I. INTRODUCTION

The task involves maneuvering a remote-controlled robot through a predefined obstacle course, clearing obstacles, and transporting green boxes into the nearest red boxes of similar dimensions to unlock the path, all while aiming to reach the finish line in the shortest time.

II. MECHANICAL DESIGN OVERVIEW

The design of this bot has been done with utmost emphasis on modularity, ease of control, consistency in output, and simplicity, considering the design constraints set forth by the rulebook.

A. *Specifications and Part list*

- Dimensions of the base chassis(approximately): 130 mm * 200 mm * 20 mm
- Wheels (4): Diameter = 66 mm
- DC Motor: 12 V
- Gripper mechanism specifications:
  - Claw:
    - 20 mm thick
    - 100 mm available holding space for the green box
  - Gripper Arm:
    - Arm length: 134 mm
- Servo (2): MG996R
- Arduino UNO
- Motor Drivers(2): L298N

B. *Material Selection and Weight Distribution*

- Base of chassis: Wood (to provide a stable base for the bot having enough strength to carry all the electronic components and the gripper arm at all times without failure).
- Gripper arm: Wood (light but enough to carry loads of around 0.5 kg through the gripper).
- Belt over the wheels: Rubber (to prevent slipping at any time).
- Claw: Plastic (3-D printed)

Justification: The choice of materials influences the bot's durability, efficiency, and overall performance. Wood is selected for the chassis as it offers a good strength-to-weight ratio, preventing the bot from being too heavy while ensuring structural integrity. Rubber belts on the wheels help reduce slipping, improving traction. A 3D-printed plastic claw is lightweight yet sturdy, ensuring the gripper can handle loads effectively. Proper weight distribution is crucial to prevent tipping during movement and lifting operations.

C. *Drivetrain mechanism*

- **Chassis & Drive Configuration:** The bot will use a 4-wheel independent drive system powered by four DC motors, with each motor directly attached to one wheel, providing precise control over movement and enabling the bot to navigate through obstacles.
- **Motor Control and Motion:**
  - **Forward & Backward Motion:** Both front and rear motors spin in the same direction and at the same rpm.
  - **Left Turn:** High rpm on left; low rpm on right
  - **Right Turn:** High rpm on right; low rpm on left
  - **Rotating in Place:**
    - Left-side motors move forward, and right-side motors move backward; same rpm (anticlockwise)
    - Left-side motors move backward, and right-side motors move forward; same rpm (clockwise)

The bot is manually controlled through a wireless remote control system and an Arduino attached on the base processes the input to translate them into motor movements.

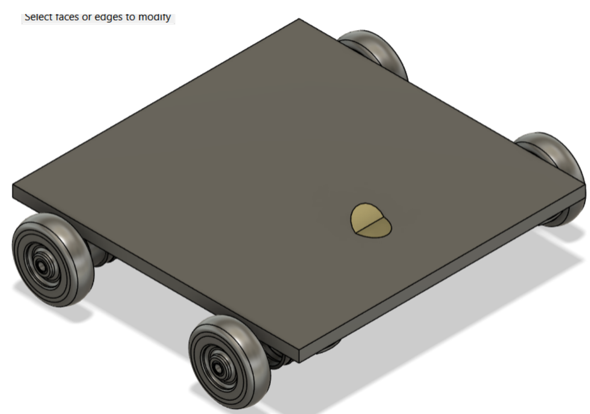

Fig. 1. Base Chassis

Justification: A 4-wheel independent drive system provides better maneuverability, allowing precise movement through the obstacle course. Direct motor-to-wheel connections ensure immediate response to control inputs. This drivetrain configuration enables the bot to make tight turns, adjust speed dynamically, and perform differential steering, which is essential for navigating a complex environment.

D. *Gripper*

The gripper consists of –

- Claw
- Gripper arm

- Servo (A and B): MG996R

Gripper Control System:

The servos are controlled via the wireless remote control system.

- **Servo A (Arm Rotation):** Controls the up/down movement
- **Servo B (Claw Opening/Closing):** Controls gripping and releasing

Gripper mechanism:

- **Gripper arm mechanism:**
  - Fixed at a height of 17 mm above the base attached to Servo A which is fixed at 25 mm above on a fixed wooden block on base. The wooden block is fixed to ensure easy movement of the arm.
  - So, the arm rotates using the servo to lift or lower the box.
- **Claw mechanism:** Attached to the moving arm via Servo B, allowing it to grip and release the box.

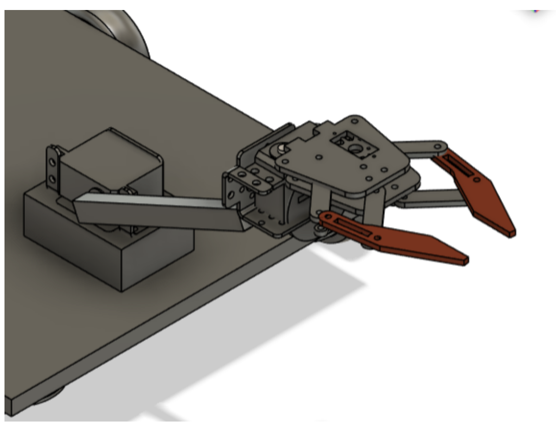

Fig. 2. Gripper

III. Some Important Calculations

1. Power Consumption

The formula gives the power, P, consumed by each motor to overcome the friction between the wheels and the ground, enabling the wheels to rotate appropriately and facilitate motion.:

$$P = V \cdot I$$

Substituting the known values V = 12 Volts and I = 0.12 A:

$$P = 12 \cdot 0.12 = 1.44W$$

2. Total height of the bot

Now calculate the total height of the bot, h, when the arm is at a 90-degree angle from the base.

$$h = d \ + \ h_{arm}$$

where,

- d = diameter of wheel
- h_{arm} = length of arm

Now, substituting the known values d = 66 mm, $h_{arm} = 134$ mm:

$$h = 65 \ + \ 134 \ = 199 \ mm$$

This calculation shows that our bot fits perfectly within the given height constraint, i.e., 600 mm.

3. Operating range of the gripper arm (in mm)

Servo operating voltage: 6 V Corresponding Maximum Stall Torque: 11 kg-cm

Since,

$$Torque = (Force) \cdot (distance\ from\ output\ shaft)$$

$$11 = (Force) \cdot x$$

$$Force = \frac{11}{x}$$

Here, load will be the only force. So, the maximum load, L, that the gripper will be able to grip:

$$L = \frac{11}{x}$$

At x = 5 cm:

$$L = \frac{11}{5} = 2.2 \ kg$$

And at x = 10 cm:

$$L = \frac{11}{10} = 1.1 \ kg$$

Since the green boxes weigh 0.5 kg at max, we can safely say that the operating range of the servo will be 5 - 10 cm (horizontal distance from the output shaft of the servo).

IV. Conclusion

The Zengrip bot has been meticulously designed to ensure efficiency, precision, and modularity in maneuvering through the obstacle course. The mechanical and electronic components work in harmony to provide smooth operation while maintaining stability. Calculations regarding power consumption and height constraints confirm that the bot meets the competition requirements. With its effective drivetrain and robust gripper mechanism, Zengrip is well-equipped to complete the course successfully and in minimal time.