Design Details Documentation - ROBOCON 2023

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The theme of ABU Robocon 2023-"Casting Flowers Over Angkor Wat, "is a game involving two robots, namely a Rabbit robot (RR) and an Elephant Robot(ER), working in coordination to toss the rings onto the poles effectively. To comply with the problem statement, the ER has distinct features like a holonomic drive and various subsystems. The subsystems include the picking and loading mechanism, feeding mechanism, and throwing mechanism. The RR design requirements are similar to ER, with an efficient mecanum drive that can climb the wedge to reach the Angkor Wat area. Both robots have semi-autonomous functioning, and all mechanisms are designed to abide by the rule book to accomplish various tasks.

I. Design of Elephant Robot (ER)

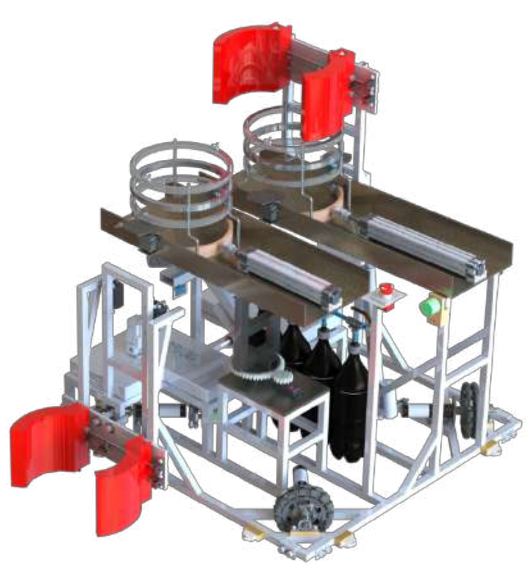

Figure 1: Elephant Robot

- **Overall dimension: 930mm×930mm×980mm**
- **Weight: 32 KG**

1 Type of drive

The Elephant Robot (ER) uses **Four wheel omni-directional Drive** mounted on a custom-made chassis. The calculation for the four-wheel omni drive are as follows:

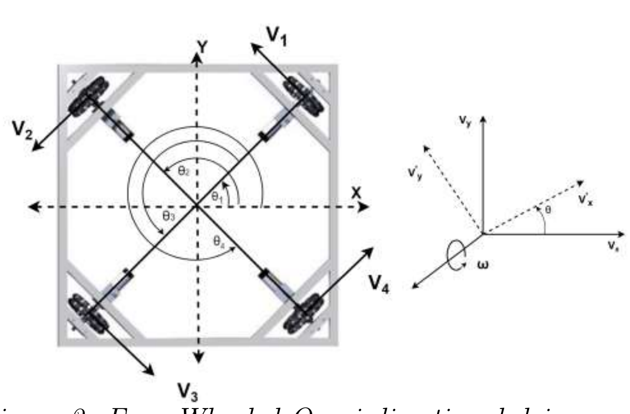

Figure 2: Four Wheeled Omni-directional drive

X-component: $V_x = -\frac{1}{2}\left(\sum_{i=1}^{4} sin\left(\theta + \left(\frac{2i-1}{4}\right)\pi\right)\right) V_i$

Y-component: $V_y = \frac{1}{2}\left(\sum_{i=1}^{4} cos\left(\theta + \left(\frac{(2i-1)}{4}\right)\pi\right)\right) V_i$

Here,i represents the number of wheels in the drive. Solving these equations,the **velocity of each wheel** is obtained as:

$$V_i = -sin\left(\theta + (2i-1)\pi\right) V_x + cos\left(\theta + (2i-1)\pi\right) V_y + R\omega$$

Velocity matrix:

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} = \begin{bmatrix} -sin\left(\theta + \frac{\pi}{4}\right) & cos\left(\theta + \frac{\pi}{4}\right) & R \\ -sin\left(\theta + \frac{3\pi}{4}\right) & cos\left(\theta + \frac{3\pi}{4}\right) & R \\ -sin\left(\theta + \frac{5\pi}{4}\right) & cos\left(\theta + \frac{5\pi}{4}\right) & R \\ -sin\left(\theta + \frac{7\pi}{4}\right) & cos\left(\theta + \frac{7\pi}{4}\right) & R \end{bmatrix} \begin{bmatrix} V_x \\ V_y \\ \omega \end{bmatrix}$$

Here, V_i is the linear velocity of ith wheel in the drive, θ is the angle with respect to the global frame, V_x and V_y are the robot's velocity in the x-axis and y-axis, and ω is the heading angular velocity of the robot.

2 Sensors and actuators

- **IMU: MPU 9250** and **ADXRS453Z** is used for localisation of robot.
- **Ultrasonic Sensor: HC-SR04** are used to avoid collision with obstacles.
- **LIDAR:** TF mini (sensing range:**0.3-12 m**) is used to avoid collisions.
- **IR and Proximity Sensor:** They are used in the ring picking and feeding mechanism to detect the rings.
- **Limit Switch: Two** Limit switches are used in the picking mechanism, which will ensure us whether our gripper has acquired its desired position(exactly above the box).
- **Rotary Encoders: Two** Rotary Encoders of **2500 Pulses Per Revolution** are mounted perpendicular to each other at the bottom for the robot's odometry and **two** on throwing mechanism mechanism
- **Camera: Kinect Xbox 360** and **5MP Raspberry Pi Zero W** Camera is mounted in

front of throwing mechanism in order to detect and find distance of the pole from the ER.

- **Pneumatics actuator: Four** Pneumatic Cylinders are used in elephant robot: **Two** in Ring picking and loading mechanism**(Bore diameter(BD):8mm, Stroke length (SL):100mm)**, **Two** in the ring throwing mechanism with **(BD:40mm, SL:300mm)** and **(BD:32mm, SL:200mm)**.
- **Servo motors: Nine** servo motors used in which **four** (**15 kgfcm**) in ring feeding, **four** (**60 kgfcm**) in ring picking mechanism and **One 60 kgfcm** is used in yaw motion of throwing Mechanism 2.
- **Electric Linear actuator: Two** Linear actuators of stroke length **300mm** and **100mm** are used to vary the angle for ring throwing mechanism 1 and 2 respectively.
- **Drive Motors: Four** DC Planetary Geared (RMCS-2012) Motor (**750 RPM, 39 kgfcm**).
- **Proportional Pressure Regulator:** It is used for regulating pressure in the robot.

3 Picking and loading Mechanism

3.1 Overview

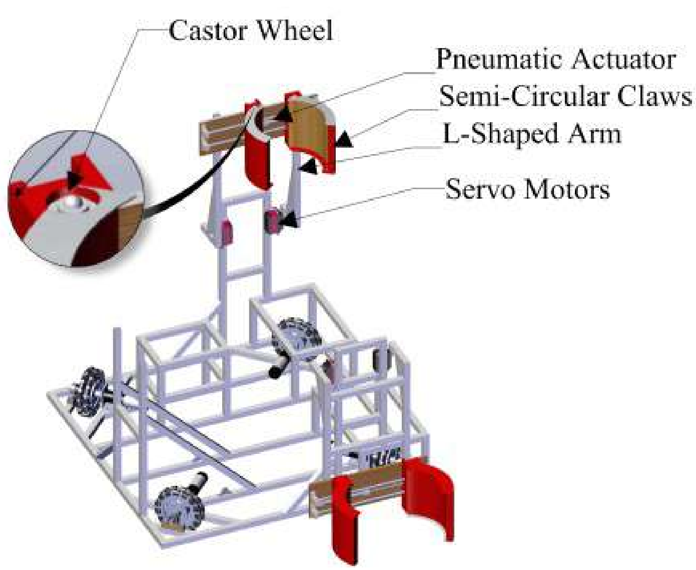

Figure 3: Picking mechanism

The ER consists of **two picking and loading mechanisms** mounted on either side of the bot. It has **two semi-circular claws** with **castor wheels** at the bottom. The loading mechanism consists of a **pair of L-shaped arms** and **two servo motors.**

3.2 Mechanism

The picking and loading mechanism involves a gripper mounted on a **rectangular plywood (375mm x 120mm)**. The gripper has two semi-circular claws, one linearly movable, attached to a **pneumatic actuator (BD : 8 mm; SL: 100 mm)** and the other is fixed. One end of L shaped arm is attached to a wooden plank and another is mounted to servo motors. Two servos are clamped at the **height of (438mm)** from the ground.

3.3 Justification

The claw is 3D printed in semi-circular shape to ensure maximum area of contact with the rings. Foam dusters on fixed claw ensure firm gripping of the rings. Castor wheels are mounted at the bottom surface of both claws to avoid direct contact with the ground while picking. With the help of servo motors L - shaped arms rotates **180°** to attain vertical orientation for the feeding mechanism.

3.4 Task objective

Initially, the ER approaches the ring zone and aligns itself in front of the ring stack. As the pneumatic piston retracts, the gripper claw grips the rings and servo motors rotates the arm to orient the ring stack above the feeding arrangement. The forward stroke of the piston releases the rings into the feeding mechanism.

4 Feeding Mechanism

4.1 Overview

Two feeding mechanisms are being employed and each of which comprises an assembly of the **cylindrical frame**, two pairs of **obstruction plates** , and two **servo motors**.

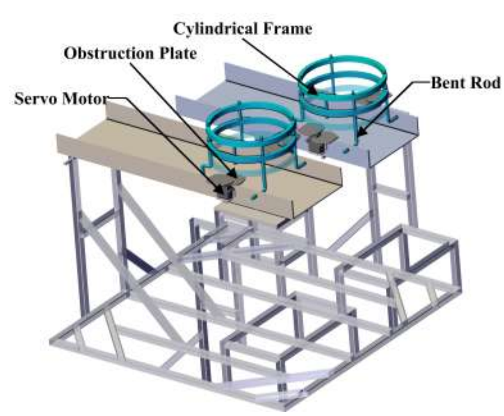

Figure 4: Feeding Mechanism

4.2 Mechanism

The cylindrical frame consists of **horizontal circular support rings(15 mm thickness; 234 mm**

diameter) made of acrylic material placed at a distance of **35 mm** between them and is connected by bent rods. The cylindrical frame is placed above the base channel of the throwing mechanism.**Two pairs of obstruction plates** coupled to servo motors are mounted diametrically opposite with reference to circular support.

4.3 Justification

Cylindrical frame is used to keep the ring stack intact and prevent any misalignment. The bent rods provide a free passage of rings along the base channel. The vertical distance between both plates is maintained so the ring gets fed successively into the throwing channel. **Two feeding arrangements** are mounted, ensuring smooth operation and passage for rings. Servo motors are operated in synchronous motion to ensure no time lag between the two feeding mechanisms.

4.4 Task Objective

After the picking and loading rings from the ring zone, the rings are sequentially fed into the throwing mechanism. The Servo motor drives the two-plate assembly, providing alternate obstruction to the rings. This results in feeding rings in the throwing mechanism one at a time.

5 Throwing Mechanism

5.1 Overview

The throwing mechanism consists of **an arciform hitter**, **a base channel**, **two pneumatic cylinders**, **an electric linear actuator**, **gear and pinion assembly**, and **servo motor**. **Throwing mechanisms - 1 and Throwing mechanism - 2** in combination facilitates the tossing of rings into poles.

5.2 Mechanism

5.2.1 Throwing Mechanism-1:

The aluminum frame constitutes the assembly base with **dimensions (850 mm x 238 mm x 57.29 mm)** to form a base channel. A double-acting **pneumatic cylinder (BD: 40mm; SL: 300mm)** is used for throwing. An arciform hitter is attached to the piston rod of the actuator. The angle-changing mechanism uses an **electric linear actuator(SL:300mm)** to obtain various ring trajectories.

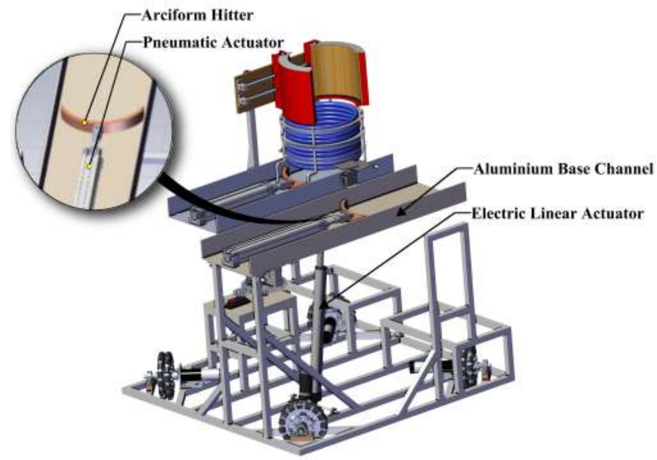

Figure 5: Throwing Mechanism-1

5.2.2 Throwing Mechanism-2:

Throwing mechanism -2 comprises of **an aluminum base channel(695 mm x 238 mm x 61.29 mm)**. An arciform hitter is attached to the **pneumatic piston (BD: 32mm; SL: 200mm)**. Angle changing is done using an **electric linear actuator(SL:100mm)** with the above specifications. The yaw motion of the mechanism is achieved by a **gear pinion** arrangement driven by a servo motor(**60 kgfcm**). The gears are made up of acrylic material and mounted on the raised platform. Power from the servo motor is supplied to the pinion, which drives the throwing assembly mounted on the driven gear.

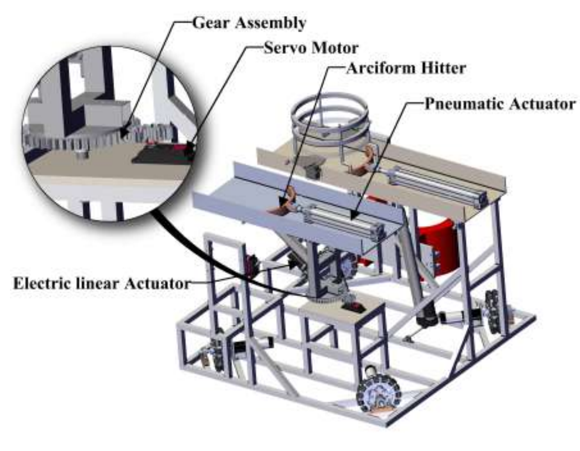

Figure 6: Throwing mechanism-2

5.3 Justification

The arciform hitter is 3D printed and is made of circular arc shape to increase the area of contact with the ring. The forward stroke of the pneumatic piston provides sufficient impulse to drive the ring along the desired path. A quick exhaust valve is used to increase the actuation speed. Angle changing of the mechanism is achieved in two different axis by the combination of yaw and pitch motion for obtaining variable trajectories and targeting different poles.

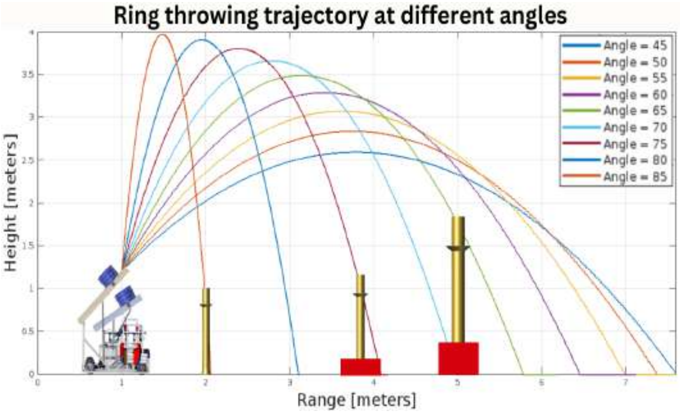

Figure 7: Throwing Mechanism in ER

5.4 Task Objective

After feeding of rings in the throwing channel, the bot aligns itself according to the required position for targeting the desired pole. The pneumatic piston provides impulse force to the rings. Angle changing and yaw motion in throwing mechanisms help to derive variable trajectories.

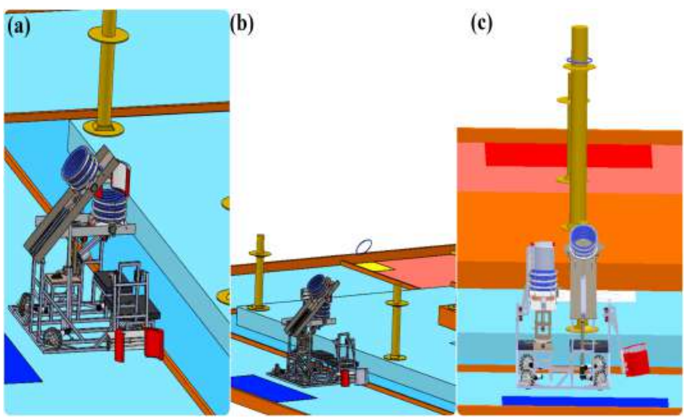

Figure 8: Throwing Mechanism-1

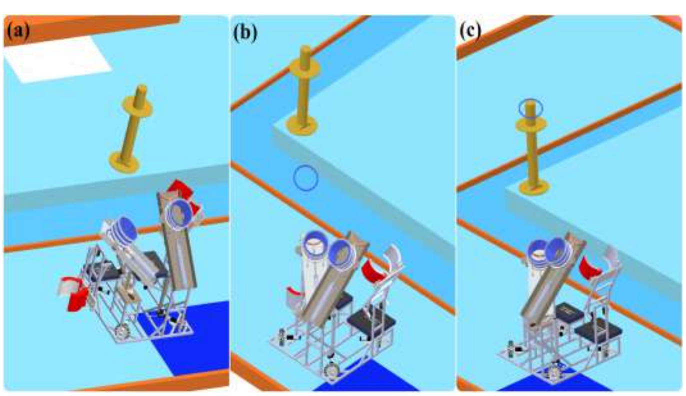

Figure 9: Throwing Mechanism-2

II. Design of Rabbit Robot(RR)

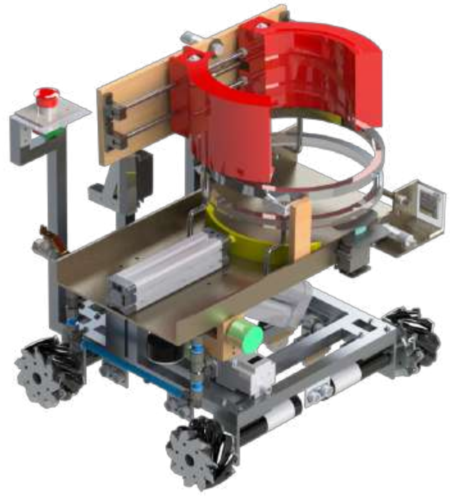

Figure 10: Rabbit Robot

- **Overall dimension: 495mm×420mm×490mm**
- **Weight: 16 KG**

1 Type of drive

The Rabbit Robot is driven by **Four Wheeled Mecanum Drive** mounted on a custom-made chassis.

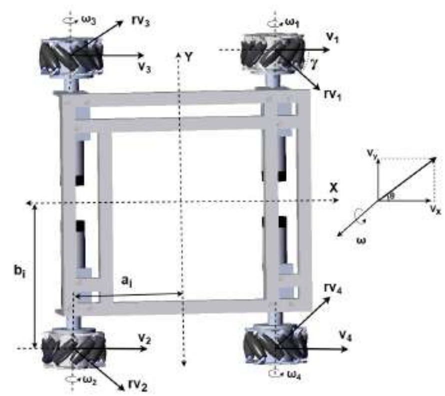

Figure 11: Four Wheeled Mecanum drive

X-component: $V_x = V_i + rV_i cos(\gamma_i) = V_x – b_i\omega$
Y-component: $V_y = rV_i sin(\gamma_i) = V_y + a_i\omega$
Here,i represents the number of wheels in the drive. Solving these equations,the **velocity of each wheel** is obtained as:

$$V_i = V_x – b_i\omega – \left(V_y + \left(\frac{a_i\omega}{tan(\gamma_i)}\right)\right)$$

Velocity matrix:

$$\begin{bmatrix} V_1 \\ V_2 \\ V_3 \\ V_4 \end{bmatrix} = \begin{bmatrix} 1 & -1 & -(a+b) \\ 1 & 1 & (a+b) \\ 1 & 1 & -(a+b) \\ 1 & -1 & (a+b) \end{bmatrix} \begin{bmatrix} V_x \\ V_y \\ w \end{bmatrix}$$

Where V_i is the linear velocity vector of the ith wheel, a_i and b_i are the distance between the centre of the robot and the centre of the ith wheel wrt x-axis and y-axis and γ_i is the angle between linear velocity and the perpendicular vector of roller velocity.

2 Actuators and sensors

- **IMU, Ultrasonic Sensor, LIDAR, IR Proximity, Limit Switch, Rotary Encoders, Cameras** (Same as mentioned in sensors of Elephant robot).
- **Pneumatics Cylinders: Two** Pneumatics Cylinders are used in Ring picking and loading (**BD:8mm, SL:100mm**),Ring throwing (**BD:40mm, SL:125mm**).
- **Servo motor: Four** servo motors used in robot which **Two** (**15 kgfcm**) in ring feeding, **Two** (**60 kgfcm**) in ring picking mechanism.
- **Drive Motors: Four** DC Planetary Geared (RMCS-2012) Motor (**750 RPM, 39 kgfcm**).
- **Linear actuator:**Linear actuator of stroke length **100mm** is used to vary the angle for ring throwing.

3 Picking and loading mechanism

The picking and loading mechanism present in RR is analogous to ER. It contains one picking and loading mechanism. The dimensions of the components consist of a base channel **(375 mm x 118 mm)**, L shaped link having a length **(170 mm)**, servo motor mounted at a height **(242 mm)** from the ground (Refer to figure(12)).

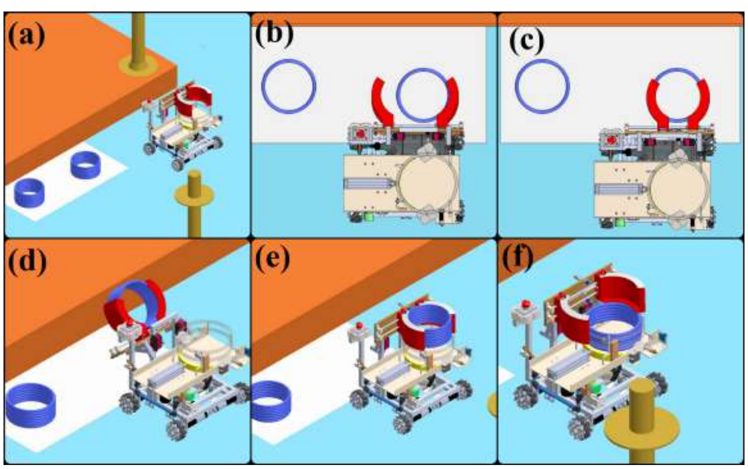

Figure 12: Picking mechanism of RR

4 Feeding Mechanism

The feeding mechanism in RR is the same as that of ER mentioned above. It uses only one feeding mechanism.

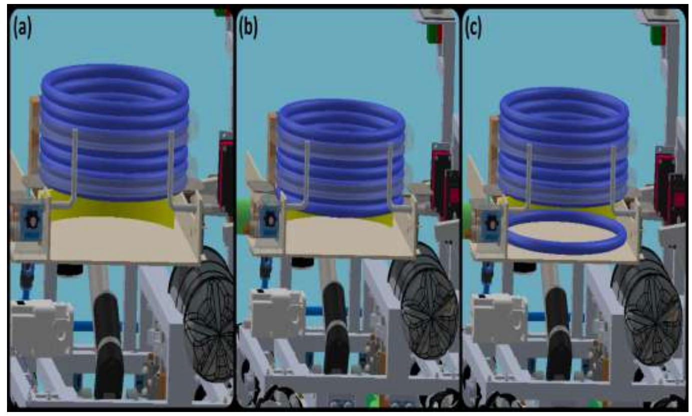

Figure 13: Feeding mechanism

5 Throwing mechanism

The throwing mechanism of RR is analogous to the throwing mechanism 1 in ER. The bot utilizes a double-acting pneumatic cylinder **(Bore diameter: 40 mm, stroke length: 125 mm)** for hitting action. An electric linear actuator **(SL: 100 mm)** is used to change angle of the throwing assembly for thee purpose of tossing rings in different poles.

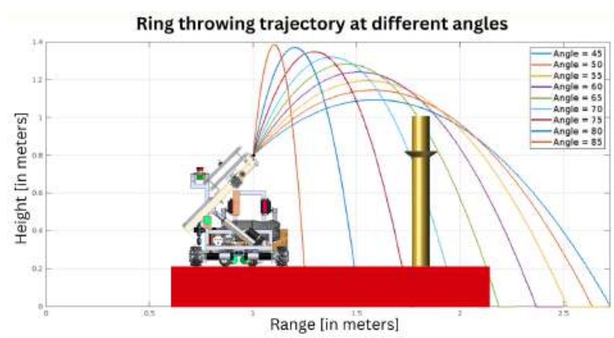

Figure 14: Throwing Mechanism in RR

6 Justifications

6.1 Jumping Mechanism in RR

The robots are designed to fulfill the game requirements without the assistance of jumping mechanism. The throwing mechanism in RR can efficiently toss rings into poles without climbing the Angkor center area. Additionally, holonomic drive wheels might lose contact with the ground surface, subsequently reducing the bot's mobility. Considering the above factors, the jumping mechanism has not been added in RR.

6.2 Passing Mechanism in ER and RR

According to the design, separate picking and loading mechanisms are mounted in ER and RR. In addition, the number of rings available to both the robots in the ring zones is the same, due to which both the robots can function independently to accomplish the required task. This eliminates the need to add a passing mechanism in both ER and RR.