The pump system, coupled with a water reservoir, facilitates the robot's ability to extinguish fires by spraying water or fire retardants. The mechanical design, control architecture, and sensor integration of the firefighting robot are discussed in detail, highlighting its key features and functionalities. Experimental results demonstrate the effectiveness of the proposed system in firefighting scenarios, showcasing the robot's remote surveillance capabilities and firefighting performance.

Keywords: Robotic systems, CATIA, 3D modelling, CNC milling, Firefighting robot, Live streaming, Pump system.

1. Introduction

The concept of fire-fighting robots has a relatively recent history, emerging in the early 2000s as a response to the need for improved fire response capabilities. Researchers and engineers recognized the limitations of traditional firefighting methods and sought to develop robotic systems that could assist in fire suppression and rescue operations. The advancements in robotics, artificial intelligence, and sensor technologies during that time provided the foundation for the development of these specialized robots. Traditional firefighting has always relied on the courage and dedication of firefighters who put their lives at risk to combat fires and save lives. However, certain scenarios presented significant challenges to human firefighters, such as high-rise buildings, industrial complexes, and chemical plants. These environments often involve toxic gases, extreme heat, limited visibility due to smoke, and structural instabilities, making it difficult and dangerous for firefighters to operate effectively. The primary motivation behind the development of fire-fighting robots was to enhance the safety of firefighters and improve the overall efficiency of fire response operations. These

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robots were envisioned as a means to perform tasks in hazardous environments where human intervention could be limited or too risky. By deploying robots, the goal was to reduce the number of human casualties and increase the success rate of fire suppression and rescue missions. Fire-fighting robots have had a profound impact on emergency response capabilities. By leveraging advanced technologies, these robots possess the ability to navigate through smoke-filled areas, withstand intense heat, and traverse challenging terrains. Equipped with a range of sensors, including thermal imaging and gas detectors, they can swiftly identify the source and intensity of fires. This information allows them to make informed decisions regarding fire suppression techniques and determine the safest and most effective course of action. Moreover, fire-fighting robots excel in search and rescue operations. They can locate and extract individuals trapped in hazardous environments, thereby significantly reducing the time required for human rescue teams to reach them. This capability has proved invaluable in situations where time is of the essence, such as during building collapses or fires in remote locations. By swiftly locating and rescuing individuals, these robots have saved numerous lives and minimized human casualties.

2. Literature Survey

Mohammed, Sanusi, et al. (2023) presented the design, implementation, and performance analysis of a smart firefighting robot. Their work focused on developing a robot equipped with sensors and communication capabilities to autonomously detect and extinguish fires. The paper discussed the system architecture, control algorithms, and experimental evaluation of the robot's performance. Sindhu, R., and T. Perarasi (2023) introduced a moving firefighter robot for firefighting applications. Their work aimed to develop a robot capable of navigating through challenging terrains and extinguishing fires. The paper discussed the design, control mechanisms, and experimental evaluation of the moving firefighter robot.

AKINLOYE, BO (2023): The author presented the development of a dual-mode firefighting robot. The robot was designed to operate in two modes: manual and autonomous. The paper discussed the design considerations, system architecture, and performance evaluation of the dual-mode firefighting robot. SB, Vinaykumar (2023): The author presented a research paper on a night vision firefighting robot. The robot was equipped with night vision capabilities to enhance firefighting operations in low-light conditions. The paper discussed the design, implementation, and performance analysis of the night vision firefighting robot. Dhiman, Amit, et al. (2022) developed a firefighting robot that utilized deep learning and machine vision techniques. Their work focused on training the robot to detect and extinguish fires using image analysis and deep learning algorithms. The paper discussed the integration of deep learning and machine vision into the firefighting robot system and presented experimental results.

Li, Sen, et al. (2022) proposed a thermal imaging flame-detection model for a firefighting robot based on the YOLOv4-F model. Their work aimed to enhance the detection accuracy of the robot by utilizing thermal imaging technology. The paper discussed the development of the flame-detection model and its integration into the firefighting robot system. Chaoxia, Chenyu, et al. (2022) presented a weakly aligned multimodal flame detection approach for firefighting robots. Their work focused on developing a system that could detect flames using multiple modalities, such as visual and thermal data. The paper discussed the algorithmic framework, multimodal fusion techniques, and experimental evaluation of the proposed approach. Zhang, Shuo, et al. (2023) conducted motion analysis of a firefighting robot and proposed a trajectory correction strategy. Their work aimed to improve the navigation and path planning capabilities of the robot. The paper discussed the motion analysis techniques, trajectory correction algorithms, and simulation-based evaluation of the proposed approach.

Zhao, Jianwei, et al. (2022) presented the design and research of an articulated tracked firefighting robot. Their work focused on developing a robot with articulated tracks for improved mobility and maneuverability in firefighting scenarios. The paper discussed the design considerations, control mechanisms, and experimental evaluation of the articulated tracked firefighting robot. Rajesh, M., K. Shenpriya, and N. K. Santhiya (2022) conducted a review focused on fire-fighting robots based on Arduino. They discussed the various aspects of fire-fighting robot design and implementation using Arduino microcontrollers. The paper provided insights into the use of Arduino in developing cost-effective and customizable fire-fighting robots. Ștefan, Amado, et al. (2022) conducted research on heat transfer through a double-walled heat shield of a firefighting robot. Their work focused on analyzing and optimizing the heat transfer properties of the heat shield to protect the firefighting robot from high temperatures. The paper discussed the experimental setup, heat transfer analysis, and optimization techniques applied to enhance the performance of the double-walled heat shield.

3. Proposed Methodology

The firefighting robot operates by remotely navigating the hazardous environment using wheels or tracks. Figure 1 shows the block diagram of firefighting robot. The robot is equipped with a camera mounted on a pan-tilt mechanism, providing a wide range of vision. The camera captures live video footage and transmits it wirelessly to a control station, allowing firefighters to assess the situation in real-time. This remote surveillance capability enhances situational awareness and helps in formulating effective firefighting strategies. To combat fires, the robot is equipped with a pump system connected to a water reservoir. The pump draws water from the reservoir and propels it through a hose or nozzle, providing a powerful water stream to extinguish the flames. In addition to water, the robot can be designed to carry fire retardants or foam, further enhancing its firefighting capabilities.

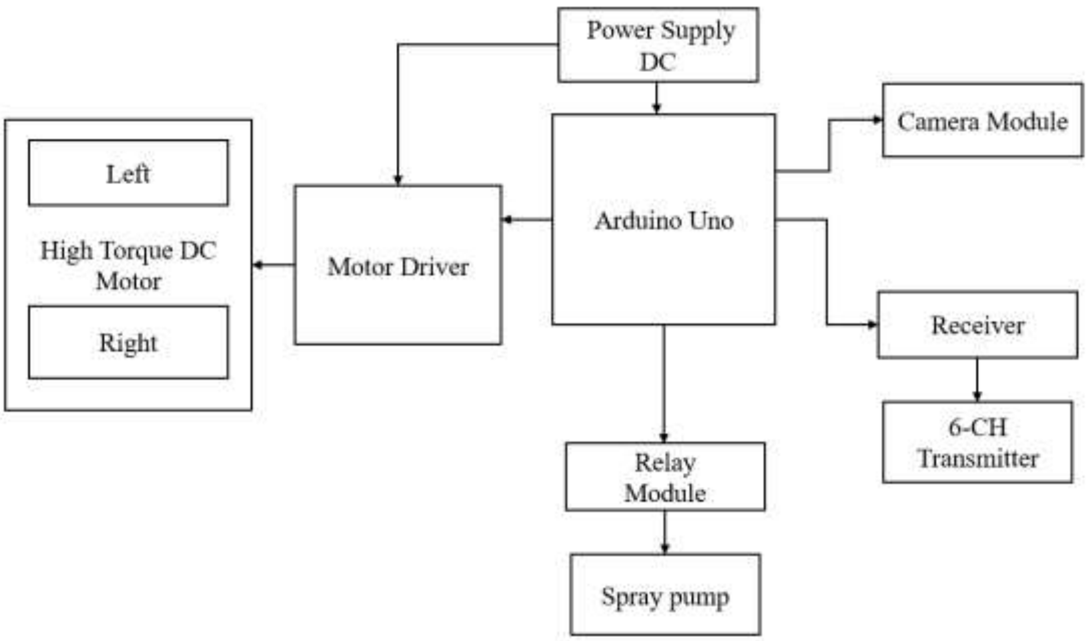

Fig. 1: Block diagram of firefighting robot.

The robot body chassis provides the structural framework and support for all the components and modules of the firefighting robot. It is designed to accommodate the Arduino UNO controller, motors, pump system, and other hardware. The chassis is typically constructed using CNC laser cutting and CNC metal bending techniques to ensure precision and durability. 3D printed brackets, clamps, and solid parts are used to mount and secure various components of the firefighting robot. These parts are designed and fabricated using 3D printing technology, which allows for customization, rapid prototyping, and precise fitting of the components. They provide structural integrity and stability to the overall robot assembly.

The Arduino UNO controller serves as the central control unit of the firefighting robot. It receives commands from the operator or the remote control system and coordinates the actions of the robot accordingly. The Arduino UNO board is programmed to interpret these commands and control the various modules and components of the robot. The 6-CH (channel) transmitter and receiver form the communication system between the operator and the firefighting robot. The operator uses the transmitter to send control signals wirelessly to the receiver connected to the Arduino UNO controller. These signals determine the robot's movements, camera orientation, and activation of the firefighting mechanisms.

Hybrid planetary general DC motors provide the necessary power and torque for the locomotion of the firefighting robot. These motors drive the wheels or tracks of the robot, enabling it to move in different directions. The Arduino UNO controller sends motor control signals to adjust the speed and direction of the motors, allowing the robot to navigate the environment effectively. The motor driver module acts as an interface between the Arduino UNO controller and the DC motors. It receives the control signals from the Arduino and amplifies them to provide sufficient power to the motors. The motor driver ensures precise control over motor speed, direction, and torque, enhancing the robot's maneuverability.

The power supply module provides the required electrical power to the firefighting robot. It converts the input voltage (usually from a battery or an external power source) to the suitable voltage levels needed by the various components and modules of the robot. The power supply ensures stable and reliable operation of the robot during firefighting missions. The relay module is responsible for controlling high-power devices such as the spray pumps or other firefighting mechanisms. The Arduino UNO controller sends control signals to the relay module, which then switches on or off the power supply to these devices. This allows the robot to activate and regulate the operation of the spray pumps or other firefighting equipment. The steering motor mechanism enables the robot to change its direction and navigate around obstacles. It receives control signals from the Arduino UNO controller, which adjusts the steering angle or direction of the mechanism. This allows the robot to effectively maneuver through different terrains and reach the desired firefighting locations.

The spray pumps module includes the water pumps or other firefighting mechanisms used to extinguish fires. The Arduino UNO controller activates the spray pumps based on the operator's commands or the fire detection signals from the sensors. The pump speed and flow rate can be adjusted to ensure an efficient and effective firefighting operation.

Methodology

The proposed methodology for the firefighting robot involves several stages, each with specific tasks and objectives.

Step 1: Design and Fabrication:

In this stage, the first step is to design the robot chassis, considering factors like weight distribution and stability. The design should also accommodate all the necessary components. Once the design is

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finalized, the chassis is fabricated using suitable materials. This ensures a sturdy and durable structure for the robot. Additionally, the pan-tilt mechanism and camera mount are incorporated into the design, allowing for proper positioning and a wide range of motion.

Step 2: Camera and Surveillance System Integration:

In this stage, the camera module is integrated onto the pan-tilt mechanism, enabling it to capture a wide field of view. Electrical connections are established to ensure seamless communication between the camera and the robot's control system. Control software is developed to facilitate camera movement and real-time video streaming. This integration provides the operator with a visual feed to monitor the fire scene and make informed decisions.

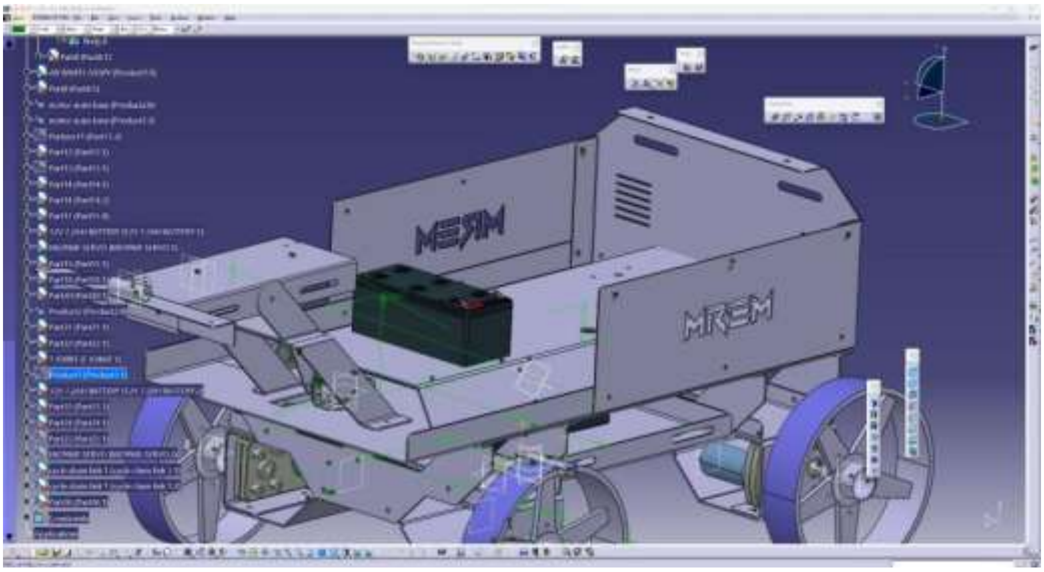
Step 3: Pump System and Firefighting Mechanism:

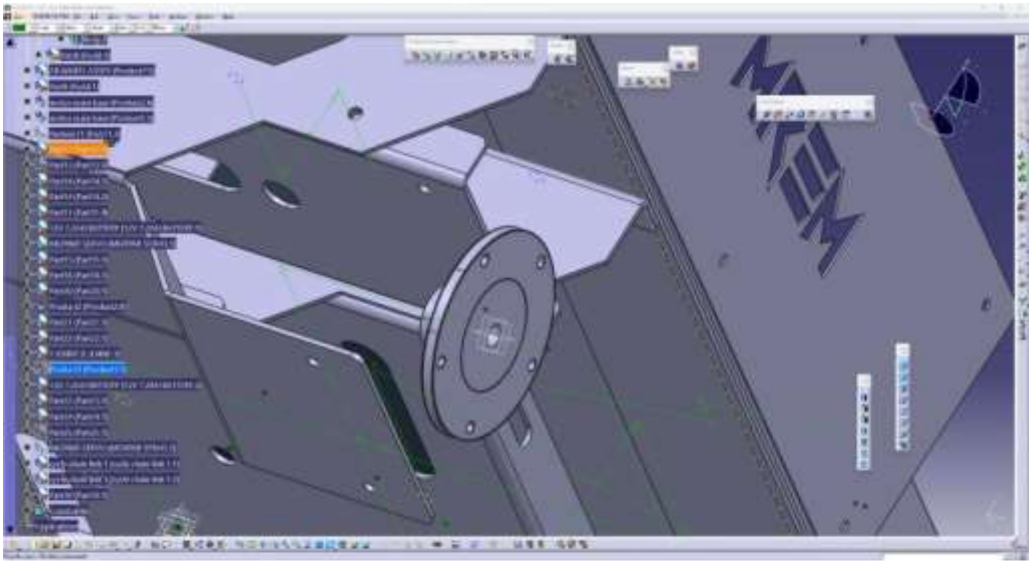
The pump system is an essential component of the firefighting robot. It includes a water reservoir and a hose or nozzle attachment. The design takes into account factors such as water flow, pressure, and spray patterns. Control algorithms are developed to regulate these parameters based on the operator's commands. Additionally, if desired, a fire retardant or foam reservoir can be incorporated into the system, with suitable mechanisms for controlled release.

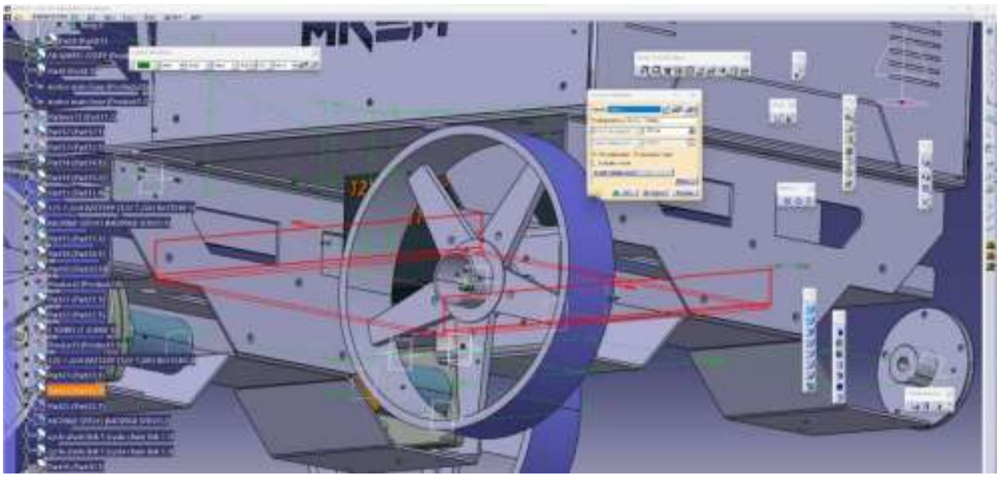
Step 4: Control System Development:

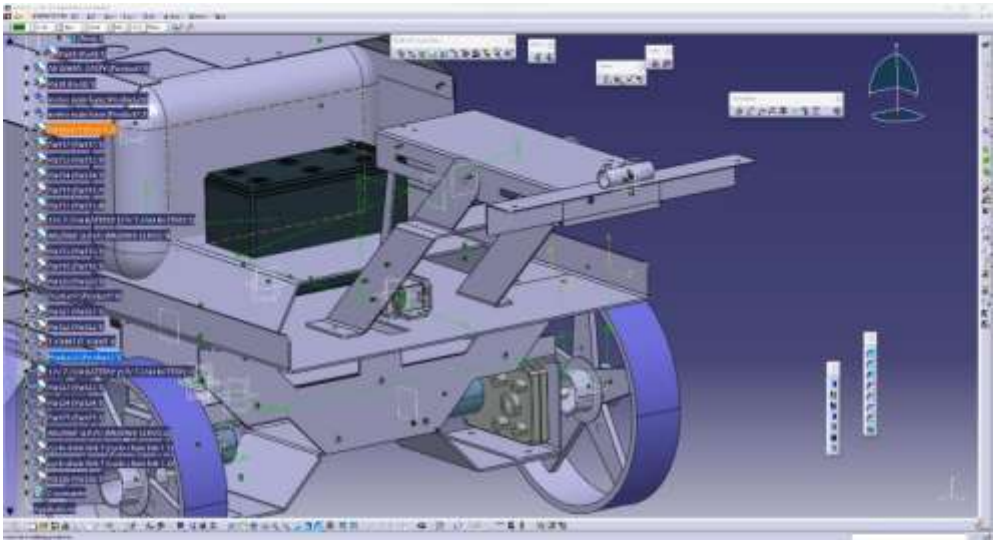
In this stage, the focus is on developing the control software for the firefighting robot. The software enables remote operation, surveillance, and firefighting functionalities. User interfaces are designed to provide intuitive control over robot movement, camera orientation, and pump activation. These interfaces allow the operator to efficiently navigate the robot, monitor the fire scene, and perform firefighting actions with ease.

4. 3D MODELLING









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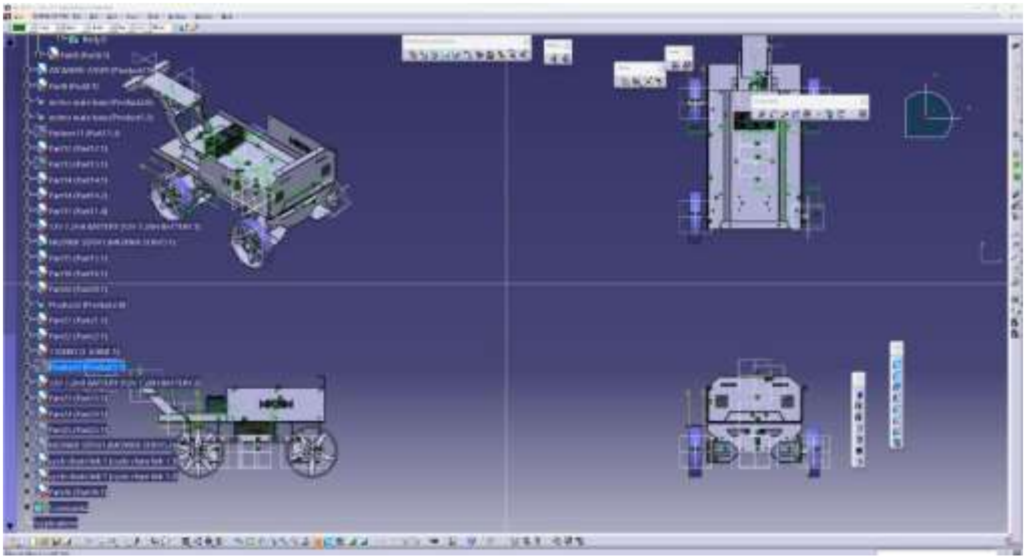

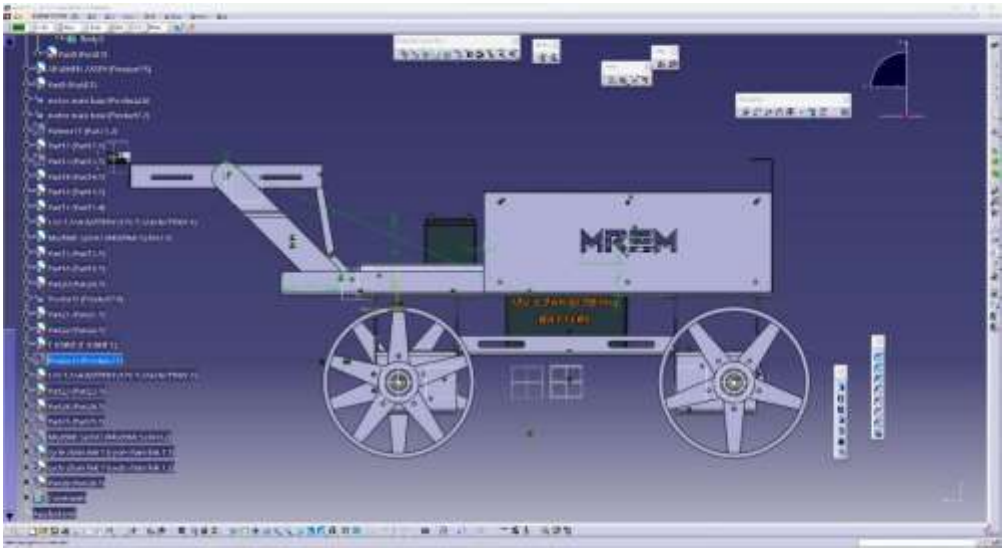

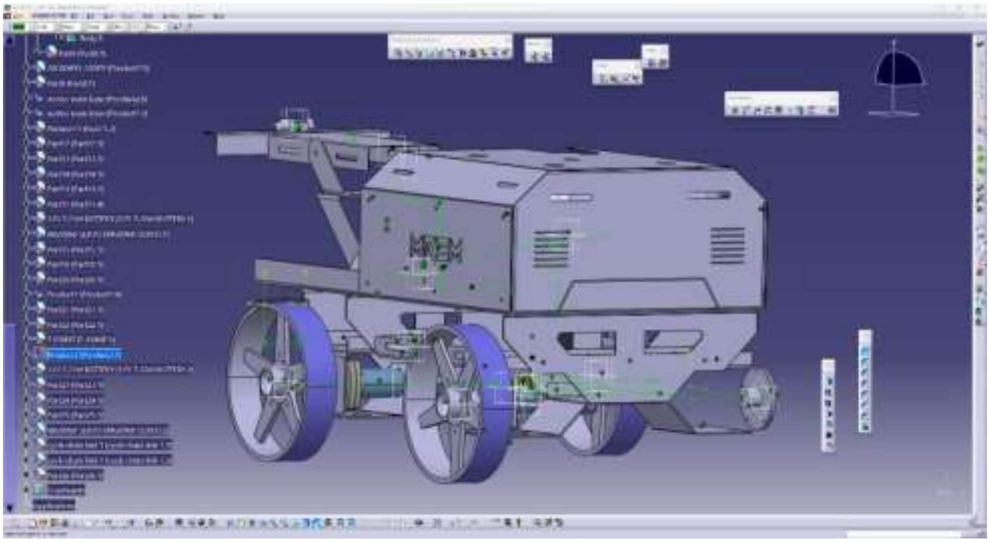

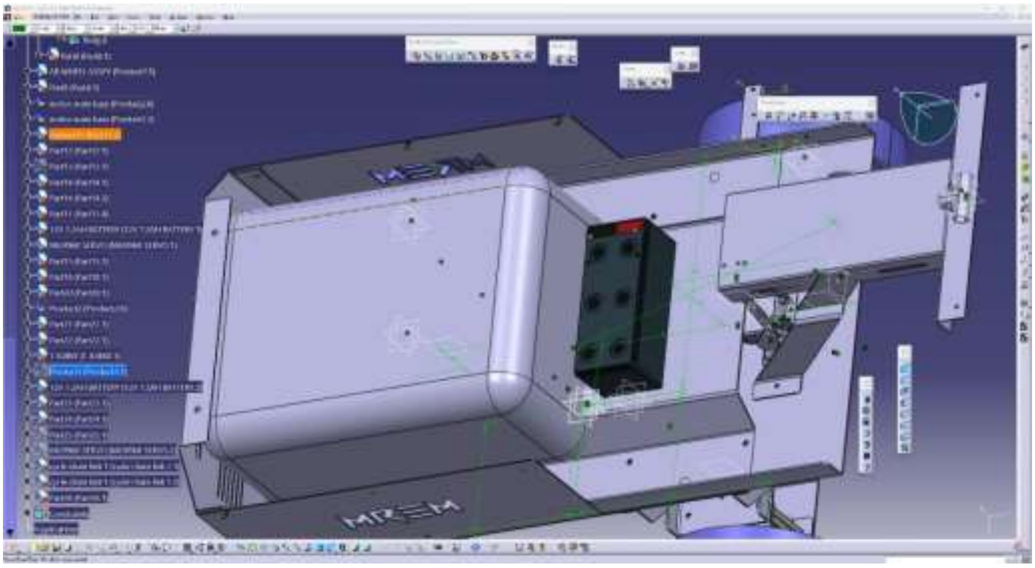

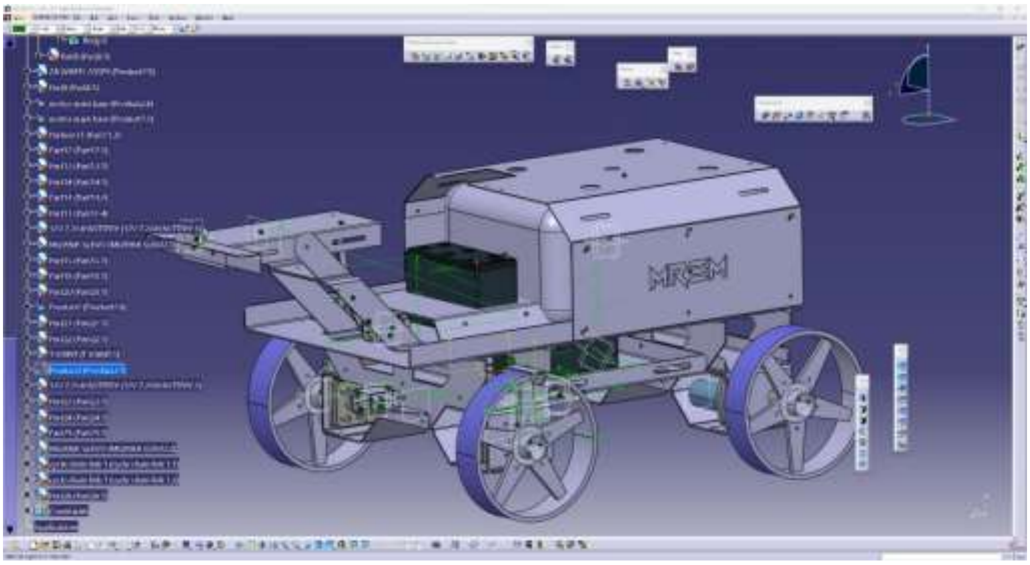

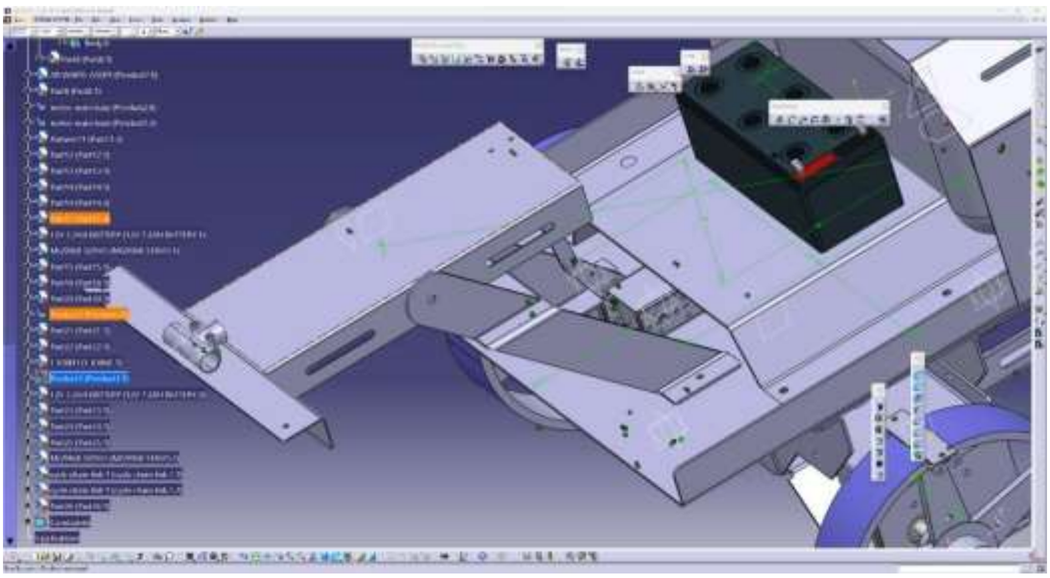

5. CONLUSION

In conclusion, the design and development of the firefighting robot presented in this project have shown promising results in enhancing firefighting operations. The integration of a camera and pump system allows for remote surveillance and effective firefighting capabilities, providing critical support to firefighters in hazardous environments. The robot's ability to stream real-time video footage and spray water or fire retardants offers valuable situational awareness and fire suppression capabilities. The experimental results have demonstrated the effectiveness of the firefighting robot in various firefighting scenarios. The robot's remote surveillance capabilities enable firefighters to assess the situation from a safe distance, reducing their exposure to potentially dangerous conditions. Moreover, the firefighting performance of the robot has been proven by its ability to extinguish fires through the controlled release of water or fire retardants.

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