Design Principle of ROBOCON-Group A01

Final design
We proposed the design with a frame consisting of profiles only (Figure 1), giving features and manufacturing considerations. Then, we drew the robot in Solidworks and select the materials used in different parts (Figure 2). Our robot consists of four critical parts: pneumatic actuator, profile frames, buffered Mecanum wheels, two masks for mounting the actuator to the profile. We believe this is the most effective, functional and easy-to-manufacture design of all. The coherent profile connected to frame stable support for moving and kicking motion and four Mecanum wheels. The reasons for the design and selection of each part are shown as followed.

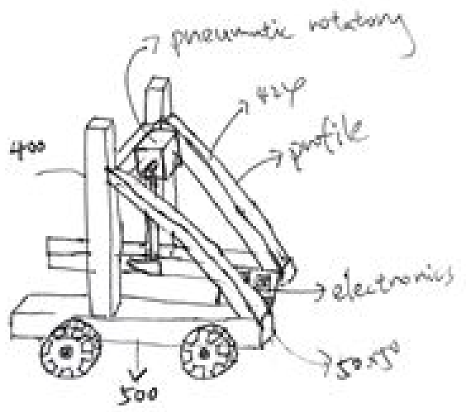


Figure 1 scratch

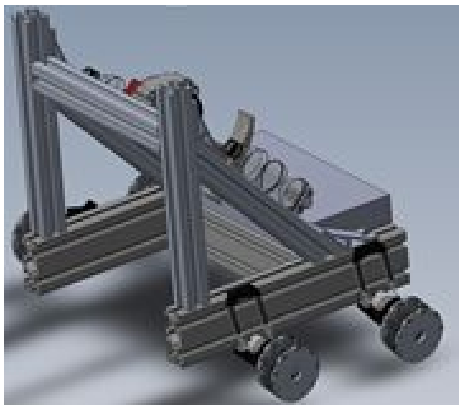


Figure 2 design CAD

Buffered Mecanum wheels
With a buffer system to absorb the collision impact and ensure group attachment. As the kicking will create a considerable amount of impact and the wheels are the ones that would bear most of it, a buffering system would mitigate such impact and elongate the serving period of the wheel. In addition, it would help to balance the non-balanced displacement to the floor of each wheel. In the task prospective, Mecanum wheels could provide movement in all directions, which help the robot to fulfill the tasks such as avoiding the moving around the obstacles and moving in position for kicking the rugby.

Profile Frame
The profile design is adopted out of simplicity and cost-efficient reason as the frame is easy and cheap to build and the whole structure is simple to analysis. The usage of standard parts highly reduces the cost of the robot. Besides, the aluminum profiles could provide enough strength to withstand the recoil that happened during the operation such as the reaction caused by the kicking process.

Pneumatic actuator
In order to kick the ball to five meters away while maintaining 1m distance to the ground, we need some calculation to determine the force and impulse needed. Some simple physics where the trajectory of the motion is a parabola is applied. We idealized the whole process and calculated the force and impulse required to kick the ball (Figure 1 & 2). The whole

calculation is attached in Appendix A. After we got the result, we searched online for different power systems and found that only the pneumatic rotatory meet the requirements of output.

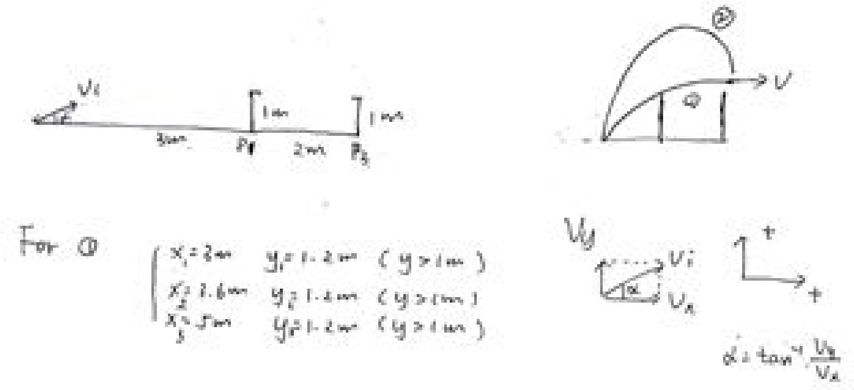


Figure 3 Physics calculation

minimum velocity	7.735373	m/s
momentum needed	7.483384	N*m
efficency	30%	
time of connection	0.1	s
torque needed	22.45015	N
length of leg	0.3	m
force needed	74.83384	N*m

Figure 4 Theoretical result

Rotary Actuator Model Selection Software

Supply pressure	0.15~1
Rotating time	0.1~1
Rotating angle	0~90
Required torque	0~36.5
Load M	0~20.09
Load Fr	0~490

Figure 5 Information of the pneumatic actuator

Masks

Bent sheet metal is used to mounting the pneumatic rotatory to the profile. Since the pneumatic actuator is weighted, we proposed to use the 3mm thickness one to make the mask. This would be effective, but this needs to be manufactured by the CNC machine.

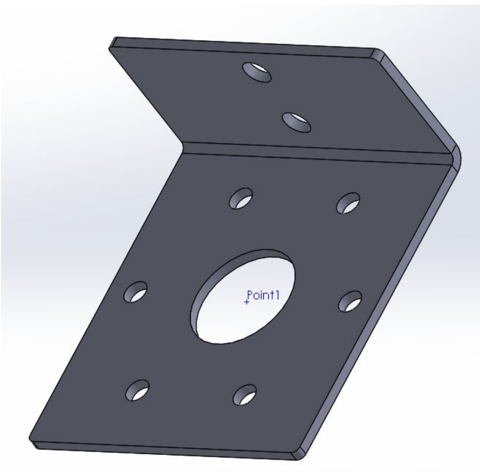


Figure 6 CAD of the mask

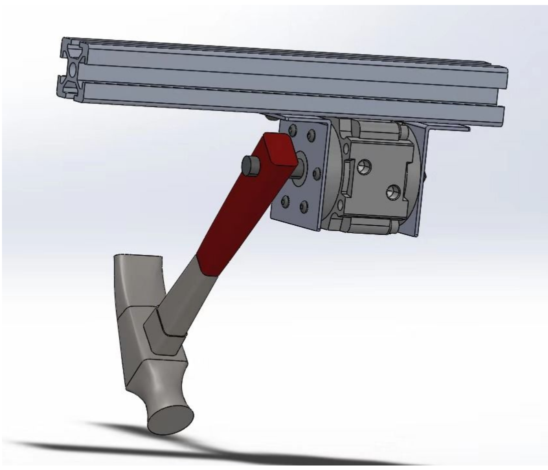
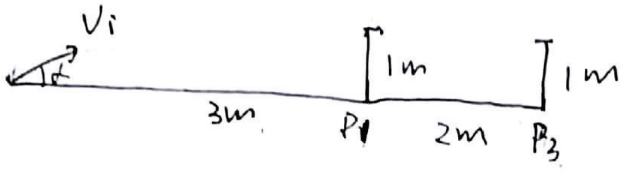
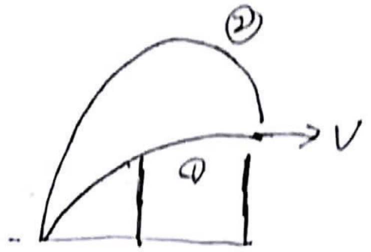


Figure 7 kicking part of the robot

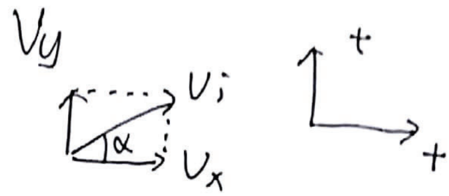
Appendix A- calcualtion of kicking force and angle





For ①

$$\begin{cases} x_1 = 3m & y_1 = 1.2m \quad (y > 1m) \\ x_2 = 3.6m & y_2 = 1.2m \quad (y > 1m) \\ x_3 = 5m & y_3 = 1.2m \quad (y > 1m) \end{cases}$$



$$\alpha = \tan^{-1} \frac{V_y}{V_x}$$

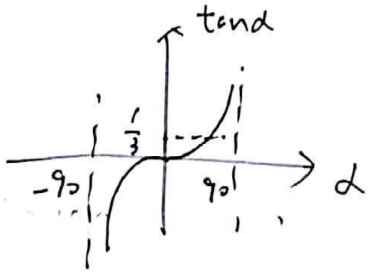
At x_1, y_1 $\quad t = \frac{3}{V_x} \quad y = V_y t - \frac{1}{2} \times 9.81\, t^2 > 1$

At x_2, y_2 $\quad t = \frac{5}{V_x} \quad y = V_y t - \frac{1}{2} \times 9.81\, t^2 > 1$

$$\begin{cases} 3\frac{V_y}{V_x} - 4.905\frac{9}{V_x^2} > 1 \\ 5\frac{V_y}{V_x} - 4.905\frac{25}{V_x^2} > 1 \end{cases} \rightarrow \begin{cases} 3V_xV_y - 44.145 > V_x^2 \\ 5V_xV_y - 122.625 > V_x^2 \end{cases}$$

$$\begin{cases} V_x^2 - 3V_xV_y + 44.145 < 0 \\ V_x^2 - 5V_xV_y + 122.625 < 0 \end{cases} \quad (V_x, V_y > 0)$$

$V_y = \tan\alpha \cdot V_x$ $\quad (0 < \alpha < 90° \Rightarrow \tan\alpha > 0)$



$$\begin{cases} V_x^2 - 3\tan\alpha\, V_x^2 < -44.145 \\ V_x^2 - 5\tan\alpha\, V_x^2 < -122.625 \end{cases} \rightarrow \begin{cases} (3\tan\alpha - 1)V_x^2 > 44.145 \\ (5\tan\alpha - 1)V_x^2 > 122.625 \end{cases}$$

$$\begin{cases} 3\tan\alpha > 1 \\ 5\tan\alpha > 1 \end{cases} \Rightarrow \begin{cases} \tan\alpha > \frac{1}{3} \\ \tan\alpha > \frac{1}{5} \end{cases} \quad 18.44° < \alpha < 90°$$

$$\begin{cases} V_x^2 > \dfrac{44.145}{3\tan\alpha - 1} = A \\ V_x^2 > \dfrac{122.625}{5\tan\alpha - 1} = B \end{cases}$$

$\tan 18.44^\circ = \frac{1}{3}$

$18.44^\circ < \alpha < 90^\circ$,

$$A = B \Rightarrow \frac{44.145}{3\tan\alpha - 1} = \frac{122.625}{5\tan\alpha - 1} \Rightarrow 220.755\tan\alpha - 44.145$$

$$= 367.875\tan\alpha - 122.625$$

$$147.12\tan\alpha = 78.47$$

$$\tan\alpha = 0.533$$

$$\alpha = 28^\circ$$

when $\alpha = 28^\circ$

$$U_x^2 > \frac{44.145}{3\tan 28^\circ - 1}$$

$\alpha > 28^\circ$ $A > B$ take A

$\alpha < 28^\circ$ $A < B$ take B

excel calculation

$$V_x > 8.62\ m/s$$

tolerance ~15°

For minuum V_i $\Rightarrow$ $\alpha = 50^\circ$ ($\alpha = 50^\circ \pm 15^\circ$)

$\alpha = 50^\circ$ $U_x = 4.97\ m/s$ $V_y = 5.92\ m/s$ $V_i = 7.73\ m/s$

$\alpha = 35^\circ$ $V_x = 7\ m/s$ $V_y = 4.9\ m/s$ $V_i = 8.55\ m/s$

$\alpha = 65^\circ$ $V_x = 3.55\ m/s$ $V_y = 7.6\ m/s$, $V_i = 8.39\ m/s$