Appendix - Flat Exploration Robot

Contents

1. Requirement specifications

1.1 Maximum payload

Although the design load is 2.5 kg, considering that some cases may require carrying additional loads, the robot's structure should be designed to ensure that it can safely carry slightly heavier loads, such as 3 kg, for a short period of time. The plan is to make the chassis using stronger materials to support the extra load and ensure that the drive system has enough torque to move the robot.

1.2 Body weight

After installing the required components, the total weight of the robot is estimated to be between 1.5kg and 3kg, with most of the robot's weight coming from the battery and drive system. In addition, sensors and other components also contribute to the total weight of the robot. When choosing materials, consider using materials that are light and strong, such as aluminum alloys or lightweight plastics.

1.3 Maximum speed

The maximum speed of the robot is designed to be 0.7 m/s, allowing the robot to move quickly in crowded environments, while also being able to respond to obstacles in time. The speed of the robot during the survey may be 0.4 m/s, so that the robot can detect the surrounding environment as accurately as possible and avoid collision in the unknown environment. Considering the changes in friction, acceleration and the time required to decelerate, the initial obstacle avoidance distance of the car should increase with the increase in the speed of the car. That is, the distance between the car and the obstacle is obtained through ultrasonic distance measurement, and the threshold of obstacle avoidance operation is set in the development board. Use a motor that provides adequate torque and speed, and ensure that the software control system can respond quickly to obstacles.

1.4 Ground clearance

A chassis height of 30 mm from the ground ensures that the robot can get over small obstacles such as wires or carpets, and if higher obstacles are present in the environment, an adjustable suspension system can be considered. Or use wheels with larger diameters to raise the ground clearance.

1.5 Minimum continuous operation time

The batteries are selected according to the expected time of the task, and the use of high-capacity batteries ensures that the robot can work continuously for more than 4 hours. Use a battery management system to optimize battery usage and monitor battery levels. For tasks that require long working hours, consider using larger capacity batteries or fast charging technology to increase the working time of the robot.

1.6 Drive configuration

The differential drive configuration enables the robot to make flexible turns and movements. Use high-performance motor controllers to ensure precise drive control.

1.7 Shape of chassis

The square design with four corners removed makes the robot less likely to collide with obstacles when turning. The edges of the robot can be designed to be sleek to further reduce friction with the environment. There are also three larger holes in it, which combine to look like a "smile" for easy wiring to pass through when installing components.

1.8 Size of chassis

The long x wide x high is 200 x 200 x 7 mm chassis provides enough space to place all the components while maintaining the stability of the robot. For different components such as motors, universal wheels, etc., there are corresponding holes for easy installation. The modular design is used so that components can be placed flexibly in a limited space.

1.9 Navigation and obstacle avoidance

Ultrasonic sensors can be used to detect the distance between the car and obstacles, and the camera is equivalent to the eyes of the robot, both of which can help the car detect and identify obstacles, ensuring the safe navigation of the robot in a variety of environments. Consider adding more sensors, such as infrared or lidar, to enhance the robot's navigation capabilities.

1.10 Size of the robot

The overall size and flat design of the robot ensure its stability in crowded environments. Consider the overall layout of the robot and ensure that all important components are located in the central part of the robot, which can further enhance its stability and protect the components from damage as much as possible in the event of an accident.

2. Robot design and model

2.1 Flat Exploration Robot

Figure 1 shows the car model after all the parts have been assembled. The overall frame of the car is flat, the length and width are nearly twice the height of the car, which makes the car chassis low, conducive to its stable operation to avoid rollover. Is that why it's called Flat Exploration Robot.

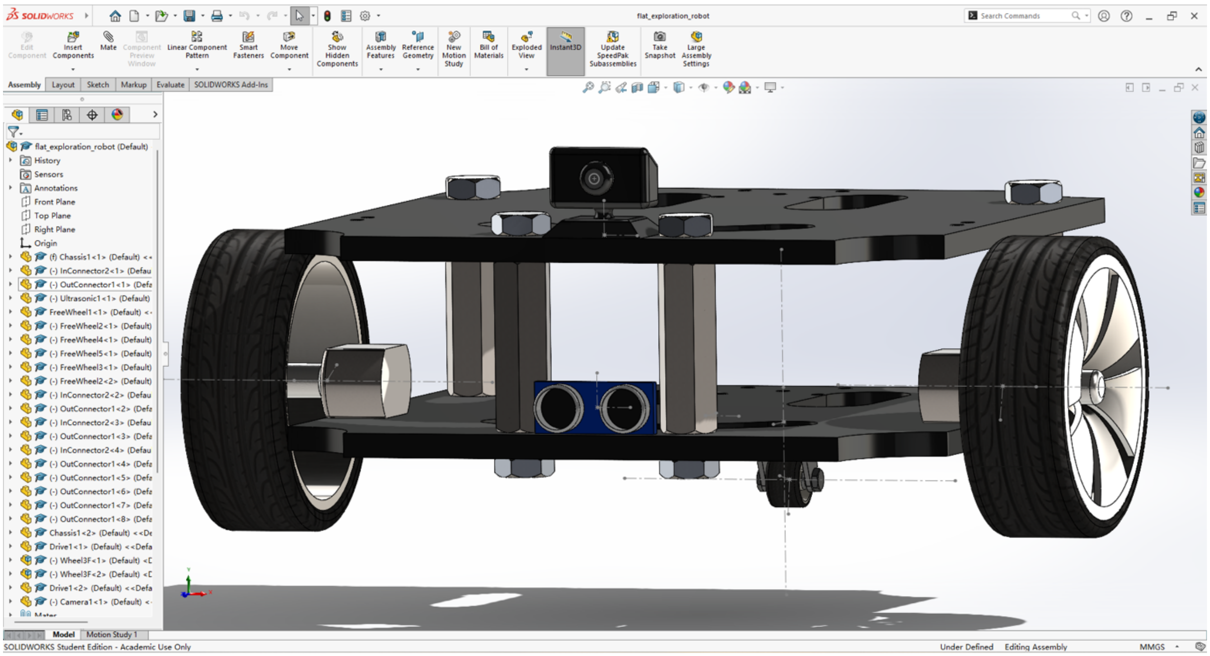

Figure 1. flat exploration robot in Solidworks

2.2 Chassis

Figure 2 shows the chassis design of the robot. The chassis is 7 mm thick so that the car is not easily damaged. The chassis of the car is a 200 mm square, and it is worth noting that this square has four corners cut off by a quarter circle with a radius of 25 mm. The purpose of doing so is to avoid collision with obstacles during the operation of the car, especially when turning, for example, when the car turns, the inside corner may collide with the wall and hang on the wall, and the car is stuck in place and cannot continue to move forward. In addition, if the chassis is circular, whether the wheels are outside the circle or inside the circle edge, it is easier to collide with obstacles than the two sides of the square. This is why the square with the four corners cut off was chosen as the chassis. In addition, the chassis has holes designed for different components to facilitate the installation of other parts, and there are three holes formed like "smile" to facilitate the installation of batteries, development board and other components. At the back of the bottom of the chassis, there are special grooves designed for the universal wheel to facilitate installation and adjustment of the universal wheel and the other two wheels to maintain the same height. The above is about the design of the chassis of the machine car, and the design of the two chassis used in the car is the same.

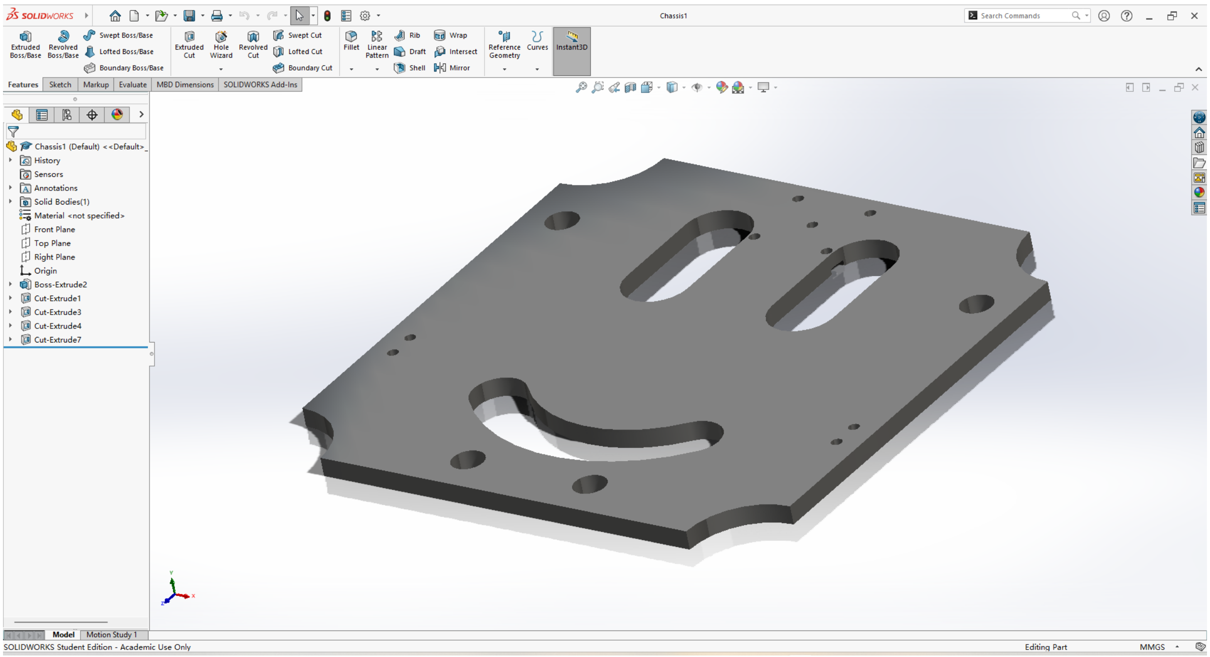

Figure 2. Chassis

2.3 Connector and screw

Figure 3 and Figure 4 respectively show the parts used to connect the upper and lower layers of the car. Connecting the two chassis are four 50 mm long metal posts and eight outer hexagonal screws. The column is 15 mm wide, and four sturdy columns ensure the stability of the car. It is easy to disassemble and assemble the trolley by screw fixing.

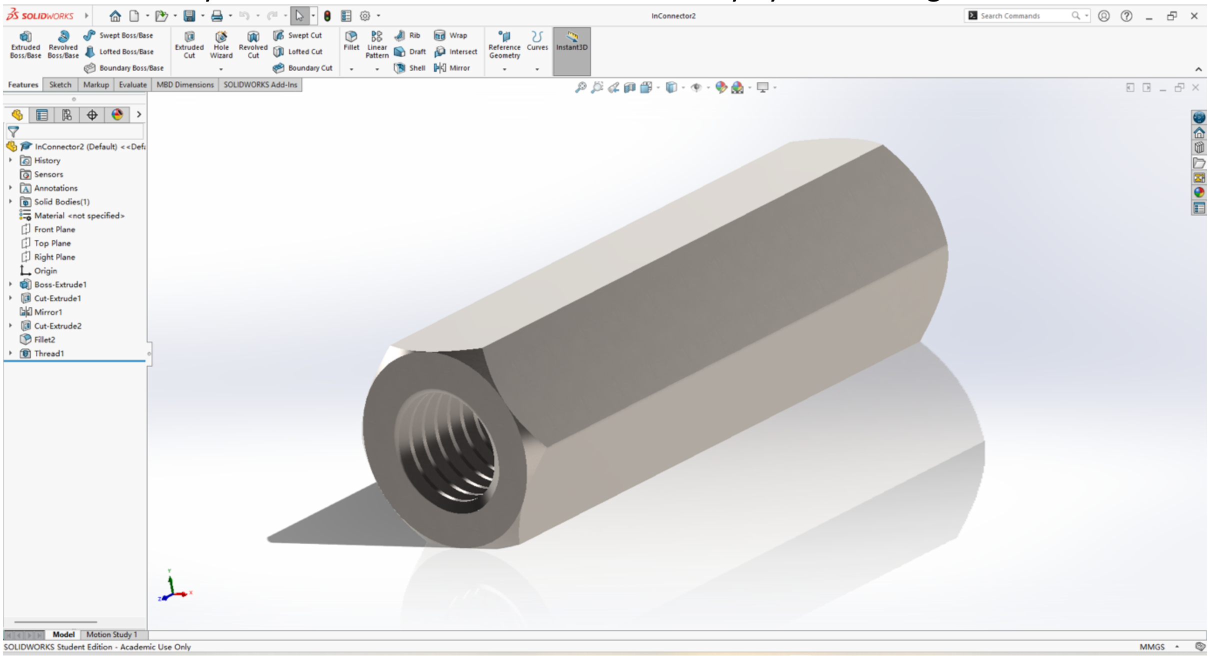

Figure 3. Connector

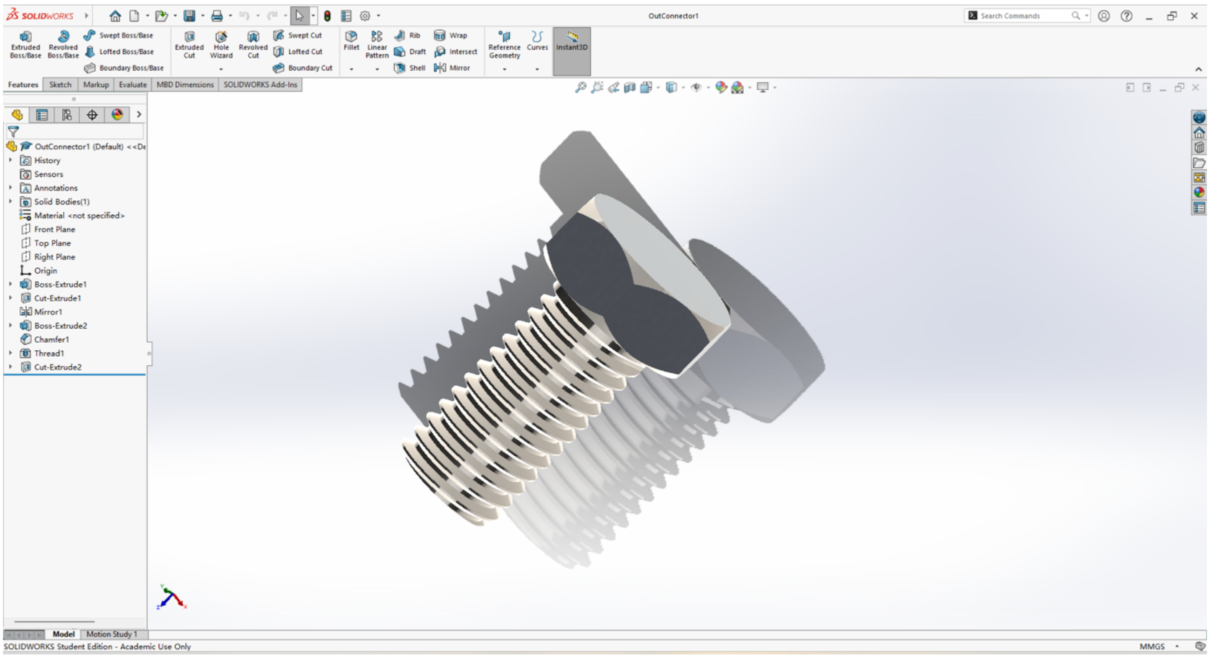

Figure 4. Screw

2.4 Wheel

Figure 5 shows the wheel. The car has two identical driving wheels with a diameter of 84 mm and a width of 31 mm, which are located on both sides of the car. The axles are made of metal, and rubber tires are considered for increased friction.

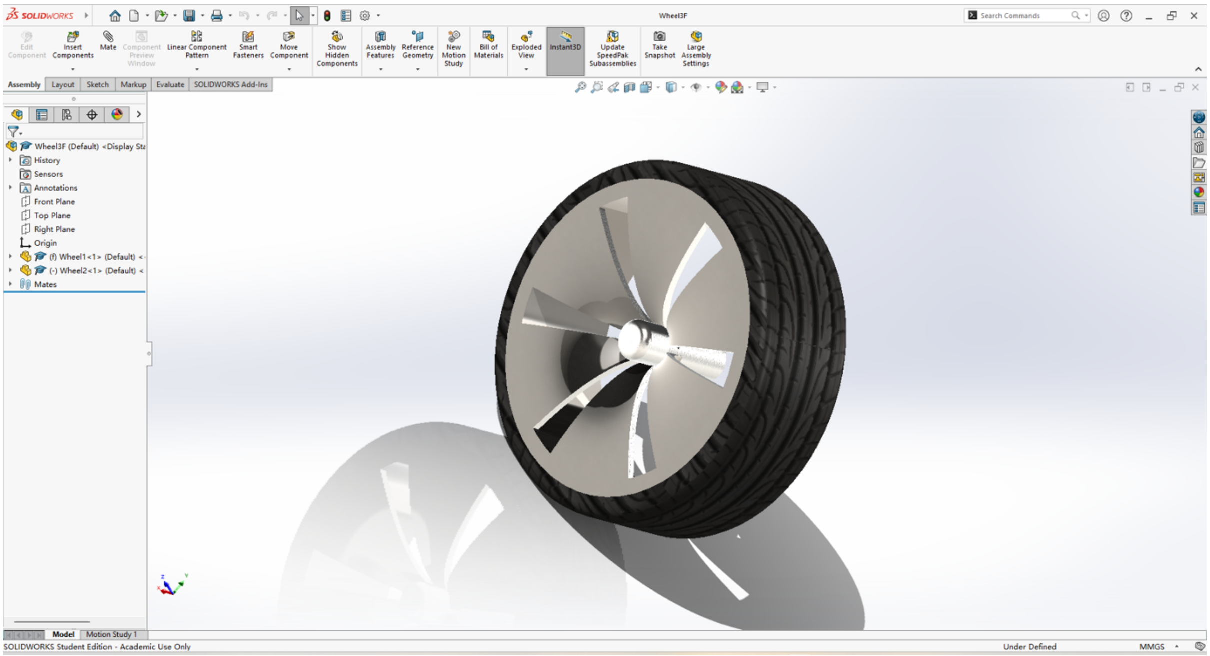

Figure 5. Wheel

2.5 Caster wheel

Figure 6 is the caster wheel, which has two rotating axes so that it can rotate freely in multiple directions. So far, the three wheels have been modeled, the overall frame of the car has been shown to be flat, and the wheels on both sides of the car are large. The design of these car frames mainly considers that the robot can move stably, is not easy to damage, and can work in a narrow environment.

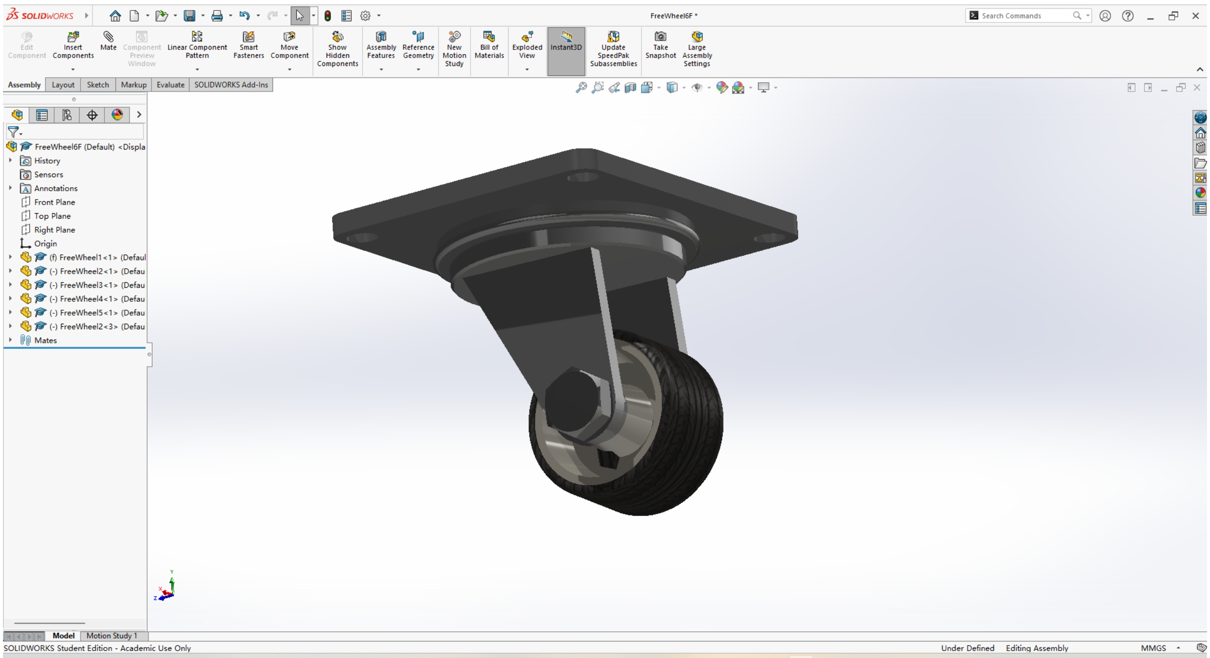

Figure 6. Caster wheel

2.6 Drive, ultrasound, camera

Figures 7, 8 and 9 are the parts: motor, ultrasound and camera respectively. The motor is used to drive the wheels, the ultrasonic sensor is 40 mm wide 7 mm high 15 mm in front of the lower part of the car for detecting the distance of obstacles, and the camera is in front of the upper part of the car with an overall length of 30 mm wide 12 mm high 25 mm.

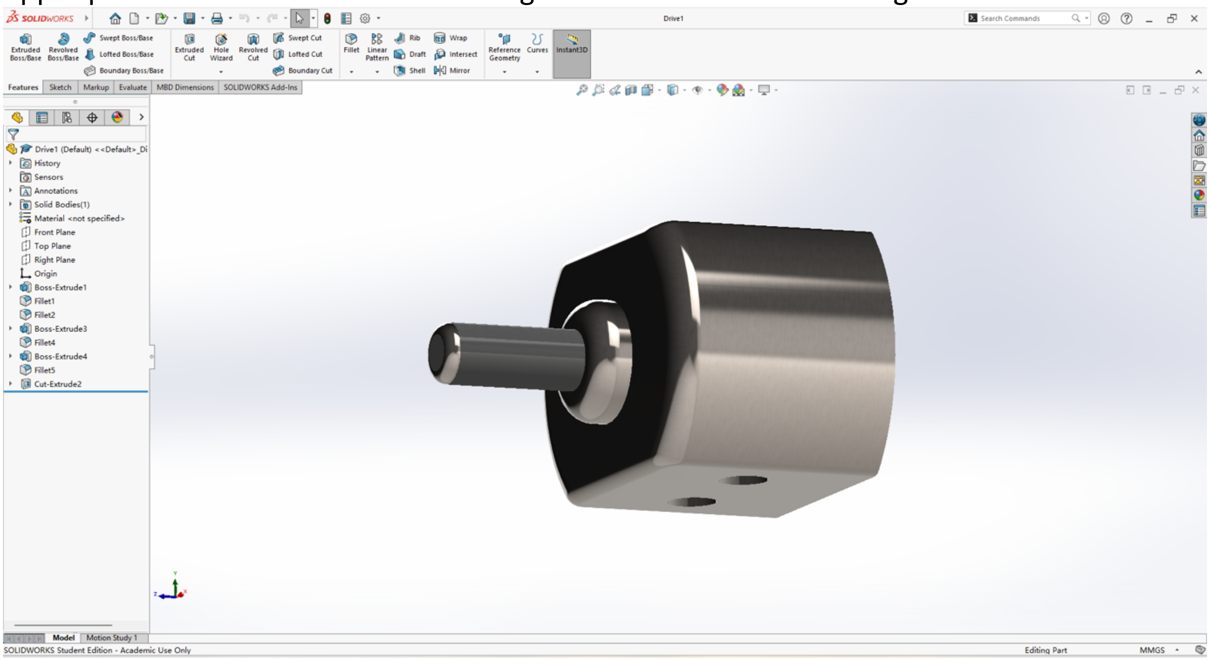

Figure 7. Drive

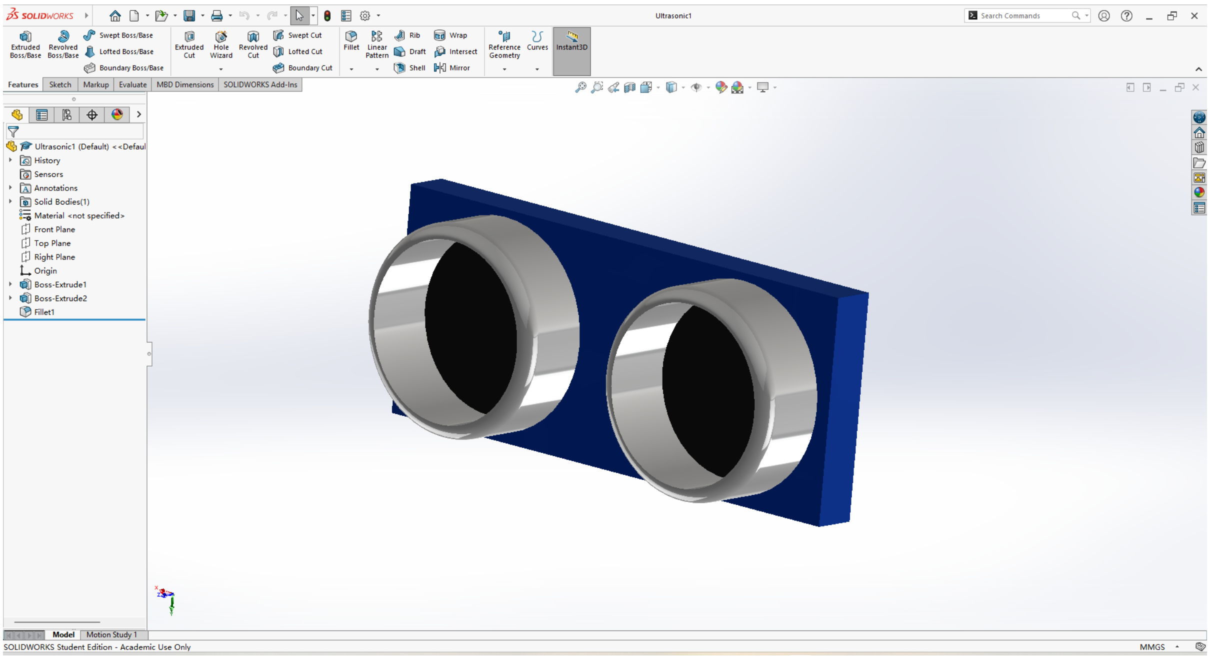

Figure 8. Ultrasonic

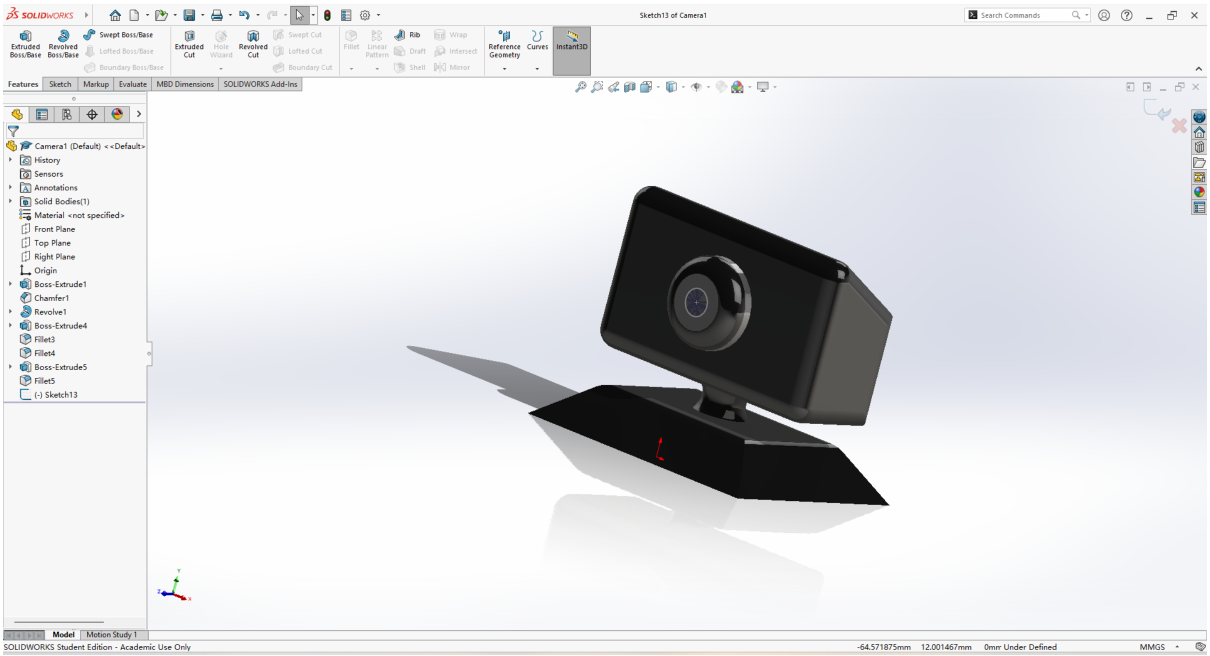

Figure 9. Camera

3. Reflection

From the conception of requirements specifications to design, from modeling to exporting the URDF file, and then running the Flat Exploration Robot in Gazebo, this process involves a series of challenges. The entire process is one of continuous learning and adaptation.

3.1 Worked

The decision to cut off the four corners of the square chassis proved effective, as this design helps prevent potential collisions during turns. The flat design approach for the robot is beneficial as its low center of gravity keeps it stable, reducing the likelihood of tipping over. Using lightweight materials such as aluminum alloy is an effective choice, providing the required strength without compromising weight. The differential drive configuration allows for smooth and precise movements, especially in confined spaces, making it essential for indoor exploration tasks. The "smiley" design for wiring holes not only fulfills its functional purposes but also adds a touch of personality to the robot.

3.2 Not Worked

Although the trimmed square chassis effectively avoids some collisions, there are still challenges in certain confined spaces, considering further rounding off after cutting the four corners. Relying solely on ultrasonic sensors and cameras for navigation indeed has limitations. Integrating infrared or LiDAR sensors would enhance the robot's obstacle detection capabilities. Additional specialized sensors might be required for specific tasks, like temperature and smoke sensors for rescue missions. While the target was a continuous working time of 4 hours, actual power consumption might be faster than expected due to the combined power demands of motors and onboard sensors. As for the ground clearance, though 3 cm is adequate for most terrains, the robot struggles in environments with larger obstacles.

3.3 Lessons learnt

Conceptualizing the requirements specification for the robot before designing is crucial. The intended application and required standards directly determine the robot's features. When choosing components, relying on just one type of sensor can limit the robot's performance in various environments. Modular design methodology is vital as it allows for easier future modifications and upgrades. Always consider the robot's operating environment. Design considerations for indoor exploration robots differ from those meant for outdoor environments.

3.4 Skills acquired

Through modeling the robot, I practiced extensively with the SolidWorks CAD software. I learned the importance of URDF files in defining a robot model within the ROS framework, allowing developers to describe in detail the robot's physical structure, dimensions, joints, sensors, actuators, and other components. With URDF, one can create a complete robot model, understanding its significance for simulation, navigation, control, and many other robot applications. I also gained practical experience in creating and modifying these files. The highlighted code in Figure 10 illustrates setting the “base_link” color to gold, and other components use the same method to change the colors of different components by modifying the URDF file. Figure 11 displays the robot in Gazebo after running the "roslaunch flat_exploration_robot gazebo.launch" command, deepening my understanding of launch files. In ROS, launch files are XML files simplifying the initiation process of complex robot software architectures.

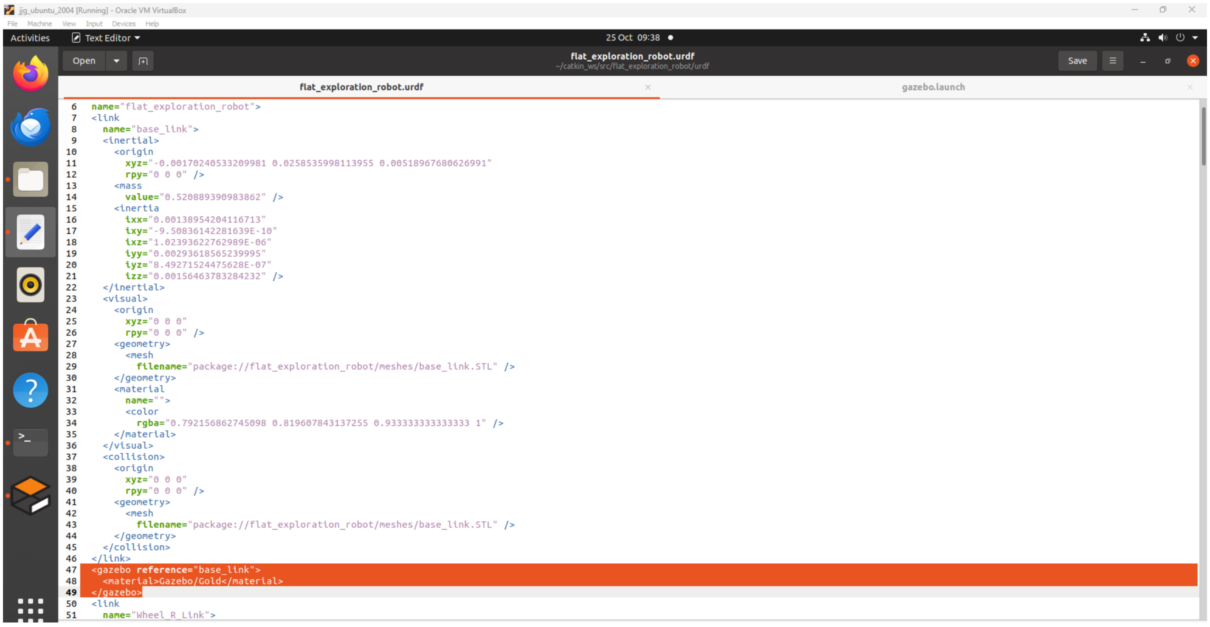

Figure 10. base_link

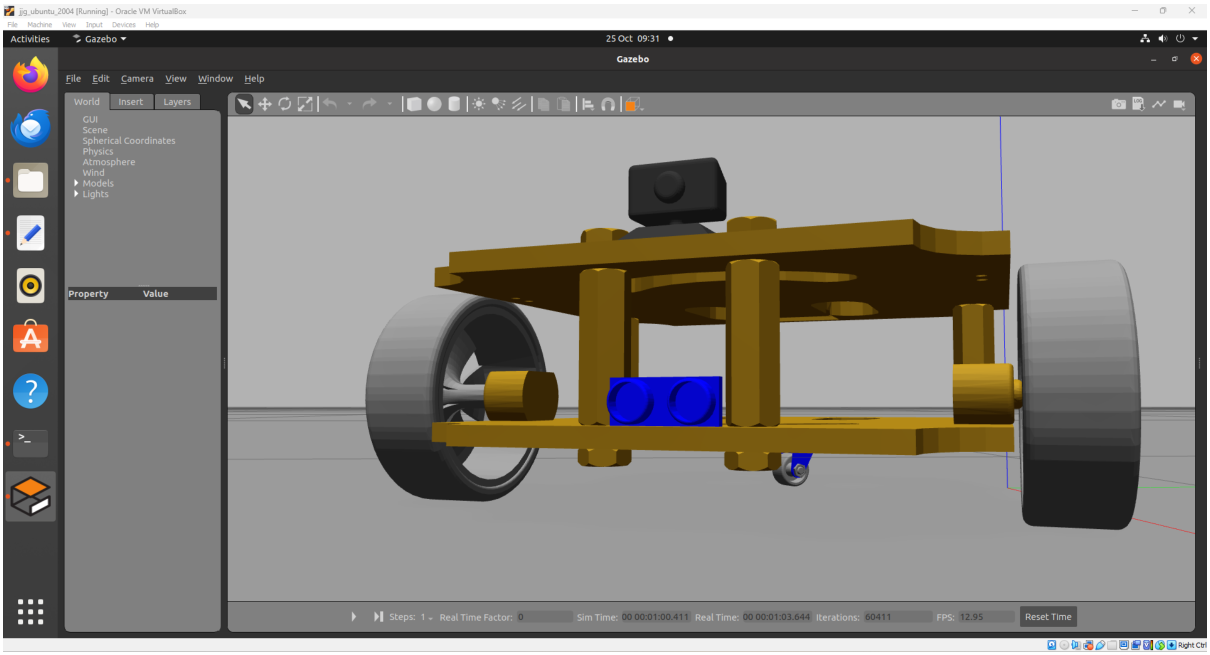

Figure 11. flat exploration robot in Gazebo

In conclusion, design the Flat Exploration Robot project was a significant learning experience. It enhanced my comprehensive understanding of the complexities in robot design and improved my problem-solving abilities, adaptability, and continuous improvement skills.