Robocon 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:

- Effectively shooting a stationary target (Hitter-R1 and Seeker-R1)
- Passing balls between robots (R1 and R2)
- Defending the robot from a moving projectile (Seeker-R2)
- Picking and piling the discs (Seeker-R2)

Game Plan / Solution Ideas

Game begins by R1 and R2 robots, taking their positions specified in the rules. From the beginning itself, R1 can take aim for its first shot at the Lagori pile. If the first shot is unsuccessful, aim can be adjusted by manual-control/automated fine-tuning during test phase and further shots will be taken till balls/round-time runs out.

In the second phase, R2 enters the Lagori Area and uses it's Disc-Picking Mechanism to grab the displaced discs one-by-one, i.e. R2 returns to the Lagori stand to place the disc every time. Multiple discs can also be piled up if needed. Reducing stationary time is our prime focus alongside high mobility speed. This is to ensure that ball-on-head (BH) isn't knocked off as well as maximum possible discs are picked. Assuming that opponent's R1 takes time t to aim and shoot BH with reasonable accuracy, we try to make stationary time smaller than t. Higher mobility ensures that opponent R1 does not have sufficient non-cooperative target tracking capabilities. In Round-2, Hitter R1 needs to shoot at opponent Seeker-R2's BH. For this, we consistently track the movement of opponent Seeker-R2 and target the stationary time when it stops to either pick a disc or place the disc, during this period, we will be making micro-adjustments to our aim and shoot.

R2 is also controlled to strategically minimise the time where R1 does not have any balls loaded. We have the capacity to store and transfer multiple balls in both R1 and R2 for this purpose.

Robot R1

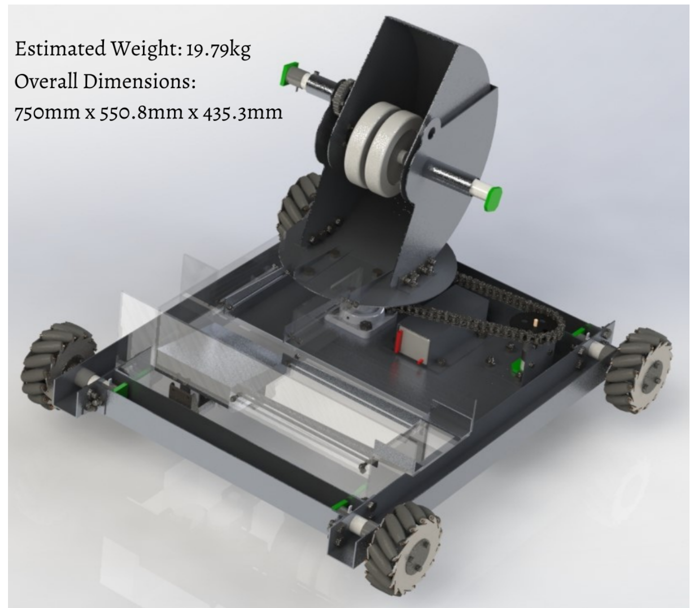

Fig. 1. R1 Isometric View

A. *Material*

Application	Material	Justification
Shooting	Aluminum	To avoid bending caused by recoil from the ball.
Chassis	Aluminium	Lightweight as well with good strength/weight ratio.
Ball Receiving Tray	Acrylic sheet	Easily workable and transparent plastic
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*

R1 Robot adheres to Four-Wheel Mecanum drive. Although the choice is not that significant because of minimal movements, it helps in omni-directionality and reduces the need for power on each wheel. Ex: The Three-wheel holonomic drive will have 33% more load than that of Four-Wheel Mecanum drive.

C. *Shooting mechanism (Seeker R1)*

While shooting, there are two parameters which should be adjusted, i.e Angle and Velocity. To have control over both, our team decided to go for an adjustable fly-hood with flywheel mechanism.

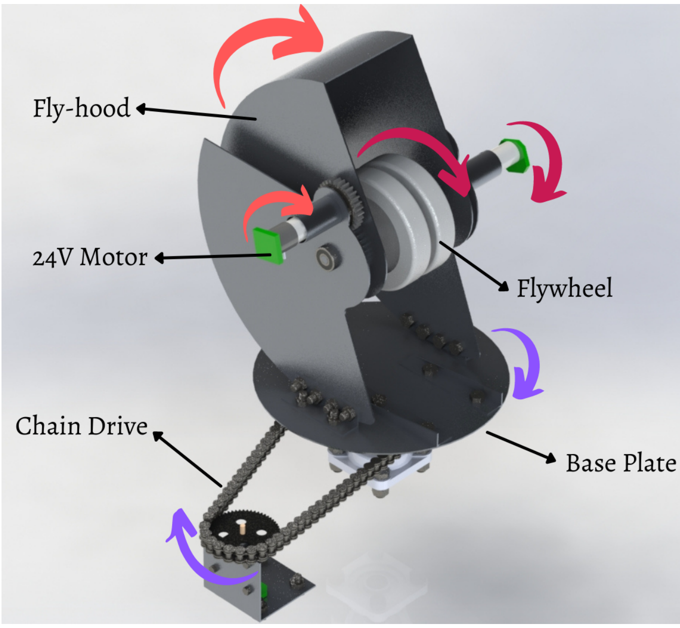

Fig. 2. R1 Shooting

The adjustable hood is connected to a motor-controlled gear mechanism. The motor changes the projectile's angle of inclination (pitch). The sprocket at the bottom of the shooting mechanism adjusts the projectile's angle with respect to ground plane (yaw).
To adjust the velocity, we control the RPM of the motor connected to flywheel axle.
Servo/Encoded motors are used in R1-Shooter with PID control to adjust velocity and angle to a specific value with low transverse time and low steady state error.

Calculations

Let the moment of inertia of fixed flywheel be I_f and its radius be R_f. Let the Moment of inertia of the flywheel on hood be I_h and its radius be R_h. The ball provided by the organiser have fixed mass $M = 200g$ and $R = 70mm$. Here V_{fi} ,ω_{fi} ,R_i and R_h are the independent variables and the rest are dependant. Assuming no-slip condition we have:-

$$\omega_h R_h = V_{fi} + \omega_{fi} R_{fi}$$

$$\omega_f R_f = V_{fi} - \omega_{fi} R_{fi}$$

. Consider the radius compression while shooting as $\Delta = R_i - R_f$. By geometry:

$$\Delta = \frac{2R_h - t}{4}$$

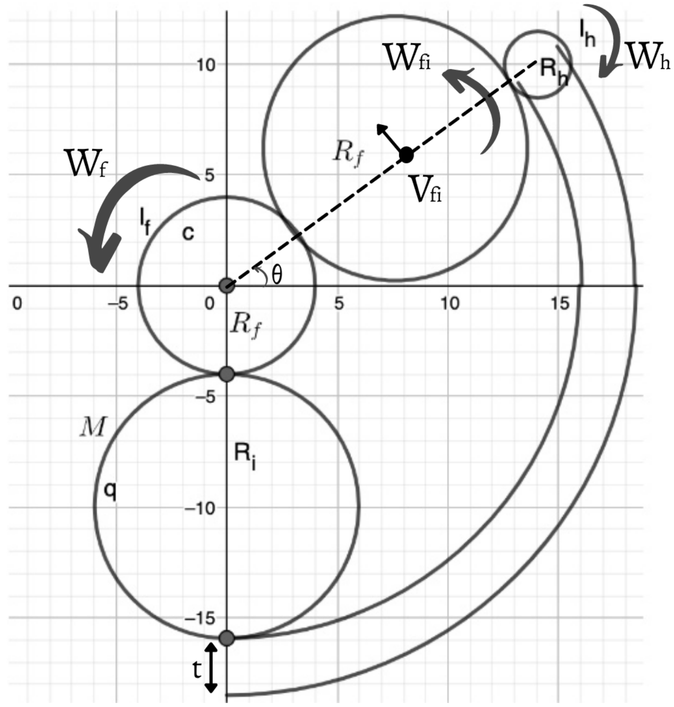

Fig. 3. Free Body Diagram of R1 Shooter

. Ideally, R_i must be slightly less than R to accommodate the balls properly, with slight tolerance for the provided radius of balls. Hence:

$$R_i = R - \delta$$

. Where δ can be around 2-3 % of R. The difference between the energy of ball in final state and initial state will be:

$$E = \frac{1}{2} I \omega_{fi}^2 + \frac{1}{2} M V_{fi}^2 + Mg(R_f + R_i) + Mg(R_f + R_{fi}) sin\theta + C.E. \tag{1}$$

Let T be the time taken by ball to reach the shooter end of fly-hood. From no-slip condition:

$$\frac{1}{T} = \frac{\omega_f R_f}{(R_f + R_i)(\frac{\pi}{2} + \theta)}$$

We assume that the overall energy difference is provided by the fixed flywheel. Hence by the definition of

$$P = \frac{E}{T}$$

The maximum torque which motor needs to provide is:

$$\tau = Mg(R_f + R_{fi}) = 0.2(0.07 + 0.0625) = 0.0265Nm$$

D. *Actuators Integrated*

- Linear electric actuator 2 Inches stroke length
- IG 52 Motor for drive train
- IG 32 Motor for flywheel/flyhood

E. *Sensors Integrated*

- Intel RealSense R200 Depth Camera
- Encoded motors

F. *Ball receiving mechanism (Hitter R1)*

Robot R2 transfers the ball at an elevation of 140 mm from the ground. The ball is released on the receiving tray and rolls through the inclined racks because of gravity. Once the ball reaches the end of the rack, the linear actuator pushes it down into another inclined rack towards shooting mechanism. The base plate can rotate itself to load the ball into the shooting mechanism.

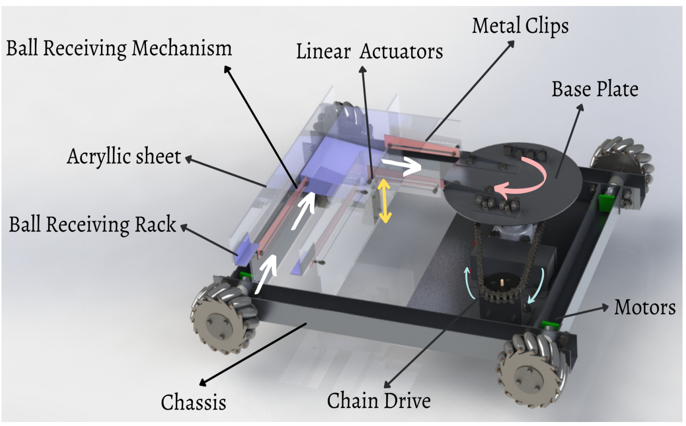

Fig. 4. R1 Ball Receiving

G. *Lagori Breaking Strategy*

Lagori Pile is located 3.5 meters far from R1SZ zone. The diameter of the ball is small when compared to total width of Lagori Pile. Therefore, the centre of pile (bottom 3rd disc at a height of 700 mm) is targeted to ensure maximum hit rate. The angle of the shooting fly-hood is chosen in such a manner that the direction of velocity of the ball while hitting the pile is pointing towards the ground which ensures that the lower disks are displaced. The optimal velocity of the ball while hitting the lagori pile is set such that it is high enough to provide enough momentum while hitting and at the same time, velocity must be limited to that disks do not scatter far away to save disc piling time in round-2

H. *Hitter/Targeting strategy*

To target the ball on the head of the opponent's Seeker R2, we use a DETR AI model for object detection. The trained DETR model detects images of soccer ball and based on the obtained coordinates, we use a PID controller to sync the shooting angle of hood to target BH of opposition Seeker R2.

Arrangements have been made so that every component can work in both manual mode and arrangements can be made to operate in automatic mode.

Robot R2

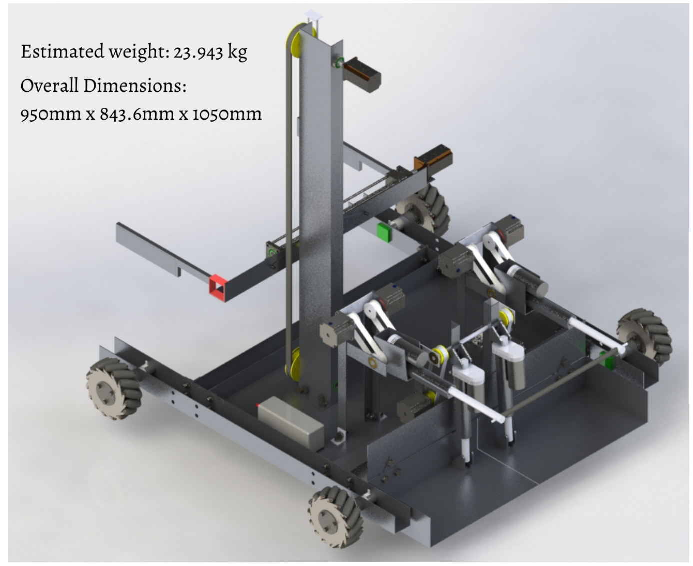

Fig. 5. R2 Isometric View

I. *Material*

Application	Material	Justification
Chassis	Aluminum	Lightweight with good strength/weight ratio
Arms and Extensions	Aluminium	Same as Chassis
Pulley	Mild Steel	Mild steel used in commercially available pulleys
Belt Pulley	Polyurethane	Chosen for strength and maintains original shape
Disk arm gripper	Hard Rubber	Provides high coefficient of friction and durability against friction

J. *Drive Train*

R2 Robot adheres to Four-Wheel Mecanum drive. This drive train is omni-directional and puts less load on each wheel compared to a Three-Wheel holonomic drive. R2 needs to do quick movements to minimise the chances of getting hit by the opponent robot. Design choices here are similar to R1.

K. *Actuators Integrated*

- Linear Electric Actuators

1) 100mm Stroke Electric Linear Actuators
2) 200mm Stroke Electric Linear Actuators
3) IG 52 motor for drive train
4) IG 32 motor for linear actuators

L. *Sensors Integrated*

- Intel RealSense Depth Camera
- IMU Sensor
- Encoders for localisation and PID control

M. *Lagori Piling mechanism (Seeker R2)*

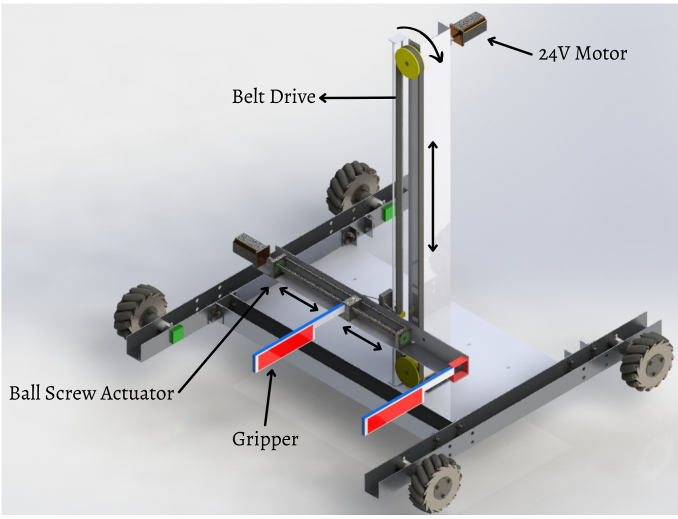

Fig. 6. R2 Disk Picking Mechanism

- R2 is designed such that it can approach discs individually as well as pile them up and use the installed gripping mechanism which comprises two jaws to grasp the disc by tightening in between them.
- The approaching order for this task will give priority to the biggest disc that is available on the field (the ones on the base don't count in this consideration) and the same will be approached foremost.
- A sequential fork-lifting mechanism then takes the disc up and approaches the Lagori Pile.
- The picked disc is delivered onto the base. There is a vacancy of 620mm at front side of R2-Seeker, so that it envelops the base facilitating the delivery of the disc over it.
- Procedure repeats for the remaining discs as well, except for last two discs, where priority is reversed and disks are piled on R2 itself. This is done to facilitate an ascending stack of discs on the base (the arrangement is introduced due to height constraints on fork-lift).
- The fork-lifting mechanism consists of a sprocket-chain system in which there's a motor in the top altitude of the forklift mechanism that will drive the attached chain, thus initiating gears in motion and providing vertical linear motion to the lift that can be controlled by changing the spin of the motor shaft.

Calculations

Let M be mass of disk, g' as effective acceleration and f as frictional force between jaws and disc.

$$Mg' = 2f$$

μ_f is the static coefficient of friction and T is compressive force on disc.

$$f = \mu_f T$$

$$T = \frac{Mg'}{2\mu_f}$$

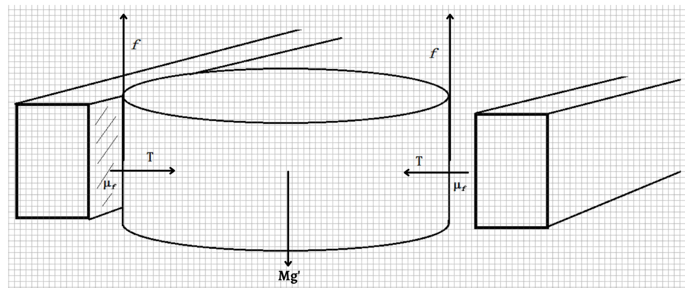

Fig. 7. R2 Disk Picking Free Body Diagram

Let a be the acceleration of disc-lifting system, τ be the required motor torque and *lead* be the displacement of ball screw per unit rotation.

$$\tau = T * lead$$

$$\tau = \left(\frac{Mg'}{2\mu_f}\right) * lead$$

$$\tau = \left(\frac{M(g+a)}{2\mu_f}\right) * lead$$

Consider g = 9.81 m/s^2, M = 0.7306 kg and at extreme situations, let a = 2 - 2.5m/s^2 and $\mu_f = 0.8$. Inserting the above values, we get:

$$\tau = 11.24 kg.cm$$

N. *Ball passing mechanism (Hitter R2)*

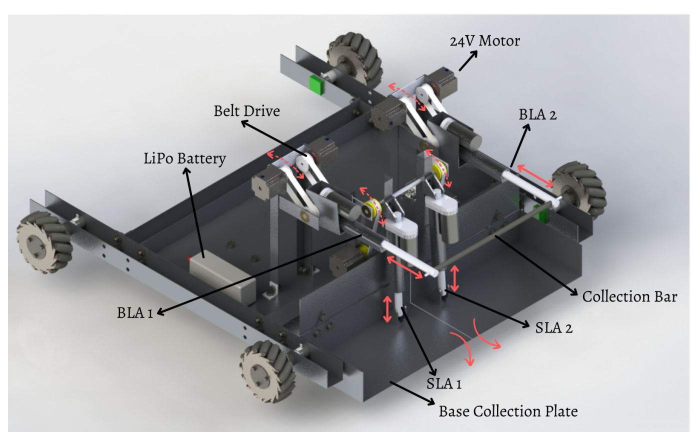

Fig. 8. Ball picking mechanism

- R2's ball-picking mechanism will first approach the ball rack at the beginning of game and extend it's linear actuators (BLA1 and BLA2) containing the foam rod (FR) in between which will be used to demount the balls, present on the rack using the oscillatory (back and forth) motion of linear actuator that can also rotate about the axis pointed in the figure.
- The de-mounted balls fall on the base-collector plates, which is a 2-part type flap system, controlled by the linear actuators (SLA1 and SLA2) and connected using brackets, where all the balls are collected at same time. We report the radius of ball (R), depth of ball-pit (h) and diameter of ball-pit (B) below:

R=140 mm, h=30mm, B=100mm

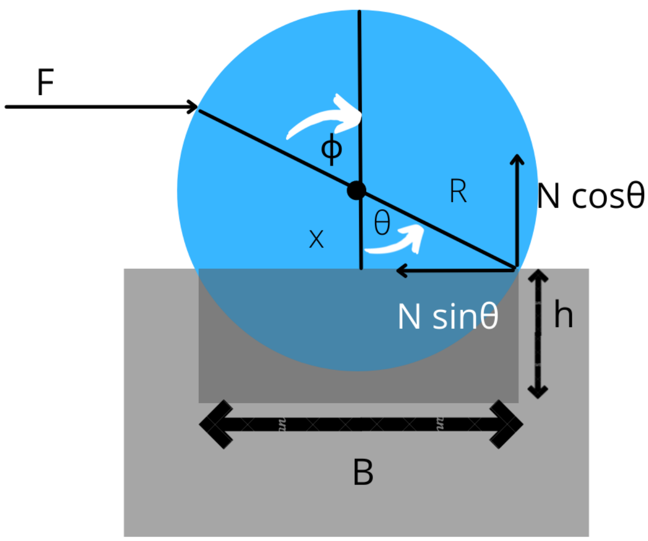

Fig. 9. R2 Ball Picking Free Body Diagram

Furthermore, we calculate the height of C.O.M. for ball above the top of rack (x) as:

$$x = R\cos\theta \tag{2}$$

From the above information, we calculate the minimum force (F) required to just topple the ball at contact point, as:

$$N\cos\theta = Mg \tag{3}$$

$$N\sin\theta = F \tag{4}$$

Therefore, the final condition comes out to be:

$$|F(x + R\cos\phi)| \geq Mg(B/2) \tag{5}$$

- Once the balls are collected, the base-plate collector system is lifted at an angle upto the height of 160 mm(approx.), which is delivery height of balls to R1 ball-receiving mechanism.
- Delivery is done by pushing these flaps (a.k.a base-collector plates) using the linear actuators (SLA1 and SLA2), which open like doors and help to deliver balls at the receiving part of R1 robot.

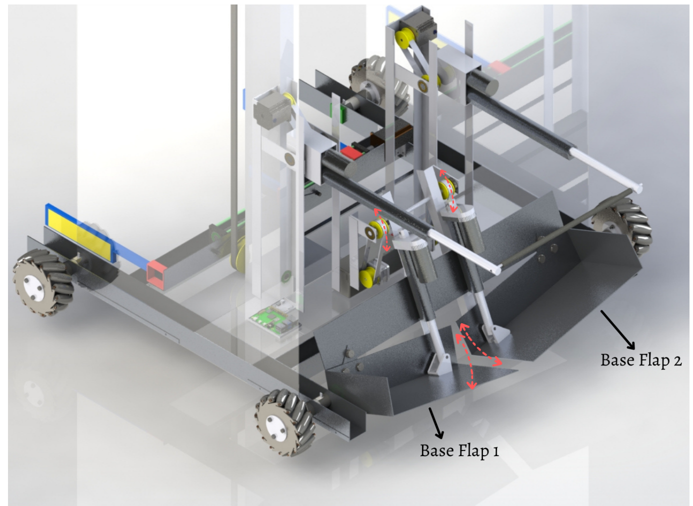

Fig. 10. R2 Opening Flaps