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Research Article

Design and Manufacturing of Frisbee Launching Robot

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Abstract

Frisbees are a common source of entertainment and sport, although the physics behind these flying discs is often taken for granted. Frisbees operate under two main physical concepts, aerodynamic lift and gyroscopic stability. Nowadays we see growth of automation not only in industries but also in sports. As Frisbee throwing is a major sport in USA, so we developed a robot for the same. This paper consists of Design, Manufacturing and analysis of "Frisbee launching Robot" for various elevation, angle and range. It consists of design and fabrication of Chassis, Frisbee Launching mechanism, Angle setting mechanism, Frisbee Loading mechanism, Frisbee pushing mechanism and PCB Circuit Board. Also various results and data is concluded after testing of robot.

Keywords: *Frisbee, PCB, Chassis, Gyroscopic.*

1. Introduction

The first plastic Frisbee was created in the 1940's and now over 50 companies produce flying discs of varying size and weight. More flying discs are sold each year than baseballs, basketballs, and footballs combined (Wham-O.com). Frisbee appeal has exploded from a mere recreational toy to spawn numerous international sports including Ultimate Frisbee, Disc Golf and Freestyle. Its popularity stems from the aerodynamic characteristics that allow a variety of maneuvers and flight paths, all relatively easy for a new thrower to learn. International governing bodies such as the Professional Disc Golf Association and the World Flying Disc Federation promote the development and advancement of Frisbee games, culminating in the appearance of Ultimate and Disc Golf in the 2001 World Games in Akita Japan as full medal sports. Walter Morrison and Ed Hedrick each played a defining role in the evolution of the Frisbee. Morrison manufactured the first disc in 1948, improving his design in 1951 to produce the Pluto Platter. Wham-O teamed up with Morrison in 1957 and began mass production. Inspired by a trip to Ivy League campuses, Wham-O executives renamed their discs "Frisbees" and currently hold the trademarked name (Hummel, 2003). Other manufacturers make discs, but only Wham-O makes Frisbees. Ed Hedrick served as executive Vice President, General Manager and CEO of Wham-O over a ten-year period. His major contributions stem from his vision to expand Frisbee to more than just a game of catch. He experimented with the design and in 1965 filed his new Frisbee model with the US Frisbee Association, he promoted and organized various Frisbee sport competitions throughout the United States, remaining active up until his death in 2002. (Kathleen Baumback,2010).

Prior to plastic, Frisbee's did exist in a somewhat similar but metallic form. As early as the 1920's, Yale students flung their left over pie tins to each other across cafeterias and campuses. The pin tins bore the stamp "Frisbee Pies" for the name of the manufacturer, the Frisbee Pin Tin Company. Other claims exist also regarding "who threw the first disc", some even jokingly tracing the earliest origins to the 450 B.C. statue of Disco bolus. patent Office, vastly improving the stability of the Frisbee. Founder of the International.

Most recently, research has been conducted into determining the coefficients that determine that magnitude of all forces acting on a Frisbee as well as the biomechanics involved in throwing a Frisbee (Hummel, 2003). Also, there is further unpublished research looking into other aspects of a Frisbee's flight including methods of taking data directly from the Frisbee's flight. (V.R.Morrison,2005)

Here we are using Volley Frisbee which are made in Germany having weight 35 grams and 240mm diameter.

2. Scope

The robot can be used in a variety of applications and in varied spheres influencing the human race. The various applications can be in the field of education, sports, defense as follows:

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- Stacking of goods in warehouse.
- Experimental setup for educational purpose.
- Can be used in defense for launching purpose.
- Sports purpose.

2. Design

Since the Frisbee flies using projectile concepts a basic review of projectile motion parameters and its working becomes essential. They are as follows:

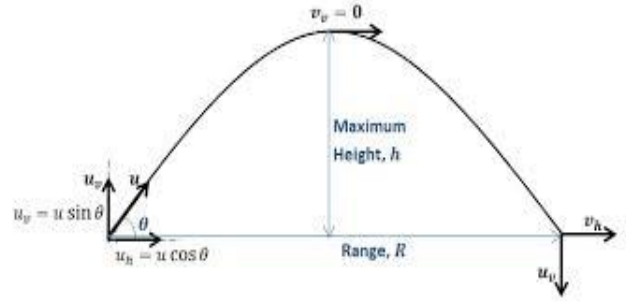


Fig.1 Projectile Motion

For a point mass the generalized projectile motion equation is as follows:

$$y = xtan(\theta) - \frac{g*x^2}{(2*(\cos(\theta)*u)^2)}$$

$$R = u^2 * \sin(2\theta)/g$$

$$H = u^2 * \frac{(\sin\theta)^2}{2*g}$$

Frisbee

It is a circular plate with considerable thickness having a cavity at bottom. The cavity at bottom makes the Frisbee equivalent to a streamline aerodynamic model. Due to its equivalence with an aerodynamic model lift and drag forces act on it. Also Frisbee is a distributed mass following a projectile motion (Abhijit Mahapatra, Avik Chatterjee, Shibendu Shekhar Roy,2009).

The various forces acting on a Frisbee are:

- Gravitational force
- Lift force
- Drag force
- Externally applied force

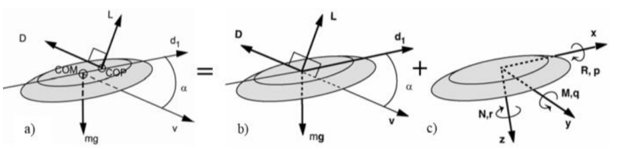


Fig.2 Forces acting on Frisbee

Gyroscopic Stability

The rotation of a Frisbee is a necessary component in the mechanics of how a Frisbee flies. Without rotation, a Frisbee would just flutter to the ground like a falling leaf and fail to produce the long distance, stable flights that people find so entertaining. This is caused by the fact the aerodynamic forces described in the previous section are not directly centered on the Frisbee. In general, the lift on the front half of the disc is slightly larger than the lift on the back half which causes a torque on the Frisbee. (Jonathan R. Potts & William J. Crowthert ,2002).

When a Frisbee isn't spinning, this small torque flips the front of the disc up, and any chance for a stable flight is lost. When a Frisbee is thrown with a large spin, it has a large amount of angular momentum that has a vector in either the positive or negative vertical direction. When the small torque is exerted, the torque vector points to the right side of the Frisbee (when viewed from behind.) This can be determined using the right hand rule with:

$\tau = r \times F$

Since,

$\tau = dL/dt$

the angular momentum vector will begin to precess to the right. This phenomenon can easily be viewed when throwing a Frisbee, this is the reason that many thrown Frisbees bank to either the left of the right. Due to this, the greater the initial angular momentum given to the Frisbee, the more stable it's flight will be.

The mathematical modeling of the drag and lift forces acting on the Frisbee can be stated as follows:

Drag Force

$$F_D = \rho * C_D * A * u^2/2$$

Lift Force

$$F_L = \rho * C_L * A * u^2/2$$

The net acceleration acting in x-direction of the projectile motion is given by:

$$a_x = -\frac{k*u_x^2}{cos\theta*m} - \rho * u_x^2 * A * C_L * \frac{sin\theta}{2*m*\cos^2\theta}$$

The net acceleration acting in y-direction of the projectile motion is given by:

$$a_y = -g - \frac{k*u_y^2}{sin\theta*m} + \rho * u_y^2 * A * C_L * \frac{cos\theta}{2*m*\sin^2\theta}$$

Taking C_L=0.026 and C_D=0.0432 m=0.36kg θ=25°
k= $\rho * C_D * A/2$=0.00117

We get

$$a_x = -\frac{0.00117*u_x^2}{cos25°*0.036} - 1.2 * u_x^2 * 0.0452 * 0.02602 * \frac{sin25°}{2*0.036*\cos^2 25°}$$

$$a_y = -9.81 - \frac{0.00117 * u_y^2}{sin25° * 0.036} + 1.2 * u_y^2 * 0.0452 * 0.02602 * \frac{cos25°}{2*0.036*\sin^2 25°}$$

$$0.5 = u_y * 2 + a_y * \frac{2^2}{2}$$

$$6 = u_x * 2 + a_x * \frac{2^2}{2}$$

Hence we get,

u_x=18.126m/s

$u_{y=}$8.452m/s

u=$\sqrt{u_x^2 + u_y^2}$

Therefore, we get, u=20m/s

Also, u=r*w

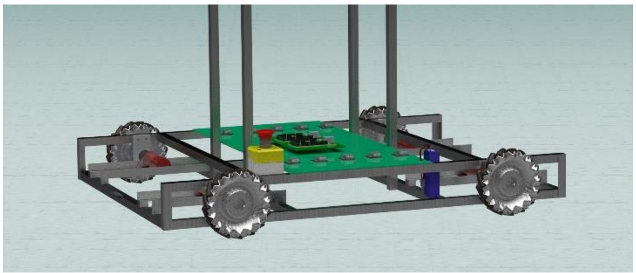
r=.24m

w=83.33rps

N=800rpm.

Hence the selected motor is having 800rpm.

3. Chassis



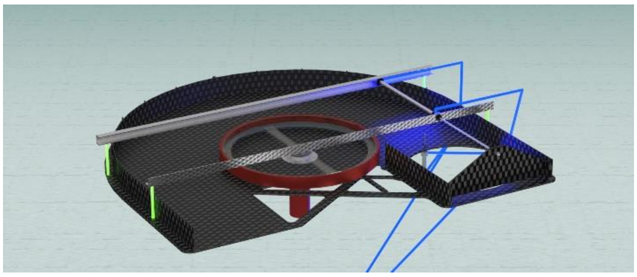
Photograph 1. Chassis

Type	Rectangular Double Layered
Materials used	Aluminum Square Sections 19mm *19 mm
Motor	Brushed Planetary Geared DC Motor. Speed- 400rpm. Torque- 29.1 Ncm.
Wheels	Meccanum wheels Diameter-120mm
Wheel Mountings	Flange, rectangular hub, rigid coupling, bearing.
Bearing	6100. Make- SKF.
Chassis Fabrication Methods and Operations	Riveting, Bolting, Welding.
Power rating	12 V max 18A

Fabrication of chassis

- The lower layer of the chassis is manufactured by welding of the aluminum sections. First the fixture was made. The aluminum sections were placed over it and then the welding was carried out.
- The flange, which is attached to the meccanum wheel, is made of aluminum and is manufactured by performing CNC and VMC operations.
- The hub, which guides the flange is made of nylon and is manufactured by water jet operation and milling operation.
- The second layer of the aluminum is bolted and is placed nearer to the wheel in order to avoid bending of the chassis.
- The bearing is press-fitted into the hub and flange for smooth rotating operation.
- The supporting elements to the upper part of the bot which are made of aluminum sections are bolted to the chassis.

4. Launching Mechanism



Photograph 2. Frisbee launching mechanism.

Wheel	Wheel diameter- 330mm. Rim thickness-5mm Rim width- 25mm Web thickness- 5mm Weight- 300gm Manufacturing method- Laser Cutting.
Wheel Mounting	Flange, Bearing. Material- Aluminum.
Bearing	61902 Make- SKF
Guide ways	Material- Acrylic
Motor	Brushed Planetary Geared Motor. Speed- 1600 rpm.
Rubber	Grip Material- ABRA 40.
Base plate	Carbon Fiber
Upper shield	Corrugated Polycarbonate Sheet.
Weight	1.7kg

This mechanism is used to land the Frisbee over the platform. It consists of a spiral path which enables the Frisbee to gain momentum. It has a centrally placed wheel mounted on the motor of 1600 rpm. This wheel gives the required linear as well as angular momentum to the Frisbee. The wheel wrapped with a rubber (ABRA 40). The wheel is coupled to the motor through flange coupling and bearing. The bearing is housed inside the base plate. The wheel rim is made up of Acrylic.

Dimensions: 165 mm radius of the spiral path

5. Loading Mechanism

Photograph 3 .Loading mechanism

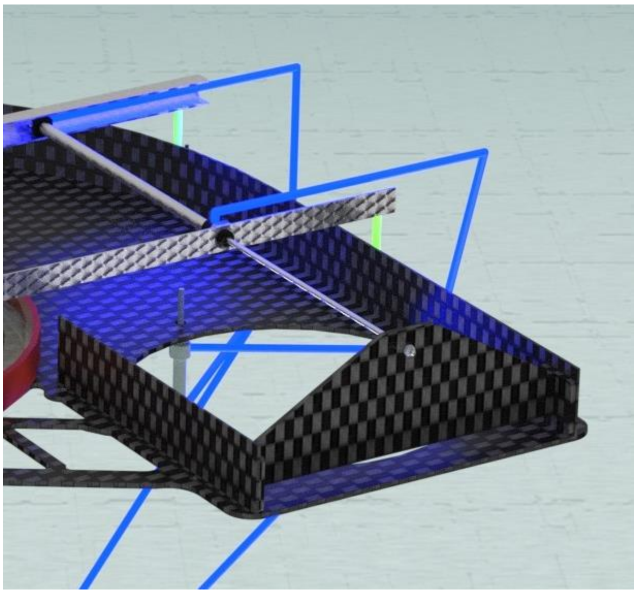
Technical Specifications of Loading Mechanism

Lead Screw Material	Stainless Steel
No of starts	4
Pitch	10 mm
Locking	Self-gliding
Nut type	Circular flange
Nut material	Brass
Bearing Used	5 I.D 13 O.D Single-Roll Ball Bearing
Upper and lower base Material	Nylon
Frisbee Platform	Acrylic
Frisbee Guide used	Poster Paper semi -circular
Base Supports	S.S hollow pipes diameter 12mm
Lead Screw Drive	Stepper Motor
Couplings	Aluminum Flexible Coupling.

6. Frisbee Pushing Mechanism

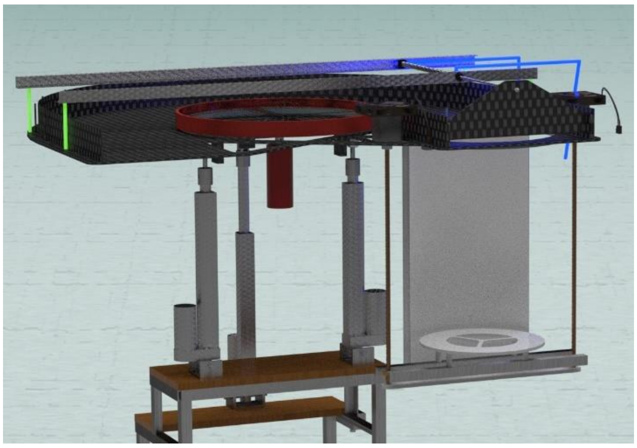
Technical Specifications of Frisbee Pushing Mechanism

Pushing Plate	Carbon Fiber.
Actuator	Pneumatic cylinder. Make: JANATICS Bore Diameter: 20mm Piston Rod: 6mm Double Acting.
Direction Control Valve Type	5/2 solenoid operated spool
Flow Control Valve	Manual setting screw type.
Pneumatic Storage Tank	Plastic Bottle
Tubes	O.D 6mm I.D 4mm Material-P U
Connectors	L –type, T-type, Cross-type.



Photograph 4. Pushing mechanism

7. Angle Setting Mechanism



Photograph 5. Angle setting mechanism

Technical Specifications of Angle Setting Mechanism

Angle setting	Actuator
Actuator Mountings	Tie- rod end, spherical-rod end, c-type Material- Aluminium.
Base	wood
Joints	Material- Nylon.

Technical Specifications of Actuator

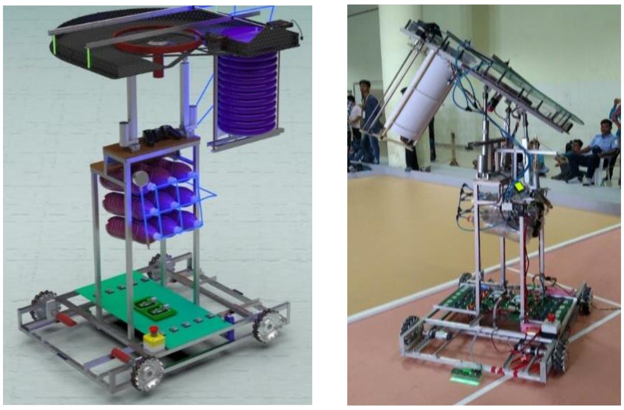
Quantity used	3
Brand	HIWIN
Type	LAS1-2-1-200-12G
Maximum Force	600N
Maximum Self-locking	300N.
Maximum Speed	25mm/sec
Stroke	200 mm
Power rating	12V, Max 6A.
Weight	1.14kg

It consists of three actuators. These actuators are placed just beneath the base plate through spherical tie-rods. This mechanism is used to provide pitching and rolling motion to the base plate of launching mechanism so as to achieve the required angle of projection. These actuators have a stroke length of 200 mm and each actuator can lift a load of maximum 600N and they are electrically actuated.

Working

- During pitching the front actuators are operated simultaneously to lift the platform from front which provides the positive angle of attack for the Frisbee.
- During rolling, one of the front actuator is lifted more than the other front actuator synchronously.
- The bottom portion of all the actuators is hinged to the chassis with the help of C-clamps.
- The yawing motion is provided by the navigation of the entire robot about its vertical axis.
- Thus both the pitching and rolling motion provides the required configuration of the launching mechanism.

8. Assembly



Photograph 6. Complete Robot

9. PCB

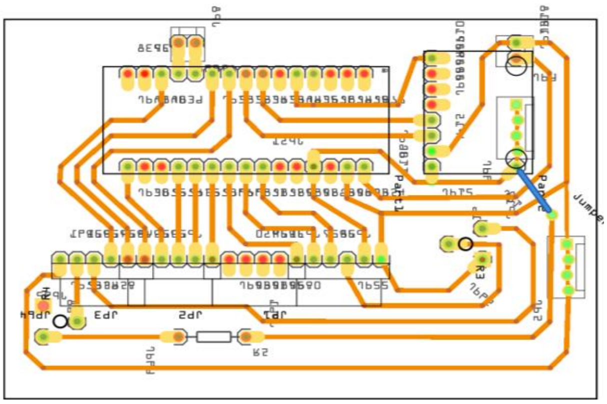


Fig. 2 PCB for Gyro sensor

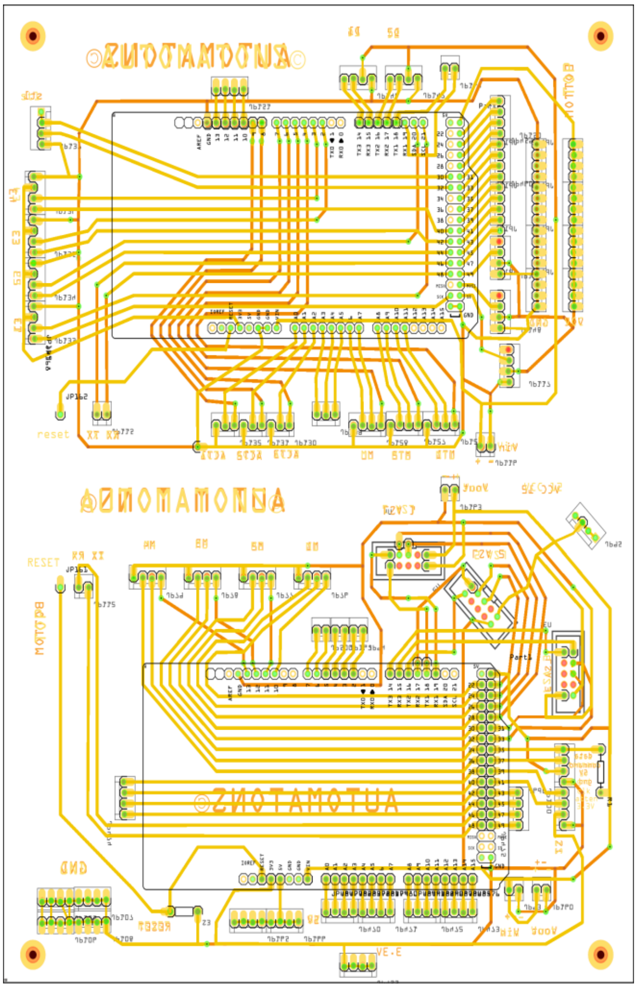


Fig.3 Main Robot PCB

10. Results and Discussions

- Position no 1 (First Pole height 1m, Range 2m)

Pitching	42°
Rolling	18°
Yawing	91°
PWM	60

- Position no 2 (Centre Pole height 1.5m, Range 5m)

Pitching	42°
Rolling	18°
Yawing	88°
PWM	111

- Position no 3(Centre Left 1 m, Range 5m)

Pitching	42°
Rolling	18°
Yawing	90°
PWM	108

- Position no 4(Centre Right 1 m, Range 5m)

Pitching	42°
Rolling	18°
Yawing	76°
PWM	109

- Position no 5 (Centre Left 0.5 m, Range 5m)

Pitching	39°
Rolling	18°
Yawing	88°
PWM	99

- Position no 6 (Centre Right 0.5 m, Range 5m)

Pitching	39°
Rolling	18°
Yawing	89°
PWM	101

- Position no 7 (Farthest Pole 1 m, Range 8m)

Pitching	52°
Rolling	34°
Yawing	82°
PWM	150

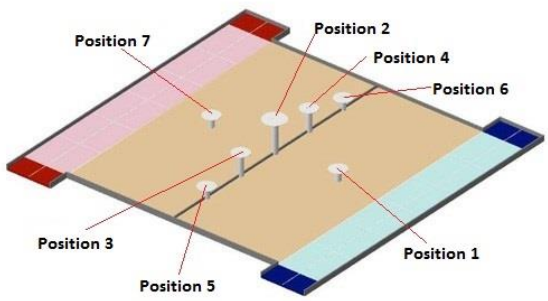


Figure 4. Testing rig.

11. Discussions

- The rolling angle is observed to be constant for center and front poles while it increases for the last pole.
- As the range increases the RPM is to be increased.
- As the height increases the RPM is to be increased.
- As the weight of the Frisbee increases its bouncing effect also increases.

Conclusion

- The Landing Mechanism – spiral path was selected as the final mechanism.
- Appropriate motors according to speed and torque requirements were selected according to the need of the landing mechanism and the chassis.
- The robot was Manufactured and Assembled successfully.
- The robot was tested successfully and various parameters needed for landing of Frisbee were determined.

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