DESIGN DETAILS DOCUMENT
ROBOCON INDIA 2021
NATIONAL INSTITUTE OF TECHNOLOGY CALICUT

1. Design of Defence Robot

1.1 Overall dimension (in mm) and estimated weight (in kg)

The dimensions of the Defence Robot are as specified in the below figure. The estimated weight of the Defence Robot is about 21 Kg.

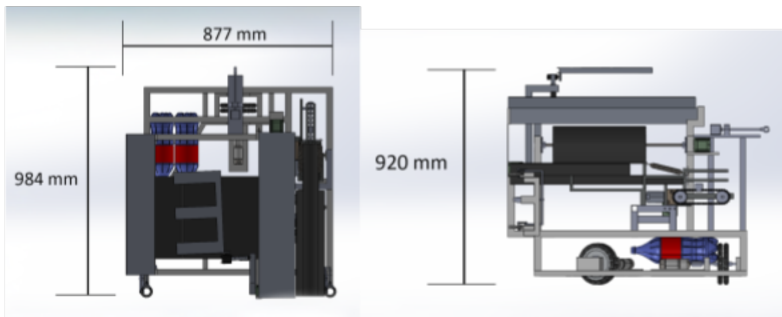

Figure 1(a): Dimensions of DR

1.2 Type of drive: Three Wheel Omni-Drive

The base is made up of square galvanized steel channels as shown in fig1(b). A tri-wheel omni drive with low ground clearance is chosen for stability, speed and better position accuracy. It provides feasibility to move and orient in any direction in order to pick and pass the arrows back to the TR. Ground clearance provides stability in defence tasks like rotating the pot tables and obstructing the arrows.

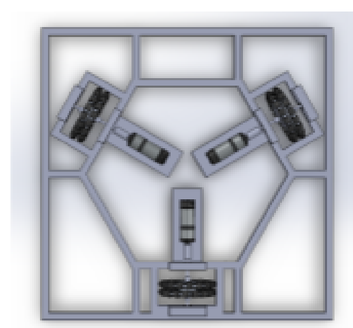
Figure 1(b): Tri-Wheel Omni Drive

1.3 Actuator and sensors integrated

- The actuators used in the Throwing robot are shown in figure.

  1. DC planetary geared motors with encoders- Locomotion
  2. Nema23 stepper motor - Conveyor actuation
  3. MG996R servo motor - Picking arrow from the ground
  4. MG996R servo motor - Orientation of picked arrow
  5. Nema23 stepper motor - Rotation of the picking arm
  6. DC encoder motor - Arrow throwing actuation
  7. Nema23 stepper motor - Orientation of arrow
  8. 20mm Stroke length piston - Grippers actuation
  9. Planetary BLDC motor(270 rpm) - Rotation for arrow interception

1.4 Arrow picking and passing mechanism

Arrow picking mechanism consists of 2 sets of forks, parallel to each other, made with acrylic as shown in figure 1(c) and actuated using servo motors positioned at the front end of the robot. the forks on the lower half of the picking tray go under the arrow while the upper half closes it from above. The distance between the forks is enough to let the body of the arrow roll in without tipping off. The picking tray, along with the arrows, can be rotated in two directions using two servo motors. One servo motor is for correcting the orientation of the arrow and the other to enable picking and dropping of the arrows. The tray is attached to an arm made of aluminium, extending from the main body of the robot. This arm moves the tray above the robot and the forks lower themselves, releasing the arrows. The arrows are dropped on a conveyor belt that transfers the arrows to the passing mechanism. The arrows are passed to the TR using a throwing mechanism as shown in figure1(d)

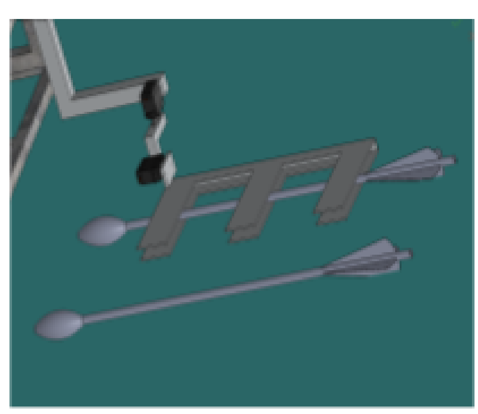
Figure 1(c): Forks lifting arrow from the ground

whose angle of projection is adjusted using a stepper motor.

This arrow picking mechanism is by far the most accurate one. Since it has two degrees of freedom, irrespective of the position and orientation of the arrow on the ground, this mechanism correctly picks and loads it onto the conveyor belt. It also has a capability to cover more area than any other mechanism which results in more precision and speed. The passing mechanism is also very precise since the angle is adjusted using a stepper motor. The length of the picking tray is 350mm which is sufficiently less than the length of the body of the arrow it picks. The vertical distance between the forks in the upper half and the lower half is 20 mm and the tray is placed very close to the the ground so the arrows resting on the ground will be able to slide inside the tray

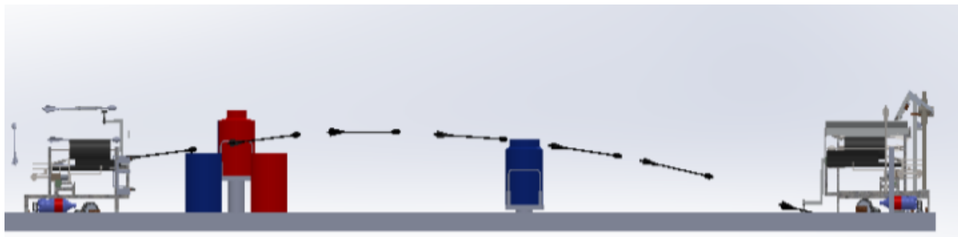

Figure 1(d): DR passing the arrow to TR

2. Design of Throwing Robot

2.1 Overall dimension (in mm) and estimated weight (in kg)

The dimensions of the Throwing Robot are as specified in the below figure. The estimated weight of the Throwing Robot is about 25 Kg.

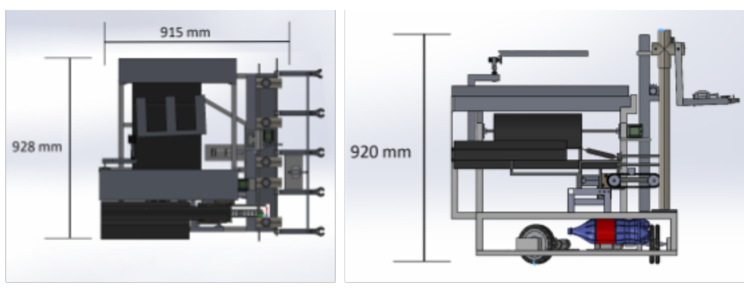

Figure 2(a): Dimensions of TR

2.2 Type of drive: Three-wheel Omni-Drive

The tri-wheel Omni drive base is shown in figure 2(b) which is built with 1-inch GI square channels. A tri-wheel Omni drive was chosen so that the throwing robot could take advantage of its holonomic movement and it provides the best balance between stability and speed. Also, provides adequate space for incorporating the other mechanisms.

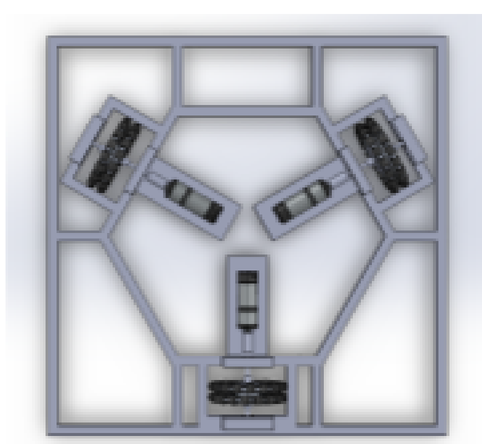

Figure 2(b): Tri-Wheel Omni Drive

2.3 Actuator and sensors integrated

- The actuators used in the Throwing robot are shown in figure.

  1. DC planetary geared motors with encoders- Locomotion
  2. Nema23 stepper motor - Conveyor actuation
  3. DC planetary geared motor - Rotating the gripping arms
  4. 20mm Stroke length piston - Grippers actuation
  5. DC planetary geared motor - Pinion rotation for rack actuation

6. MG996R servo motor - Picking arrow from the ground
7. MG996R servo motor - Orienting the picked arrow
8. Nema23 stepper motor - Rotation of the picking arm
9. DC encoder motor - Arrow throwing actuation
10. Nema23 stepper motor - Orientation of arrow

2.4 Arrow picking and receiving mechanism

The arrows passed by the DR lie near the TR on the ground. The arrows are picked with a similar mechanism used by the DR to pick the arrows lying on the ground. As the arrows are near the areas feasible for throwing, arrows can be picked and thrown without moving the TR to different locations. Arrow receiving mechanism is the same as picking from the ground mechanism of DR as it throws the arrow near to TR.

For the selection of motor for picking the arrow from the ground for bot TR and DR, the max torque required based on the designed mechanism has been calculated. The max torque is taken when the arm is horizontal.

$$
\begin{aligned}
&\text{Mass of rod connected to stepper} = 26g = m_o \\
&\text{Mass of rod perpendicular to } m_o = 95g = m_1 \\
&\text{Mass of rod connected to picking tray} = 35g = m_2 \\
&\text{Mass of picking tray} \quad = \text{Mass of forks} + \text{Mass of servos} + \text{Mass of rod between servos} \\
&\qquad\qquad\qquad\quad = 200g + 2 \times 55g + 25g \\
&\qquad\qquad\qquad\quad = 335g = m_3 \\
&\text{Torque Required} \quad = m_o \times 0 + m_1 \times 16.5 + m_2 \times 33 + m_3 \times 37 \\
&\qquad\qquad\qquad\quad = 15117.5gcm \\
&\qquad\qquad\qquad\quad = 15.12Kgcm
\end{aligned}
$$

Based on these calculations, we have selected a NEMA23 18.9 Kgcm Torque stepper motor for this mechanism.

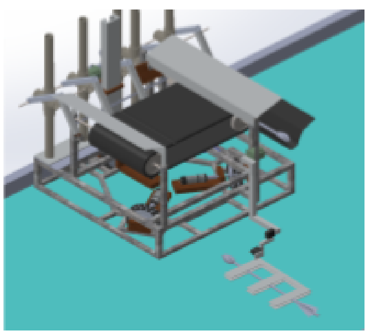

Figure 2(c): Arrow is grabbed by the fork

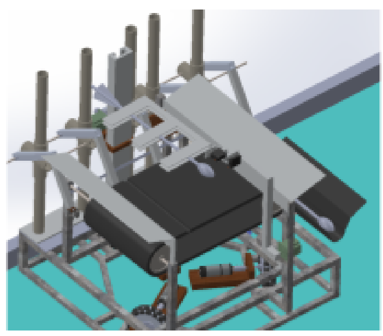

Figure 2(c): arrow is lifted above the conveyor

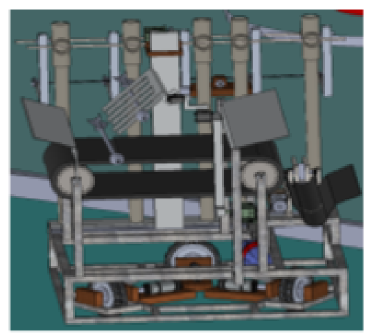

Figure 2(c): arrow is dropped onto the conveyor

3. Throwing Mechanism

3.1 Design and Working of Mechanism for collecting arrows from Rack

This mechanism picks the arrows from the arrow rack and places them on a conveyor. The loading of arrows into the throwing mechanism from the arrow rack is carried out by a mechanism consisting of five arms. 5 arrows in the arrow rack are placed vertically which are separated by 200mm each as shown in figure 3(a). The arrow collecting mechanism is supported by 5 PVC pipes which are attached to the base, each consisting of an L-shaped arm projected towards the arrow rack. Each gripper is attached to every arm which is used for holding the arrow. The arms are assembled to the support such that the centre axis of each gripper coincides with the centre axis of every corresponding arrow as shown in figure 3(b). This mechanism picks the arrows from the arrow rack and places them on a conveyor to pass them to the throwing mechanism one after the other to facilitate the throwing process as shown in figure 3(c).

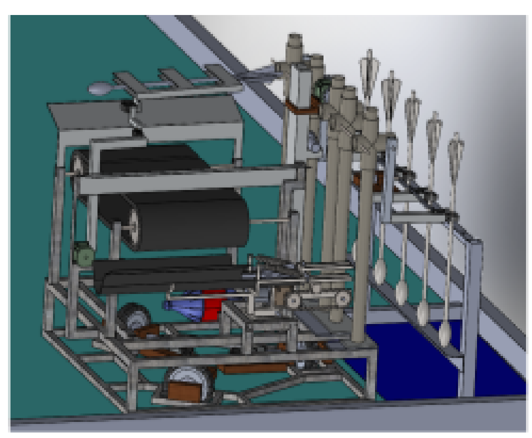

Figure 3(a) Picking from Rack Mechanism

The actuation of the grippers is achieved with the help of a 30mm stroke length pneumatic cylinder which is coupled with all the grippers. Once the grippers hold the arrows, the rack in the slider is actuated by a pinion to move arrows upwards. Then, all the arms which are coupled together by an MS rod, are rotated by an angle about 220 -225, which is actuated by a DC encoder motor fixed to a wooden block as shown in fig. When the arrows are rotated to a position parallel to the conveyor belt and blob facing front of the robot as in fig, grippers are opened and arrows are released onto the conveyor. The conveyor belt is customized with a groove of width

(20 mm) equal to the arrow's body diameter and depth (10mm) such that only one arrow fits in the groove. Then a wedge is placed just above the conveyor belt as shown in figure 3which is used to guide the corner arrows into the groove and block arrows from moving with the belt other than the arrow inside the groove. Thus, for every one rotation, only one arrow is carried in the groove which is dropped to facilitate the throwing process.

More time is saved since all five arrows are picked at a time compared to picking a single arrow at a time. Since a wedge is used to direct the arrows onto the conveyor belt, spaced is saved.

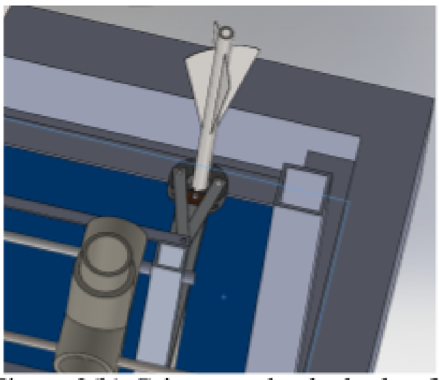

Figure 3(b):Gripper grabs the body of the arrow

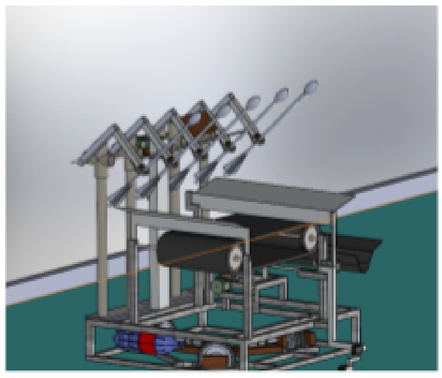

Figure 3(c):Arm rotates 270°

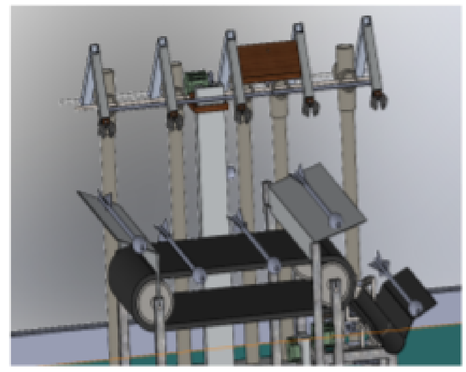

Figure 3(d):Arrows are dropped onto the conveyor

3.2 Design and working of Throwing Mechanism

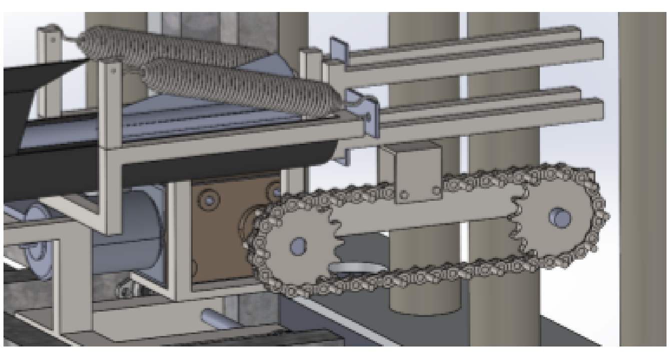

Figure 3(e): Chain Drive Mechanism

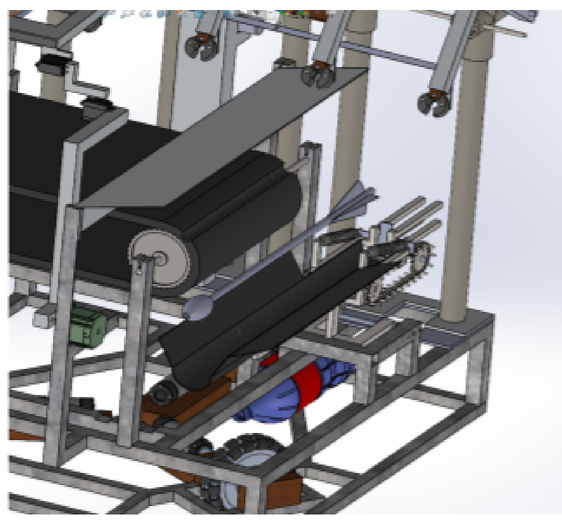

Figure 3(f): Arrow loaded into the Throwing Mechanism

The arrows are thrown using a spring based mechanism. After acquiring the arrow from the conveyor as shown in figure 3(f) , springs are extended using a chain drive as shown in figure 3(e) using a DC motor until the required length is reached. Throwing angle is adjusted using a stepper motor for the required range. The initial energy of the system is the potential energy of the arrow and spring energy of the extended spring. Approximately 60% of spring energy is dissipated while stopping the throwing plate. Range from TR to aimed pot is calculated from the arena. From the range and height of the aimed pot, angle is adjusted using a stepper motor. With the angle of projection, height and range of the pot, the time of flight is calculated. Extension of the spring is calculated from the velocity of the arrow. Force applied by the spring is regulated by adjusting the chain drive. Arrow's angle of projection and range are adjusted by localizing TR with respect to the aimed pot.
For

(TR height) initial height $h = 0.4m$,
(pot height) final height $H = 0.5m$
(range) $R = 4.78$
(angle of Projection)$\theta = 70°$

$$T = \sqrt{\frac{2(H - h - Rtan\theta)}{g}} = 1.63s$$

$$V_x = V cos\theta = \frac{R}{T} = 2.93m/s$$

$$V = \frac{V_x}{tan\theta} = 8.57m/s$$

we get a velocity of $8.5723m/s$ for a 70° angle

$$\frac{2}{5}(n \times \frac{1}{2}kx^2) = \frac{1}{2}mv^2 + mg(0.02sin\theta)$$

for angle of 70°, velocity is $8.572 m/s$, spring constant is $826 N/m$, extension of $0.1 m$ and a spring constant of $1000 N/m$ to $1500 N/m$ is used. As we are using a stepper motor, the angle can be adjusted precisely.Since we are using a chain drive, spring can be extended continuously. Usually spring based mechanisms take two actuators for extending and locking the spring. But we managed to use only one actuator for both by extending the spring from contact using the chain drive. Arrow is thrown into pot as shown in figure 3(g) .

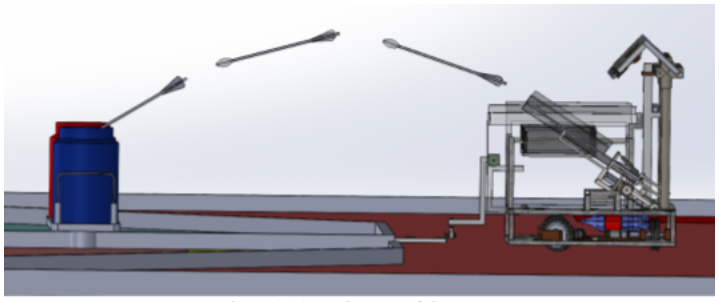

Figure 3(g): Trajectory of the arrow

4. Table Pushing Mechanism and Arrow Interception Mechanism

4.1 Design and working of Arrow Interception Mechanism

The mechanism consists of an arrow mounted to a spinning platform attached to a BLDC motor. This system is mounted to an extension on the base platform. The arrow is mounted such that the center of gravity of the arrow lies along the line of the shaft of the BLDC motor in order to nullify any possible vibrations due to the high RPM of the motor. The arrow is rotated at a high speed using the above setup as shown in figure 4 (a). When the robot is moved in such a way that the arrow thrown by the opponent passes by the rotating arrow, the opponent's arrow is deflected there by altering its actual trajectory.

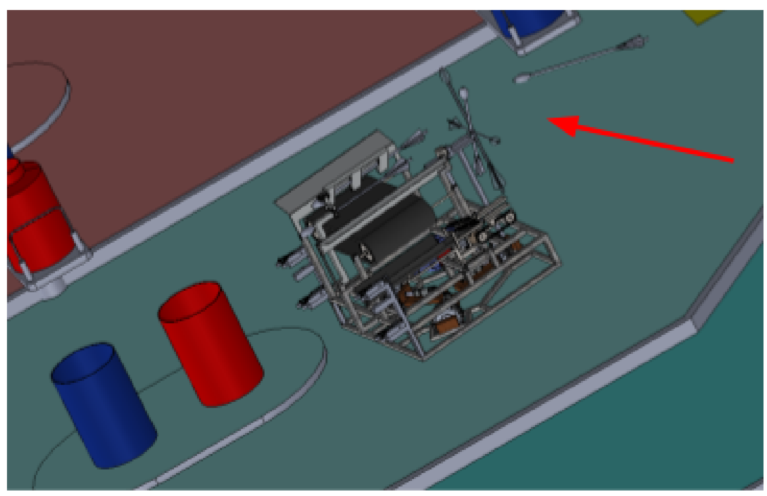

Figure 4(a): Interception mechanism blocking the trajectory of the arrow

The axis of rotation is placed at a height of $570 mm$ from the ground so that it deflects upto a height of 1100mm . So it can deflect the opponent's arrow aimed for all types of pots easily as shown in figure.

4.2 Design and working of Table Pushing Mechanism

The table pushing mechanism consists of two pairs of support plates that are positioned at the opposite corners of the robot. Between each pair of support plates we have platforms whose orthogonal projection extends beyond the base of the robot. the height of these platforms are appropriate to reach the handles of the type-2 and type-3 tables. A gripper is placed on each of these platforms that hold the vertical part of the handles on the table. The tables are rotated by gripping the handles and rotating the base of the robot . Both the grippers positioned on the same pair of support plates are connected to a single actuator and operate simultaneously no matter which of the two is in proximity of the handle. The table pushing mechanism consists of four orthogonal projections, two on each corner of the base, supported by plates on either side, holding one gripper each. The grippers at one corner are actuated using a single actuator. The projections are at different heights suitable to grip the handles of the type-2 and type-3 pot tables. The gripper holds the handles, and by moving the base, the tables are rotated in the required directions. Having the mechanism on both corners of the robot always enables one of them to be on the side nearer to the tables.

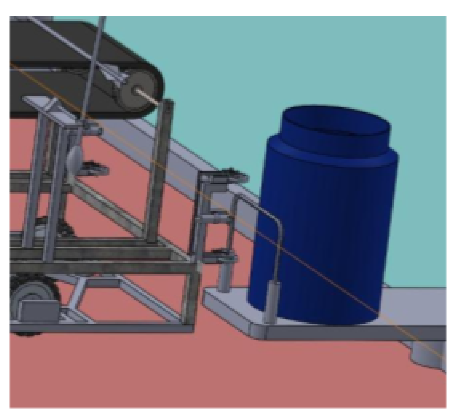

Figure 4(b): Support plates gripping the table's handle