Robocon-2023 Design Document

IIT Jodhpur

Introduction

Various mechanisms and strategies used by IIT Jodhpur have been described in this design document.

Our team subdivided the problem statements into the following important mechanisms:

Elephant Robot

- Effectively shooting a ring on poles
- Picking and piling the rings

Rabbit Robot

- Effectively shooting a ring on poles
- Picking and piling the rings

Game Plan / Solution Ideas

In the beginning, both Elephant Robot and Rabbit Robot are be stationed in the start zone, as mentioned in the game rules.

As soon as the time starts, the Elephant Robot (ER) will move to the ring zone and pick up all the rings. Then it will move to a suitable location to aim efficiently for the maximum number of poles. If the first few shots miss, the aim will be adjusted manually during the test phase. Further shots will be taken with the updated settings until the time runs out.

Meanwhile, the Rabbit Robot (RR) moves towards the inner ring zone. It will move to a region suitable for shooting. ER will focus on whatever poles are in the vicinity, and RR will focus on reclaiming any pole occupied by the enemy. RR can also supply any missed ring to the ER if all the outer zone rings are exhausted. Considering the amount of time the opponent takes to shoot on one pole, we can adjust the priority of the target poles. ER can store multiple rings and shoot them in rapid succession, and RR can be used to shoot one ring at a time with more accuracy.

Elephant Robot

Fig. 1. ER Isometric View

A. *Material*

Application	Material	Justification
Shooting	Aluminum	To prevent vibrations while shooting the rings.
Chassis	Aluminium	Lightweight as well with good strength/weight ratio.
Motor Brackets	Aluminum Sheet	Ease in bending as per the required form.
Bearings	Stainless Steel	Market standard material for ball-bearings.
Flywheels	Nylon,TPR Rubber	Provides high friction and good moment of Inertia to the flywheel
Gears	Carbon steel	Market-Standard material for Gears.

B. *Drive Train*

Elephant Robot adheres to Four-Wheel Mecanum drive because a Four-Wheel drive provides better power division than a Three-Wheel drive. The Three-wheel holonomic drive will have 33% more load than that of Four-Wheel Mecanum drive. AI is being used to align the robot accurately with the pole to prevent ring deviation in the horizontal direction while shooting.

C. Mechanism for Ring Pick Up

The role of the picking mechanism is to take the rings and put them in the storage area in a stack. The robot achieves this with the help of a pair of cylindrical jaws. The jaws will be staged on an aluminum plate that can rotate in its place with the help of a motor. They will be connected to the plate via another motor to facilitate the rotatory movement required to pick up the rings. First, the jaws open and surround the rings. The jaws will close, and the aluminum plate will rotate so that the jaws hover over the loading region and store the rings until they are ready to be shot.

D. Ring Throwing Mechanism

The rings are now standing in the storage region, and the motor-controlled flaps situated near the ring will push it in a pinball fashion into the shooting area. The conveyor belts provide enough traction to shoot the ring. Only two of the four wheels are powered by motors in a measured manner so that the ring can hit the target. The two motors rotate at the same RPM and torque using motor drivers to prevent the ring from getting displaced due to unbalanced forces. Moreover, the shooting area containing the belts and the wheels is hinged to adjust the shooting angle appropriately. There are two poles near the corner of the shooting area with pulleys attached on their top. These corners are connected to a motor through wires going over the pulleys. This motor will control the angle of projection.

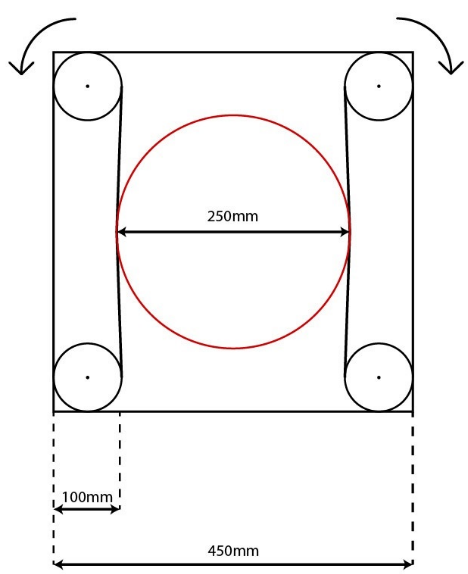
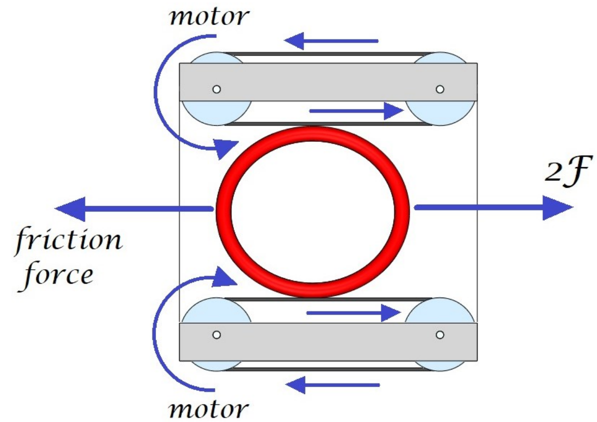


Fig. 2. ER shooting (Top View)

Calculations

The ring is thrown by a conveyor-belt mechanism. The diagram of above mechanism is shown below. We need to determine the velocity at the time of the projection. The equations for the same are derived below.



From Newton's second law

$$F_{net} = ma$$

$$2F - f = ma$$

F is the friction-force between ring and belt. f is the friction force between ring and launching platform.

$$2\mu_1 P - \mu_2 mg = ma$$

μ_1 and μ_2 are the coefficient of static friction between ring-belt and ring-launching platform. We know that form Newton's third equation of motion,

$$v^2 = u^2 + 2aS$$

. Assuming the ring has negligible velocity when it comes in contact with the belt. We get,

$$2\mu_1 P - \mu_2 mg = m\frac{v^2}{2S}$$

S is the length of the launching platform.
The ring is slightly deformed by certain amount in radial direction, as it comes in contact with the rollers of mechanism. Let that radial deformation be δ. This deformation can be expressed in terms of external load, geometrical and material properties of the ring.

$$\delta = \frac{0.149PR^3}{EI}$$

. Here, P is external radial load, R radius of ring, E is Young's modulus of elasticity.I is moment of inertia of ring cross-section, which is $\frac{\pi R^4}{4}$.

NOTE: The above formula is valid under the assumption that the deflection theory for straight beams is applicable.

From the above equation we can determine P and then the velocity of projection.

E. *Actuators Integrated*

- IG 52 Motor for drive train
- IG 32 Motor for flywheel
- NEMA 17 (Stepper) for conveyor

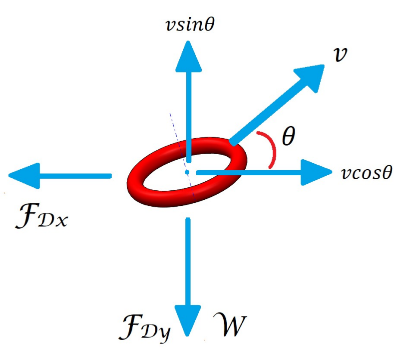
F. *Sensors Integrated*

- Intel RealSense D455 Depth Camera
- Encoded motors

I. Ring Trajectory

When the robot launches the ring, it travels in the air to reach the desired pole. The forces that act on it during the flight are the drag forces and its weight due to gravity. Using Newton's second law, we can relate the x and y positions of the ring with respect to time. The above two equations can be solved to determine the ring's path.
NOTE: When the ring is in flight, we assume it is not spinning about its axis.

A. *Force Analysis in x - direction*



1.) The drag force in x-direction can be written as:

$$F_{Dx} = ma_x$$

$$\frac{1}{2}C_{Dx}\rho_{air}A_xV_x^2 = m\frac{\mathrm{d}^2x}{\mathrm{d}t^2}$$

.

$$kV_x^2 = \frac{\mathrm{d}^2x}{\mathrm{d}t^2}$$

Here k is a constant= $\frac{1}{2m}C_{Dx}\rho_{air}A_xV_x^2$ and V_x=$\frac{\mathrm{d}x}{\mathrm{d}t}$ = v $\cos\theta$. C_{Dx} is the drag coefficient. On further simplification, we get

$$\frac{\mathrm{d}^2x}{\mathrm{d}t^2} - k(\frac{\mathrm{d}x}{\mathrm{d}t})^2 = 0$$

.

2.) The drag force in y-direction can be written as:

$$F_{Dy} + mg = ma_y$$

$$\frac{1}{2}C_{Dy}\rho_{air}A_yV_y^2 + mg = m\frac{\mathrm{d}^2y}{\mathrm{d}t^2}$$

.

$$kV_y^2 = \frac{\mathrm{d}^2y}{\mathrm{d}t^2}$$

Here c is a constant= $\frac{1}{2m}C_{Dy}\rho_{air}A_yV_y^2$ and V_y=$\frac{\mathrm{d}y}{\mathrm{d}t}$ = vsin θ. C_{Dy} is drag coefficient.On further simplification, we get

$$\frac{\mathrm{d}^2y}{\mathrm{d}t^2} - c(\frac{\mathrm{d}y}{\mathrm{d}t})^2 - g = 0$$

3.) The trajectories are

$$x(t) = k_2 - \ln\frac{k_1 + kt}{k}$$

$$y(t) = \frac{1}{c}\ln(\sec(\sqrt{gc}t + c_1) + c_2$$

Rabbit Robot

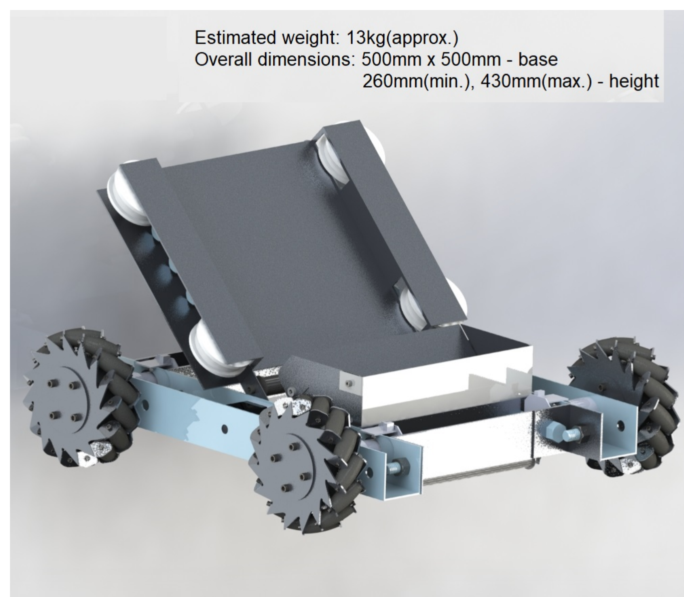


Fig. 3. RR Isometric view

B. *Material*

Application	Material	Justification
Chassis	Aluminum	Lightweight with good strength/weight ratio
Rollers and Attachments	Aluminium	Same as Chassis
Pulley	Mild Steel	Mild steel used in commercially available pulleys
Belts	Polyurethane	Chosen for strength and maintains original shape

C. *Drive Train*

Rabbit Robot adheres to Four-Wheel Mecanum drive because a Four-Wheel drive provides better power division than a Three-Wheel drive. The Three-wheel holonomic drive will have 33% more load than the Four-Wheel Mecanum drive. AI is used to align the robot accurately with the pole to prevent the ring from deviating in the horizontal direction while shooting.

D. *Actuators Integrated*

- Linear Electric Actuators
  1) NEMA 17 (Stepper) for conveyor
  2) IG 52 motor for drive train
  3) IG 32 motor for linear actuators

E. *Sensors Integrated*

- Intel RealSense Depth Camera
- Encoders for localisation

F. *Mechanism for Ring Pick Up and Storage*

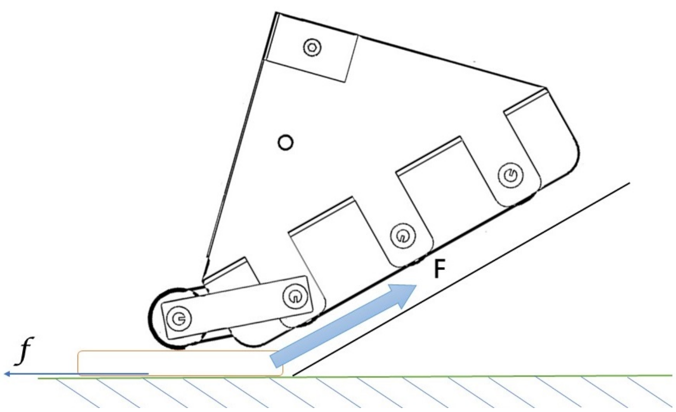
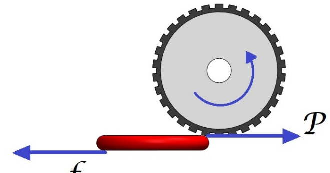


Fig. 4. RR Disk Picking Mechanism

- The Rabbit Robot's picking mechanism consists of rollers and a conveyor belt. The rotating roller is connected at the end of the conveyor belt. It falls on the ground due to the gravitational force acting on it.
- As the ring comes under the roller, it applies traction as it falls on the ring, and as it is rotating, it gives the ring a horizontal velocity and slightly curves the ring upwards. This enables the conveyor belt to pick it up.
- A combination makes the conveyor belt of two belts controlled by motors and carries the ring upwards. The sides provide the required traction.
- It is to be noted that the length between the belts is slightly less than the outer diameter of the ring, thus providing the required traction.
- The rings carried to the top by the conveyor belt are then dropped into the storage container.

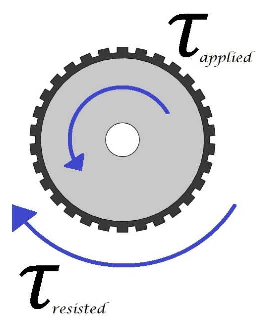
Calculations

Let m and M be mass of ring and roller respectively, g as acceleration due to gravity and mu as coefficient of static friction between ring and ground. Let P be the force responsible to move the ring by a given acceleration a.



$$P - \mu(m+M)g = ma$$

Let r be the radius of roller, α be the angular acceleration, $\tau_{applied}$ be the applied motor torque and τ_{resist} be the resisting motor torque.



$$\Sigma T = I\alpha$$
$$\tau_{applied} - \tau_{resist} = I\alpha$$
$$\tau_{resist} = Pr$$
$$\tau_{applied} - Pr = I\alpha$$
$$\tau_{applied} - \mu(m+M)gr = I\alpha$$

The relationship between the motor torque $\tau_{applied}$ and current A is shown below, where k and c are constants

$$\tau_{applied} = Ak - c$$

G. *Ring Throwing Mechanism*

The ring, picked up by the rollers and metal plate, is then allowed to fall onto the throwing mechanism at the end of the metal plate. The throwing mechanism consists of an array of rollers whose angle can be adjusted as the rollers rotate along a horizontal axis. A motor and gears control each roller's rotation speed in the array of rollers. Due to the variable speed of the rollers, the ring can be thrown from different distances from the pole. The angle of the array is changed by pulleys and a motor. A rope connecting the top end of the array is pulled through the pulley. This assembly is controlled by a motor. The angle of the array is decreased as the motor releases the rope.