Design Details Documentation - ROBOCON 2022

Sardar Vallabhbhai National Institute of Technology, Surat

I. Design of Robot(R1)

R1 - Robot

- **Overall dimension: 818mm×755mm×850mm**
- **Weight: 22 kg**

1 Type of drive

The R1- Robot uses a **Three Wheeled Omni-directional Drive** mounted on a custom-made chassis. Calculations for the three wheeled Omni-directional drive are as follows:

$$\vec{v} = \vec{\omega} \times \vec{r}$$

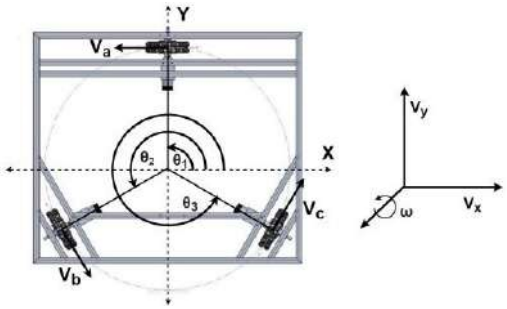


Figure 1: Three Wheeled Omni-directional drive

$\vec{v}$ and $\vec{\omega}$ can be resolved in X and Y directions [Figure 1].

X-component: $v_x + \omega r sin\theta_i = v_i cos\theta_i - v_{ir} sin\theta_i$

Y-component: $v_y + \omega r sin\theta_i = v_i sin\theta_i + v_{ir} cos\theta_i$

Here, v_i and θ_i represents velocity and angle of i^{th} wheel in the drive. Solving these equations, the **velocity of each wheel** is obtained as:

$$v_i = v_x cos\theta_i + v_y sin\theta_i + \omega r$$

For three Wheeled Omni-directional drive the equations are:

$$V = \begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} = \begin{bmatrix} cos\theta_1 & sin\theta_1 & r \\ cos\theta_2 & sin\theta_2 & r \\ cos\theta_3 & sin\theta_3 & r \end{bmatrix} \times \begin{bmatrix} v_x \\ v_y \\ \omega \end{bmatrix}$$

2 Actuators and sensors integrated

- **Mini Planetary Motor with inbuilt Encoder: Three** Mini Planetary motors of **600 rpm** are used to drive R1 robot using encoder's **(1000 PPR)** velocity feedback.
- **Rotary Encoders:** Rotary Encoders of **1000 PPR** are mounted perpendicular to each other for finding distance travelled by robot in X and Y axis to localize it.
- **Johnson DC Motor**: **One** Johnson DC Motor is used in ball storing mechanism.
- **Stepper Motor**: **One** Stepper Motor **(NEMA 10.1 kgcm)** is used in angle adjustment of ball throwing mechanism of R1.
- **RS-775 DC Motor: One** RS-775 DC Motor is used in ball throwing mechanism of R1.
- **IMU**: **MPU 6050 IMU** sensor is used to localize the robot.
- **Pneumatic Cylinder: One** Pneumatic Cylinder **(Bore Diameter: 16mm; Stroke Length: 100mm)** is used in ball feeding mechanism.
- **Camera**: **5MP Raspberry Pi Zero W** Camera Module is used in R1.

3 Brief description of Lagori breaking(Seeker R1)

A. **Overview**

The throwing mechanism is a belt driven flywheel coupled with high rpm dc motor. Trajectory of the ball is controlled by an angle adjustment mechanism.

B. **Mechanism**

- **Throwing Mechanism:**

The flywheel **(Diameter: 100mm)** is mounted on shaft which is driven by RS 775 DC motor. Flange bearing is used at both the end of shaft to provide

smooth rotation of flywheel. The power is transmitted from motor to the shaft with the help of timing belt and pulley. Parallel support for the curved frame is constructed of composite. The flexible plywood of **180mm** radius is mounted concentrically with a flywheel to create passage for ball which also supports the angle adjustment mechanism.

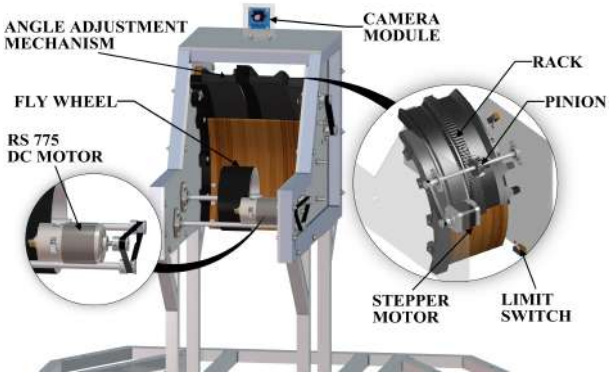


Figure 2: Throwing and Angle adjustment Mechanism

- **Angle adjustment mechanism:**

The angle adjustment mechanism uses a circular rack and pinion arrangement coupled with a stepper motor. The motor is attached to the ball throwing frame and belt drive is used to transmit power. The circular rack rests on a curved slider that slides on a parallel guide [Figure 2].

C. **Justification**

The distance between the outer surface of the flywheel and the plywood is less than the diameter of the ball throughout the path thus the ball gets compressed by nearly **10mm** when it is fed into the throwing mechanism. As a result, the flywheel and ball remain in **continuous contact** throughout the curved path, so the ball ejects with high velocity. The angle is adjusted by an angle adjustment mechanism to achieve different ranges of motion. The motor drives the pinion, which moves the rack, back and forth, changing the trajectory followed by the ball while escaping from the throwing mechanism.

D. **Task Objective**

At the time of lagori breaking, the ball is loaded into the throwing mechanism using the ball feeding mechanism. The ball travels along the circular path and leaves the path tangentially with high speed to break the lagori. With the assistance of the angle adjustment mechanism, different lagori discs can be targeted, and the above procedure is repeated until all three balls are thrown, or the tower has been completely broken. (Rule 2.2.5 in Rule book).

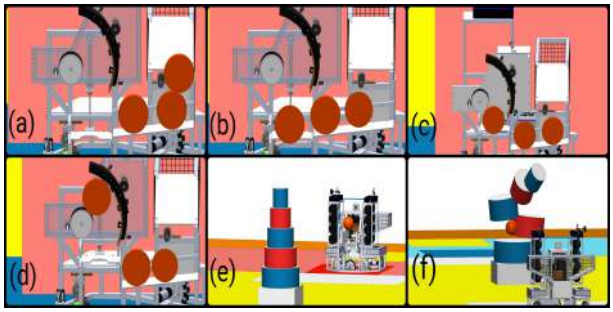


Figure 3: Work flow of Lagori breaking mechanism

4 Ball receiving mechanism and hitting of Ball on Head

4.1 Ball Receiving Mechanism

A. **Overview**

This mechanism has two systems: a ball storing system and a ball feeding system. The ball storing system comprises a roller, a Johnson motor, a collection area, and an inclined storage rack. The ball feeding system consists of pneumatic cylinder and a ball aligning plate.

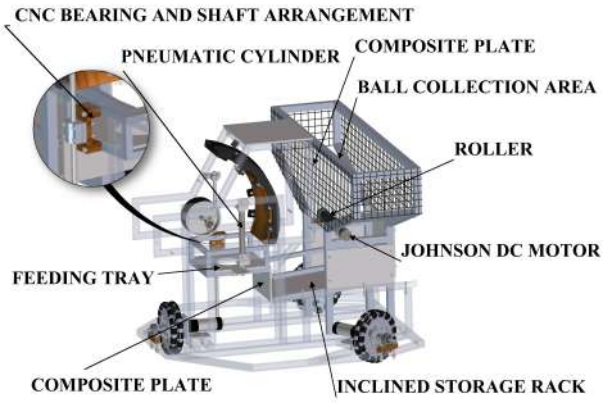


Figure 4: Ball Receiving Mechanism

B. **Mechanism**

- **Ball collecting and Storing system:**

The collection area is an aluminium box-section frame enclosed using fencing and composite plate[Figure 4]. Two openings of dimension **780x160*mm*^{2}** and **190x145*mm*^{2}** are provided at the top and bottom of the collection area, respectively. A roller **(Diameter: 25mm)** is positioned below the bottom opening of the collection area to obstruct the motion of the balls. The roller is actuated using a Johnson DC motor **(300 RPM)**. An inclined storage rack **(Breadth: 165mm; Inclination angle: 5°)** made up of composite material is provided to store and pass balls individually into the feeding mechanism.

- **Ball Feeding System:**
  The feeding system is used to load the stored balls into the ball throwing mechanism. A feeding tray is enclosed from three sides, with a composite plate underneath it that has a hole with a diameter of **40 mm** at the center [Figure 4]. It is used to hold the ball received from the storage area. The Feeding tray is lifted using pneumatic cylinder **(Stroke length: 100mm; Bore diameter: 16mm)**.

C. **Justification**
The top opening of the collection area is designed to make sure that it collects all the balls at once from the passing mechanism. An inward slope is provided to the aluminium bars to help in converging the balls at bottom opening. A roller is installed such that allowed passing space for the ball is **130x190*mm*^{2}**, to avoid jamming and ensure one by one ball passing into storage rack. The feeding tray is designed to accommodate only one ball at a time. A hole **(Diameter: 40mm)** is provided in the base plate of the feeding tray to position the ball correctly for the throwing mechanism. One composite plate is fixed on the feeding tray such that at the time of loading a ball into throwing mechanism, the rest of the balls are restricted to storing area [Figure 3(c)]. A Pneumatic cylinder is used to lift the feeding tray, and it is ensured that when piston is retracted, the placed ball gets in contact with the rotating wheel.

D. **Task Objective**
The passing mechanism of the R2 bot releases three balls into the collection area of the R1 bot. The roller starts rotating and passes one ball at a time, and the ball aligns into the storage rack. The forward stroke of the pneumatic cylinder descend the composite plate, and thus the feeding tray aligns with the ball on the inclined storage rack. After that, the ball positions itself in the hole of the feeding tray due to gravity. Then, The ball is loaded into the throwing mechanism by retraction of pneumatic cylinder.

4.2 Hitting of Ball on Head(BOH)

After the balls are received, it is fed into the throwing mechanism for hitting BOH (ball on head) mounted on seeker R2 bot. To hit balls in different direction, orientation of the bot is changed by rotating robot. Along with it, angle changing is used to aim the BOH at different positions. The dimensions of the R1 bot is considered such that the bot moves in a circle of 850mm diameter which is less than the dimensions of the R1SZ (1000x1000 mm) which follows the rule as mentioned in the rulebook (rule - 1.11).

- **Calculations**
  Neglecting the air drag,
  Initial velocity (v) = 7.9m/s
  Initial height of ball (h) = 0.5m
  Targeted height is (H) = 1.374m
  y = H - h
  Thus, using the formula of projectile motion,

$$y = R\tan\theta - \left(\frac{gR^2}{2v_o^2\cos^2\theta}\right)$$

The equation obtained by using above formulae are as follow:

$$0.875 = R\tan\theta - 0.0785R^2\sec\theta$$

Therefore, by using the above equation for y, the Trajectory of ball at different angles can be calculated.

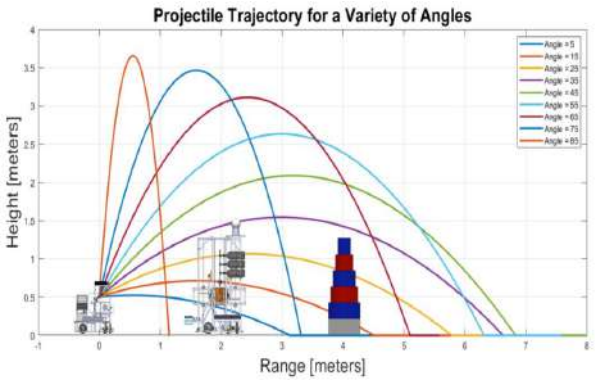


Figure 5: Trajectory of projectile at velocity v = 7.9m/s

II. Design of Robot(R2)

R2 - Robot

- **Overall dimension: 982mm×957mm×1223mm**
- **Weight : 27 Kg**

1 Type of drive

The Robot (R2) uses a **Three Wheeled Omni-directional Drive** mounted on a custom-made chassis.

2 Actuators and sensors integrated

- **Mini Planetary Motor with inbuilt Encoder**: **Three** Mini Planetary motors of **600 rpm** are used to drive R1 robot using encoder's **(1000 PPR)** velocity feedback.
- **Rotary Encoders: Two** Rotary Encoders of **1000 PPR** are mounted perpendicular to each other for finding distance travelled by robot in X and Y axis to localize it.
- **Stepper Motor**: **Three** Stepper Motors are used in lagori picking and piling mechanism in which **two (NEMA 18.9 kgcm)** are used for timing belt and **one (NEMA 10.1 kgcm)** is used in gripper.
- **Servo Motors**: **Two** Servo Motors **(60 kgcm)** used in gripper of lagori picking mechanism.
- **IMU**: **MPU 6050 IMU** sensor is used to localize the robot.
- **Pneumatic Cylinder: Two** Pneumatic Cylinders are used in ball picking mechanism **(Bore Diameter: 8mm; Stroke Length: 50mm)** and ball passing mechanism **(Bore Diameter: 32mm; Stroke Length: 150mm)**.
- **Ultrasonic Sensor**: **Four** Ultrasonic Sensors used in the robot. Two Ultrasonic sensors are used for alignment of robot in ball passing mechanism and other two Ultrasonic sensors are used for ball picking mechanism.

3 Piling up the Lagori discs

A. **Overview**

This mechanism is implemented to complete two tasks i.e lagori picking and lagori piling. Lagori picking is carried out by a parallel gripper that uses rack-pinion arrangement, stepper motor and servo motors. The lagori piling task is performed with timing belts, timing pulleys, and stepper motors.

B. **Mechanisms**

- **Lagori Picking:**

In the lagori picking mechanism, two rectangular plywood boards are mounted with parallel grippers on the front side. The grippers are operated by servo motors (one for each gripper), which can move freely about the motor shaft's axis so that it helps in picking the lagori discs easily irrespective of their orientations. An adequate length of gear rack is mounted on each plywood board. Another plywood board is placed at the centre for mounting the pinion gear [Figure 6], and it is connected to a stepper motor on the opposite side of the centreboard. Shaft and CNC bearing arrangement is used to facilitate friction-less linear motion of plywood boards. As the motor is actuated, if the pinion rotates in a **anticlockwise direction**, the grippers approach each other and recede away when the pinion rotates in the **clockwise direction**. Racks are supported with ball bearings to ensure smooth operation.

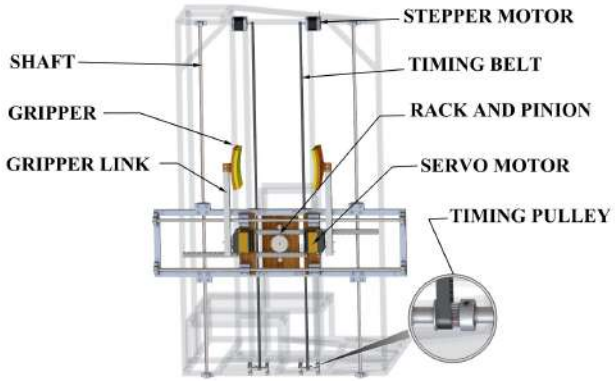


Figure 6: Lagori Picking and Piling mechanism

- **Lagori Piling:**

Lagori piling mechanism uses two timing belts connected with the timing pulleys mounted at the bottom face of the robot chassis. The other side of the belt is connected with two stepper motors clamped at the top. Arrangement of shaft and CNC bearings is used to avoid an imbalance of the lagori picking mechanism while functioning. Once the lagori disc is picked up by the lagori picking mechanism, it is raised to a predetermined height using timing belts driven by stepper motors.

C. **Justification**

Foam duster is attached to the inner surface of the grippers in order to grip the lagori disc firmly. The servo motor has better holding torque **(60Kg-cm)**, it can pick up the lagori disc irrespective of its size and weight [Figure 7(b)]. Timing belt is actuated using stepper motors as they have good precision measurements that allow raising the picking mechanism to place the lagori disc at required height.

D. **Task Objective**

After the R2 bot positions itself in front of the lagori, the distance between the gripper arms is adjusted according to the size of the lagori, with the help of the rack and pinion. Once the lagori is between the gripper jaws, they move towards each other and grip the lagori. The lagori is held tight by both arms and is lifted and placed on the square base. Further, the arms begin to recede away after releasing the lagori disc, and this process continues until the final lagori has been placed.

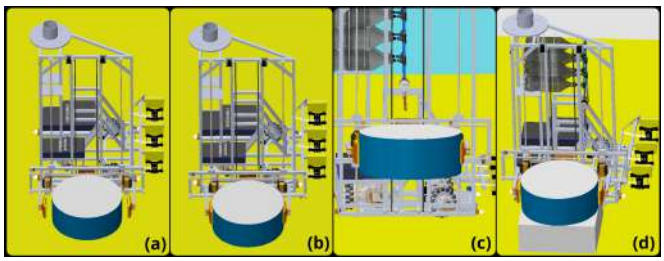


Figure 7: Work flow of lagori picking and piling mechanism

4 Ball picking and passing mechanism

A. **Overview**

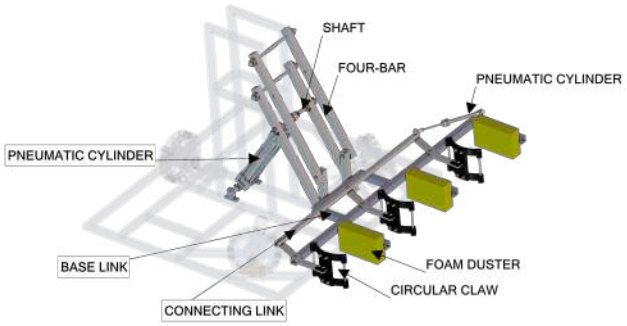


Figure 8: Ball Picking and Passing Mechanism

The ball picking mechanism consists of three angular grippers actuated using pneumatic cylinder. Ball passing mechanism is used to pass ball by lifting the ball picking mechanism.

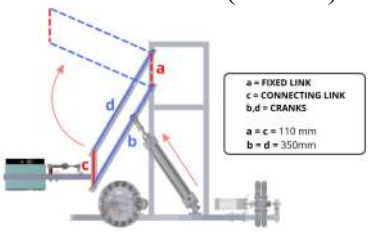
B. **Mechanisms**

- **Ball picking:**

This mechanism uses a pair of two parallel four-bar linkages sharing a common connecting link. Connecting link is actuated using a pneumatic cylinder **(Bore diameter: 8mm; Stroke length: 50mm)**. A 3D printed circular claw is attached at the end of the lever of four-bar linkages. A foam duster is attached to a fixed link opposite to each claw.

- **Ball passing:**

The parallelogram four-bar mechanism (a-b-c-d) is used in passing mechanism. Two such type of four bar mechanisms are connected parallely at a **122mm** distance and



this assembly is attached to the chassis. A shaft is passed through b link of both four bar linkages at **110 mm** distance from the end of link b. One pneumatic cylinder **(Bore diameter: 32mm; Stroke length: 150mm)** is connected with shaft to actuate the mechanism.

C. **Justification**

Claw is 3D printed in a circular shape to ensure that surface of the claw remains perfectly in contact with the ball. The picking mechanism is designed to pick all balls using single actuation from the ball rack. Grippers are integrated with each other by a linkage, such that when the common link is actuated using a pneumatic cylinder, it grips all balls from the ball rack at once. Foam dusters on fixed claws ensures firm gripping with balls. According to Grashoff's parallel four-bar law, connecting links always remain parallel to a fixed link. The picking mechanism is mounted on link c (connecting link), ensuring that its orientation remains the same throughout the process.

D. **Task Objective**

The hitter R2 robot moves in the ball area and aligns itself with the ball rack after completion of the lagori break shot. As the pneumatic piston expands, the connecting link rotates the gripper arm, and the gripper claws grip the balls. After picking the three balls, it is lifted to a height of **580mm** for successfully passing the balls to the receiving mechanism of hitter R1 without touching the arena, ensuring rule 2.1.13.

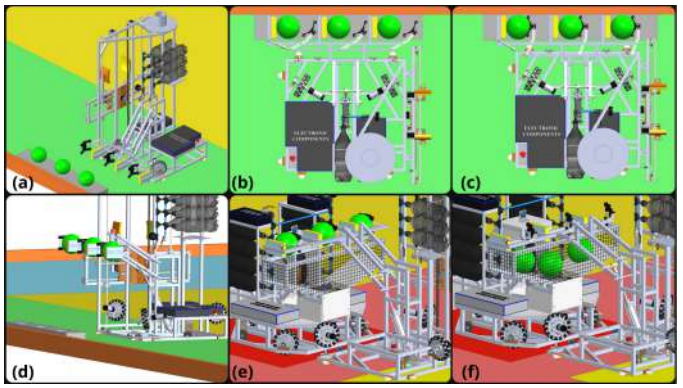


Figure 9: Work flow Ball Picking and Passing Mechanism