PICK

For picking the arrow, the DR bot is manually taken near to the arrow such that the arm length is sufficient to pick the arrow. Once the DR is at sufficient distance from the arrow, the camera attached at the base (Joint1) of DR measures the distance of the arrow.

After getting the distance of the arrow from the camera (‘d’) and knowing the Y-coordinate as height of the robot, we obtain the X-coordinate using the Pythagorean theorem from the right angle triangle as shown below in the diagram. From inverse kinematics we obtain the angles required to rotate the joints.

Once link2 and link3 are adjusted such that the arrow is reachable, gripper orientation is manually changed to pick the arrow. Then we manually control the mechanical gripper to pick up the arrow from ground and then store (drop) it in its basket using the same inverse kinematics as depicted below.

PASS

After the arrows are picked up by the DR arm, they are dropped into its basket by following the inverse kinematics again. Since we know the distance between basket and base of arm we take it as X-coordinate and the height of the basket as the Y-coordinate we can calculate the angles needed to rotate the links using the formulas given below.
Once a sufficient number of arrows are collected by DR, then the passing mechanism comes into play. For passing the arrows between the bots, the DR basket is raised to a height using the servo-screw raising mechanism.

After reaching the sufficient height, the DR basket is docked with the basket of TR. This is done by properly aligning the two bots. Then the DR’s basket is lowered into TR’s basket. Docking is done manually.

RECEIVE

As there is a provision of changing the horizontal position of the TR basket, it is adjusted perfectly to align under the DR basket. Now that the two baskets are aligned, they are ready to be docked. Once docking is done, the base of the DR basket (a lid, connected to a servo motor) is opened, enabling the arrows stored in the basket to fall into the basket of TR.

Arm Manipulator for picking arrows and loading into the shooter

Components:

- Total 5 Servo Motors in the arm2 revolute joints
- Total Degrees of Freedom: 4

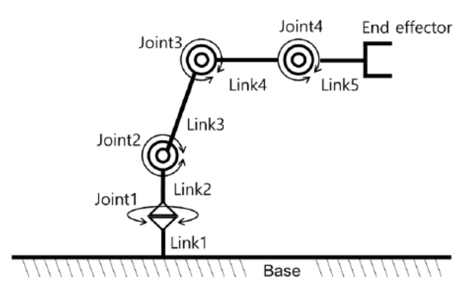


FIGURE 13-1 Basic structure of the manipulator

The Joint1 of the arm has the freedom to rotate 360 degrees (twisting joint) about the yaw axis. Joint2 is a revolute Joint connected to link1. Link2 connects Joint2 and Joint3, which is also a revolute Joint. Link3 connects Joint3 and the

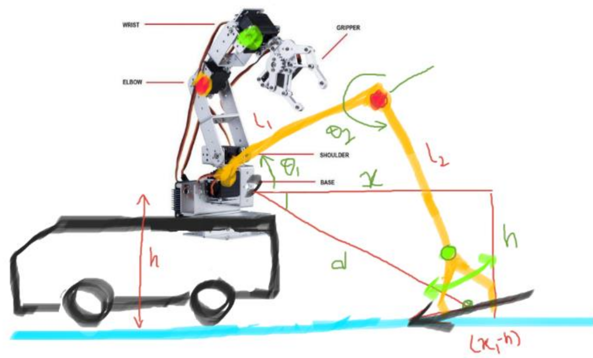
Joint4. Joint4 is attached to the End effector of the arm, which can rotate 360 has a mechanical Gripper with two fingers

INVERSE KINEMATICS

Using the camera attached on Joint1 of the DR bot we find the distance from camera to arrow using Python and OpenCV.

Let this distance be ‘d’. Since we know the height of the base from ground(almost same as the height of the robot), using pythagorean theorem we obtain the coordinates of the arrow as shown below:

Once the coordinates of the arrow are obtained, they are fed into these equations hence we obtain the angles needed to rotate each link.



$$x = \sqrt{\left(d^2 - h^2\right)}$$

$$\theta_2 = \cos^{-1}\left(\frac{\left(x^2 + y^2 - l_1^2 - l_2^2\right)}{2 l_1 l_2}\right)$$

$$\Theta_1 = \frac{-(l_2 \sin(\Theta_2) x + (l_1 + l_2 \cos(\Theta_2)) y}{(l_2 \sin(\Theta_2)) y + (l_1 + l_2 \cos(\Theta_2)) x}$$

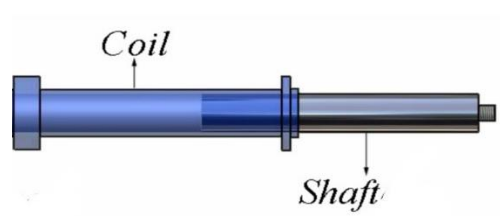
After link3 is positioned to reach the endpoint, the gripper's orientation is adjusted manually to hold the arrow.

Once the arrow is caught, it is then dropped into the DR basket using inverse kinematics again, as we know the coordinates of DR’s basket.

Throwing Mechanism

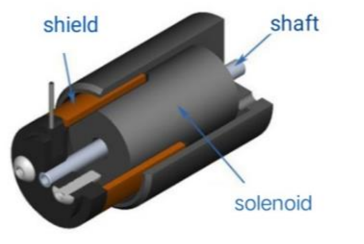
The mechanism is based on self-inductance principle, when the electricity passes through solenoid, magnetic field is created. When we increase the number of cycles or the amount of electricity, there will be a stronger magnetic field. The Magnet materials (used as shafts) are absorbed or repelled through magnetism.

A coil is wrapped around a cylinder containing a shaft. The shaft is a permanent magnet. Using Electromagnetism, the shaft is moved into, or out of the cylinder(shield) by reversing the flow of current. Self-inductance is calculated using the wheeler's formula.



In order to enter a stroke by which the speed of the arrow increases to more than 32.35 m/s, we need a force about 45j from the shaft. This force will be created with a coil with 923 circles in 6 layers with a wire which has 0.65mm thickness and 450V voltage.

To produce enough voltage for solenoid and control it -
1)A DC-DC converter circuit is used. (They change DC electrical power efficiently from one voltage level to another. They are used because DC can't simply be stepped up or down using a transformer.)
2)A solenoid controlling circuit (a condenser with high capacity, a few resistances and a switch element part.) is used.



In order to solve the problem of a source with very high voltage and electricity (a condenser with high capacity)., we put the source in a firm, non-conductor, and out of hand box.

The solenoid design will not return to the first place after the stroke, because after imposing and cutting the voltage from Solenoid, its shaft will be stopped in the last possible place. For returning it to its first condition, we will place the shooter vertically so that the shooter receives the arrow from the robotic arm, and also help the shaft return to its original position with the aid of gravity.
When the current passes through the solenoid, it creates a magnetic field which pushes the valve and this valve in turn pushes the arrow loaded in the gun. To get the valve back to its original position the gun is tilted vertically.

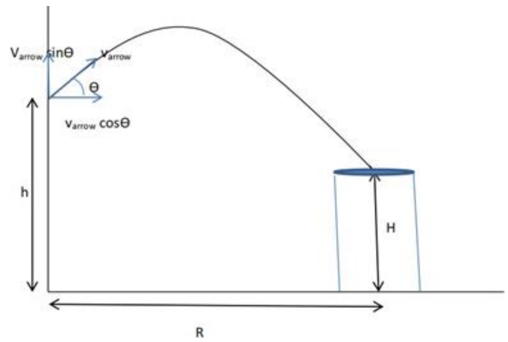
Now assuming velocity of valve when it just hits the arrow is v_{valve} , mass of the valve is m_{valve} ,velocity of arrow just after it gets hit by valve is v_{arrow} and mass of arrow is m_{arrow} (86 g) .
Considering the collision to be purely elastic, $\frac{1}{2} m_{valve} v_{valve}^2 = \frac{1}{2} m_{arrow} v_{arrow}^2$

Now taking that the gun is at height h from ground and makes an angle θ with the ground, the trajectory of center of mass of arrow shot follows that of a projectile explained below.

Let v_{xi} be initial velocity parallel to ground (i.e. horizontal component) and v_{yi} be intitial velocity perpendicular to ground (i.e. vertical component)

$v_{xi}= v_{arrow} \cos\theta$

$v_{yi}= v_{arrow} \sin\theta$



v_x , v_y be horizontal and vertical components of velocity of arrow at time t respectively.

These velocity components are independent, and gravity acts only in the *y* direction, which means that v_x is constant (assuming there is no resistance due to air) only v_y changes with time

$V_x = v_{xi}$
$v_y = v_{yi} – gt$, g is acceleration due to gravity which is a constant.

The center of mass of the arrow is generally a little towards the arrow head from the center of arrow.

If you want to know the *x* and *y* positions of the center of mass of arrow at any time, you can easily find them. You know that *x* is

$x = v_x t = v_{xi} t = v_{arrow} \cos\Theta$

And because gravity accelerates the arrow vertically, here's what *y* looks like $Y = v_{yi} t - \frac{1}{2} g t^2$

You figure out the time it takes an arrow to reach the pot which is at height H above ground when shot straight up (ignoring air resistance) like this:

$H\text{-}h = v_{yi} t - \frac{1}{2} g t^2 \quad V_{arrow} \sin\Theta\, t - \frac{1}{2} g t^2 + h - H = 0$

Air drag is given by $F = \frac{1}{2} \rho v^2 C_D A$, where F is the drag force, ρ is the density of the air, v is the speed of the object relative to the air, A is the cross sectional area, and C_D is the drag coefficient, a dimensionless number.

But for now we are ignoring air drag.

On solving $V_{arrow} \sin\Theta\, t - \frac{1}{2} g t^2 + h - H = 0$, we get time (t) = $(V_{arrow} \sin\Theta + \sqrt{(V_{arrow} \sin\Theta)^2 + 2g(h-H)}\,) / g$

By solving this equation, we will get the time taken by center of mass of arrow to reach the mouth of the pot which is at height H above the ground but in reality we just need the head of arrow to reach mouth of the pot so the value of H is little more than height of mouth of the pot and range is little less than the distance between center of mouth of pot and position of center of mass of arrow just after it was shot.
Knowing the time allows you to find the range of center of mass of arrow which is distance between center of mouth of pot and center of mass of arrow when it was just shot (which we approximate to be at same height as the gun) along the ground:

Range (R) = $v_{xi} t = v_{arrow} \cos\Theta\, t = v_{arrow} \cos\Theta\, (V_{arrow} \sin\Theta + \sqrt{(V_{arrow} \sin\Theta)^2 + 2g(h-H)}\,) / g$

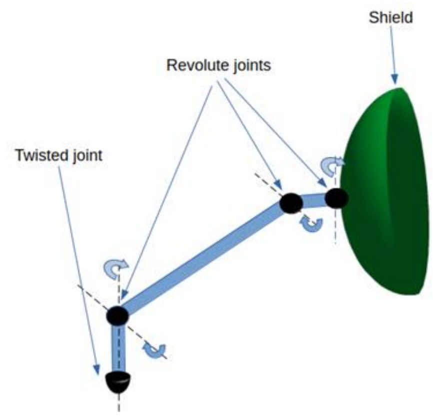
So there we have it — now we can figure out the speed of the arrow and the angle at which it was shot given the range of the arrow.

There can be many sets of values of v_{arrow} and Θ that satisfy the above one but we will consider the one that has minimum arrow velocity. Less the velocity, less the air resistance, less the energy required to shoot and less the resting time.

ARROW INTERCEPTION:

A. Mechanism: The basic idea is to use a shield to block the path of the opponent's arrow & prevent it from reaching a pot.

The model is constructed using 3 revolute joints and a twisted joint and other components. The twisted joint is present at the base (the DR), used to rotate the entire structure. Three revolute joints are present, revolute joint A, revolute joint B and revolute joint C. Revolute joint A and B have a sort of opposing motion to sustain a particular orientation of the shield while revolute join C is used for horizontal rotation of the shield.



B. Components:

Twisted Joint: The twisted join is used to rotate the entire structure and make the shield face different directions. It rotates the structure on an axis perpendicular to the base and helps the shield to face different directions.

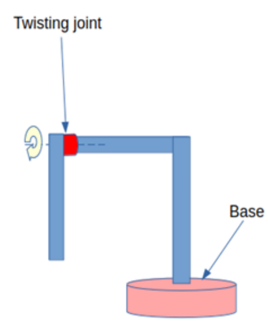
Revolute joint A and B: These two are used to raise and lower the shield, basically alter the altitude of the shield in order to intercept the incoming arrows. Maximum allowed angle for the attached bar to revolute joint A to rise is around 90 degrees.

Revolute joint C: This joint is used to change the direction the shield is facing as well. The maximum freedom of rotation allowed by this join is around 120 degrees.

IV. TABLE PUSHING:

A. Mechanism: A universal pusher could be modeled by utilizing a single revolute joint and a structure that could basically reach the heights of pot type-II and type-III. The revolute joint would utilize its rotational ability and push the table causing horizontal rotation.

B. Components: Revolute joint: A single revolute join is present that is allowed to rotate 90 degrees from its rest position which causes the pushing action.



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