DESIGN DETAIL DOCUMENT

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1. Arrow pick and pass:

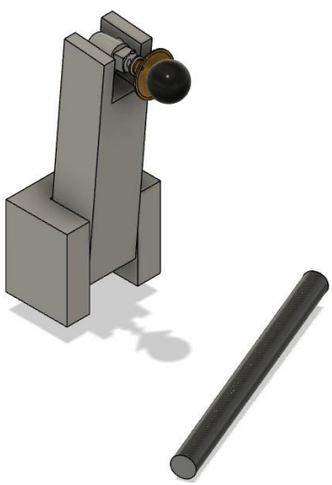
Mechanism:

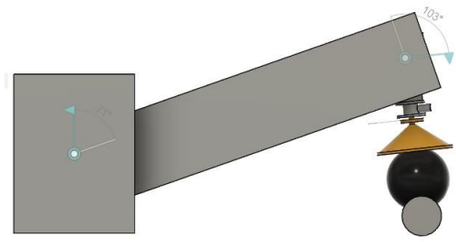
The task of picking arrows is accomplished using an amorphous universal gripper attached to the end of a 3-DOF manipulator in RRR configuration, i.e. 3 revolute joints. A link that can rotate about the horizontal axis is attached to the chassis, to which another link that rotates about the same axis is attached. This link is then attached to the part which houses the funnel. This part can rotate about its axis. The balloon sits inside the funnel. Servo motors are used for actuating revolute joints. The gripper works on the principle of "jamming". Granular material such as coffee, when compressed, can become very rigid.
The gripper setup consists of a funnel, a rubber balloon, coffee powder, hose, air filter and syringe. The syringe is actuated with a lead screw. The balloon is filled with coffee powder and attached to an air hose, whose other end is attached to a syringe. To prevent coffee powder movement in the air hose, a filter is attached. When the syringe slightly pressurizes the balloon, the granules are loose and easily rearranged. By pressing the balloon against the arrow, the granules will move around it and take its shape. However, when the air is sucked out of the balloon, the granules are compressed and grip the arrow. The rubber surface of the balloon also helps to keep a hold of the arrow.
The arrows are picked up from the ground as well as from the rack by jamming the gripper against the arrow. The manipulator is moved and aligned accordingly using the servo motors used to actuate it. Once the manipulator and the gripper are aligned with the arrow, the gripper picks up the arrow by jamming against it and drops it into the outer area from where the throwing bot can pick up the arrow using an identical gripper attached to it.
The following paper was referred to for the design of the gripper: https://www.pnas.org/content/107/44/18809
CAD File link: STEP: https://drive.google.com/file/d/1-fpwiWzdxGtJIqij4RBlzIllr0oqK5g5/view?usp=sharing
STL: https://drive.google.com/file/d/12xIIGidqGtoVqeEkzYVAOdscbCAYeIo-/view?usp=sharing

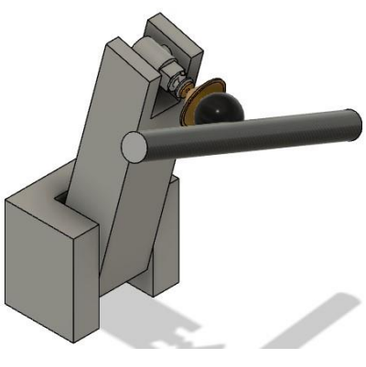
Justification:

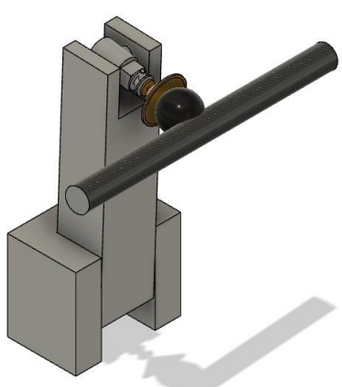
This gripper was chosen for the following reasons:

- It can reduce the likelihood of potential slip while the arrow is being moved.
- The hardware and software complexities associated with conventional grippers are reduced.
- It is easier to manipulate the arrow before placing it into the receiving mechanism of the throwing robot. This makes it possible to lift the arrow from the ground by approaching the arrow from any side since it can easily be reoriented in the right direction for loading.



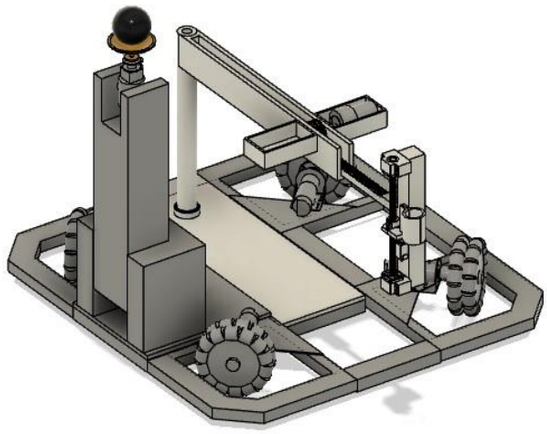






2. Table pushing and arrow interception:

Mechanism:

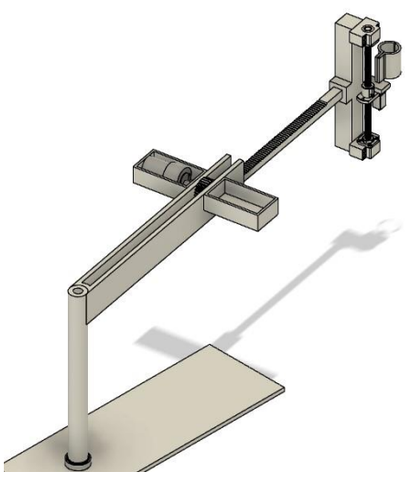


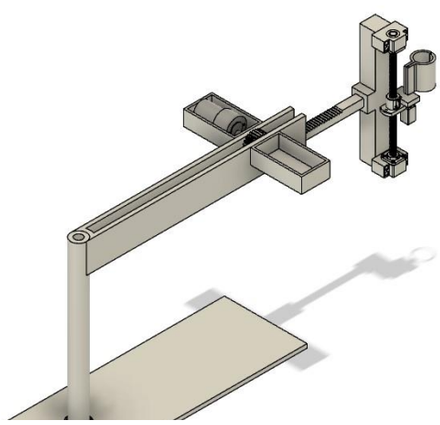
- The mechanism used for table pushing is a 3-DOF manipulator in an RPR configuration, i.e. 1 revolute joint and 1 prismatic joint and another revolute joint. A horizontal rack guide way is welded onto a vertical shaft which is attached to the defence robot chassis. The vertical shaft is placed on a bearing and thus can rotate about its axis. The rack guide way has rollers that support the rack.
- Near the front end of this guide way, a pinion, actuated by a DC motor, is placed to control the rack's forward and backwards motion. A T-shaped structure is attached to the front end of the rack. This T-shaped appendage has a lead screw and a platform containing the gripper is attached to the screw. The gripper consists of two C shaped fingers one of which is stationary and the other which is actuated by a servo motor which is located at the bottom of the platform.
- The robot positions itself in front of the turntable so that the gripper can grip the handle. The gripper-handle contact acts like a revolute joint. After the gripper holds onto the handle, the rack can be extended or retracted, which causes the turntable to rotate. After the desired rotation, the gripper lets go of the handle.
- **Arrow interception** is accomplished using the same mechanism used to pick up arrows. The third servo motor attached to the gripper that works on the principle of jamming, allows it to rotate about its own axis. Thus, after picking up an arrow from the ground the gripper can rotate about its own axis and this can be used to wave the arrow and intercept the incoming arrows of the opponent team.

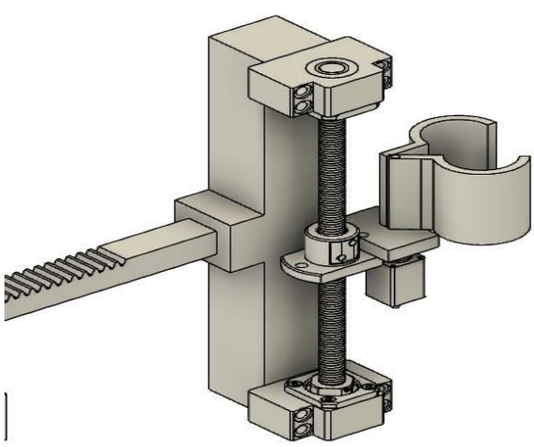
CAD File link:
STEP: https://drive.google.com/file/d/1-_GgverNVLWefymZXa6_NCRDkC-rQIgI/view?usp=sharing
STL: https://drive.google.com/file/d/1UUtujKHJyJ3a2WAXXgw4YtSp6S6UuUL_/view?usp=sharing

Justification

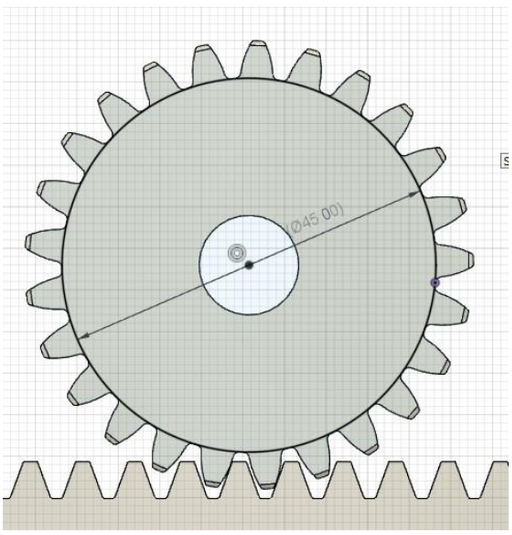
- The turntable rotation mechanism uses a rack and pinion arrangement. The pinion is actuated by a servo motor and hence the turntable can accordingly be rotated accurately by any angle desired.
- By using a lead screw to actuate the platform containing the griper, the platform may be moved up and down by any desired amount to rotate any of the turntables present in the arena at different heights.
- By attaching a third servo motor to the gripper in order to enable rotation of the gripper about its own axis, the gripper's versatility increases since the same gripper used to pick up arrows from the ground can be used to wave arrows for arrow interception.

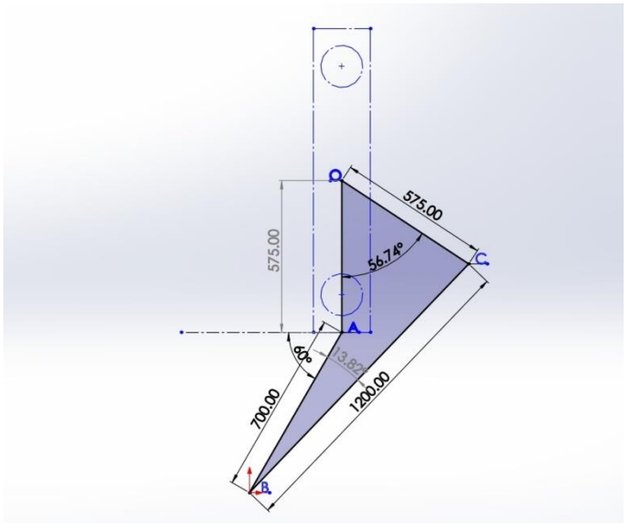






Calculations:





- Consider the two diagrams above. The first diagram shows the diameter of the gear to be 45 mm.
- The second diagram depicts the top view of the turntable and the rotating arm of the mechanism. AB is the initial length of the arm = 700 mm. BC is the length of the arm after the rack is extended forward fully i.e 1200 mm. The mechanism grips the turntable at an angle of 60 degrees with the horizontal as shown.
- After the arm fully extends forward the turntable is rotated by **54.74 degrees**. Thus the turntable can be rotated by 54.74 degrees by this mechanism when it grips it at an angle of **60 degrees** with the horizontal.
- Now, considering the mechanism in its initial position, let the force applied by the mechanism onto the turntable be **F**. Thus the torque applied is given by **T = F*r*sin(60).**
- Here **r = 575mm or 0.575 m** which is the distance of the handle from the centre of the turntable.
- The force is thus given by: **F** = $\frac{\mathbf{T}}{\mathbf{r}*\mathbf{sin}\,(\mathbf{60})}$
- Assuming T = 5 N.m as given in the document, **F =** $\frac{\mathbf{5}}{\mathbf{0.575}*\mathbf{sin}\,(\mathbf{60})}$ **= 10.04 N.**
- From Newton's 3rd law, the same force acts onto the rack from the handle and thus the same force must act onto the gear teeth as well. Assuming the force to be perpendicular to the gear tooth, it is clear that the torque that must be applied by the DC motor to actuate the gear must be: $\mathbf{T_{motor} = F*R_{gear}}$
- $\mathbf{R_{gear}}$ **= 45 mm = 0.045 mm** from the figure above.
- **Therefore minimum torque that must be applied by the motor to initially actuate the mechanism is:**
  $\mathbf{T_{motor}}$ **= 0.045*10.04 = 0.452 N.m**

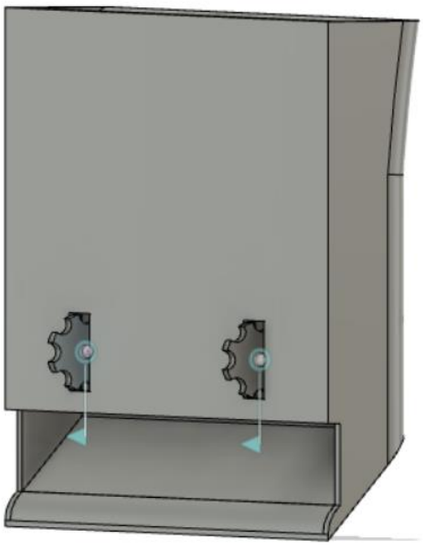
3. Arrow Receiving:

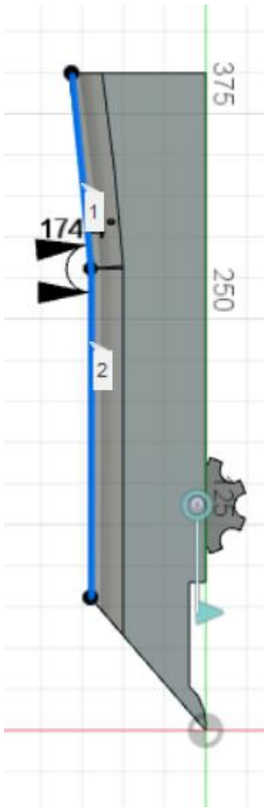
Mechanism:

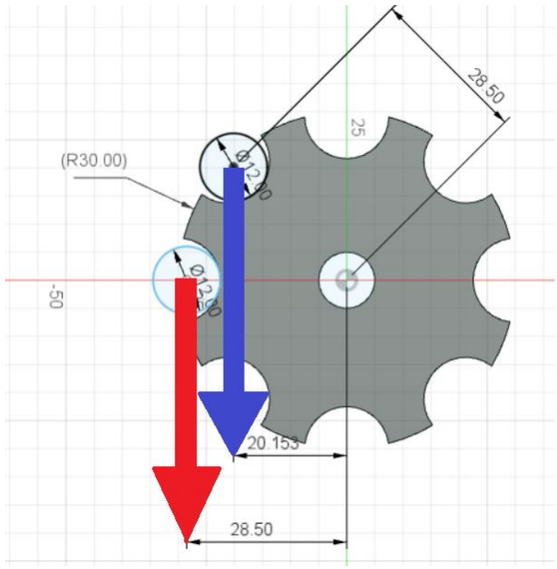
- This mechanism serves the purpose of storing and dispensing arrows to the throwing mechanism. The reloading mechanism can be broadly described as a "funnel-like shaped cartridge".
- The arrows are held in position by a specially cut gear wheel. This wheel is cut in such a way that it can hold a single arrow (lower most one) separate from the rest of the arrows within the cartridge. This is employed when the throwing mechanism requires a single arrow to be loaded into it.
- The wheel rotates by means of a servo motor used to actuate it and it releases one arrow into the throwing mechanism and separates the next arrow, this happens consecutively until all the arrows are exhausted.
- Each arrow is dispensed onto hooks on the throwing mechanism which in turn rotate and load the arrow into the shooting chamber. The hooks are also actuated using servo motors.

Justification/Calculations:

- The rotation of the wheels by means of servo motors ensures that the wheels accurately rotate and dispense only one arrow at a time.
- Hooks present allow the arrow to accurately be placed onto the throwing platform.







(All dimensions in mm)

Maximum torque on the wheel is present when all arrows are loaded into the cartridge.

The red vector represents the force exerted by the single arrow (one which is separated from the rest) due to its weight.

The blue vector represents the weight of the other four arrows loaded in the cartridge.

Given:

Weight of each arrow= 107g

Diameter of each arrow=12mm

Therefore maximum torque= (107*28.50+4*107*20.153)*9.81*10^-6=0.1145 Nm

CAD File link:

STEP: https://drive.google.com/file/d/1IcvQxN6XdoyoGUzbpXMHAbUT7DnLEOCN/view?usp=sharing

STL: https://drive.google.com/file/d/1CH2PvFd7JAcy9qEXqvHMxGSUBVX81y_U/view?usp=sharing

4. Arrow Throwing:

Mechanism:

- The throwing mechanism has a slab like base on the chassis connected to a similar solid slab plate and the angle between them can be varied.
- The angle is varied with the help of a lead screw and links attached to the upper plate containing the entire throwing mechanism.
- The upper plate consists of a bow at the front end and an elastic band is attached to it. Initially the band is slack. The band consists of two pads attached to either end, and these pads come in contact with another set of pads attached to the chain below by means of a slot. The elastic band also consists of a small square plate and when the arrow is loaded onto the mechanism and the elastic band is released, it helps to push the arrow and propel it forward.
- The sprockets attached to the chain are actuated using servo motors and before the arrow is loaded onto the throwing platform, the elastic band is stretched by means of the chain and the corresponding pads attached to it. Now the arrow is loaded onto the platform by means of the funnel and hooks attached to the side of the throwing platform. As the chain is further rotated, the pads attached to the chain lose contact with those attached with the elastic band and the arrow is propelled forward by the square plate attached to the band.

CAD Files:

Throwing Bot:

STEP

https://drive.google.com/file/d/1EWLJKI3WIBkxlW5ZV9KMzzUMZC-xSLID/view?usp=sharing

STL

https://drive.google.com/file/d/1f0dNPruGw7VPadmjXe43ubfLz5hQ-Jms/view?usp=sharing

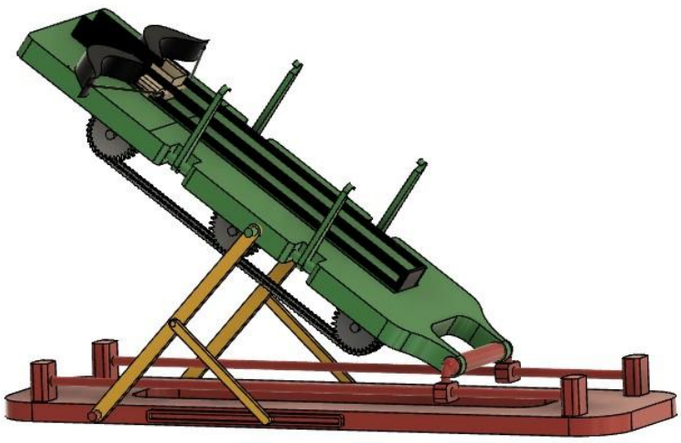
Throwing Mechanism:

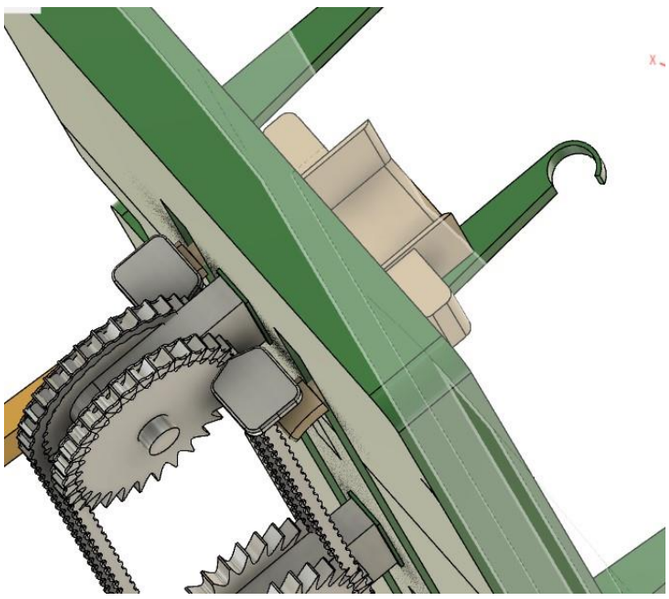
STEP:

https://drive.google.com/file/d/1kjumn3gFXZ-f-Kt86wkWU40vDDlCpuX5/view?usp=sharing

STL:

https://drive.google.com/file/d/1LI2kzyHbQ1rYERqXjRSeKK6uZUZzyJFA/view?usp=sharing





Justifications:

- From the mechanism chosen it is evident that the speed with which the arrow is propelled forward is more or less the same ignore the effects of stress on the elastic band. The angle of projection of the platform can be changed using the lead screws.
- Thus upon knowing the speed we can accurately estimate the range of projection of the arrow according to the angle that the platform makes with the ground.
- The platform itself can rotate from 0 to 60 degrees enabling us to throw the arrow into the desired pot as shown in the figures below: