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DESIGN AND DEVELOPMENT OF DISC THROWING ROBOT WITH VARIABLE ANGLE MECHANISM

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Abstract: **The said research proposes design and development of disc throwing robot with variable angle mechanism. The angle is changed with the help of a chain drive and planetary DC geared motor with encoder. This robot can change its position with the help of wheels and can carry multiple number of discs. Specially designed stack of disc holder is used for the loading the disc on to the robot. The displacement of the robot is precisely controlled by the encoder. In addition, the robot is equipped with the manual remote controller. The autonomously driven program can function based on the manual operator. Main aim of these paper is to design the robot and to drive the robot in multiple direction for throwing the disc at specific position.**

***Index Terms*: Disc, Robot, Autonomous System, Variable angle mechanism.**

I. INTRODUCTION

As seen in many sports and in defense industries, the specially designed disc is used to throw at distant places. In the Olympics, during the game of shooting, the disc thrown at a certain inclination and the shooter needs to shoot the disc with speed and accurate calculation. In defense industry, there is a need to throw bombs and various other things at a certain distance. These applications there is a need to design a system which would perform these tasks accurately, fast and which will reduce the human fatigue. . The accordingly the robots are designed and developed. The robot will be a hybrid-controlled robot which will be driven autonomously and by remote control. . It is proposed that the robot will have a provision to activate or de-activate the robot by a remote control. Human intervention is required when the robot has a limitation to judge the surface non-linearity and worst climate condition which can lead to failure of sensors and encoders. Thus, manual mode is also required to control the robot. Whereas in the constrained condition, there is limited space and a wrong calculation will lead to failure. Considering these conditions, we have selected autonomously controlled mechanism. The robot is designed by considering variability in the angle and drive selection.

Apart from the above stated application, wherever there is precision required and space constraint, these robots can be used in warehouse for stacking the products at a certain location, elevated platform, etc. The other application is in the educational field to demonstrate the laws of mechanics. During the launching of the disc, of the design calculations are based on parameters such as wind, pressure, etc..

II. ELECTRONICS GENERAL FLOWCHART:

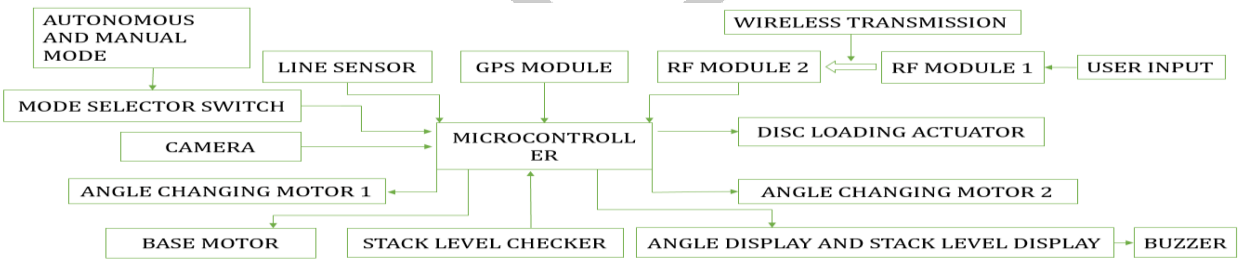

Figure 1: Electronics Flowchart

1. ELECTRONICS PART DESCRIPTION:

a. MODE SELECTOR SWITCH: The mode of the actuation of robot was selected from these switches. This type of toggle switch has first mode as autonomous and second one as manual mode. This mode should be selected before the robot is activated since the button only decides whether the robot will move in either modes. This switch act as a start and stop button because no command is given unless and until tthe user presses the button in manual mode and unless and until the camera senses the motion in autonomous mode.

b. MICROCONTROLLER: It is the most important part of the whole system since the all the analytical and logical calculation is been done by this controller only. This controller receives all the sensing data from the sensor and act accordingly through the actuators.
c. LINE SENSOR: This sensor was used for sensing the line or used to follow the line. Thus if the control was in manual mode then the robot follows the line and acts accordingly where ever the line takes to him.
d. GPS MODULE: This module works in the autonomous as well as in manual mode in order to locate the location of the robot wherever in the world. With the help of this module it becomes easy to operate the robot in autonomous mode.
e. RF MODULE 1: This is signal transmitter from the user to the robot itself. Whenever the user presses any switch on the remote then it sends it to the RF module 2.
f. RF MODULE 2: This is the signal receiver from the user to the robot itself. It provides directly the signals cached from the RF module to the robot.
g. CAMERA: This camera detects the trajectory of the disc with depth sensing. Thus it becomes easy to change the angle of the disc launcher accordingly. It plays most important role in placing the disc at the desired location. With the help of this camera the controller develops certain algorithm for placing the disc.
h. DISC LOADING ACTUATOR: The discs are loaded on to the robot in the form of stacks. It becomes very important to load the disc into the launching mechanism one by one. Therefore this actuator helps the robot to load the discs one by one by pushing the disc into the mechanism.
i. ANGLE CHANGING MOTOR 1: This motor defines the pitch angle of the robot. This motor is controlled by the microcontroller and the camera. As soon as there is a need of the increase or decrease of the pitch angle then controller sends the command to the actuator to rotate accordingly.
j. ANGLE CHANGING MOTOR 2: This motor defines the roll angle of the robot. This motor is controlled by the microcontroller and the camera. As soon as there was a need of the increase or decrease of the roll angle then controller sends the command to the actuator to rotate accordingly.
k. BASE MOTOR: Base motor used to displace the robot in desired direction. Each wheel was driven separately using individual motors.
l. STACK LEVEL CHECKER: The level of the disc was indicated with the help of this checker and tells the user to load the disc whenever the level of the disc decreases.
m. ANGLE AND STACK LEVEL DISPLAY: The angle of the pitch and roll was displayed on the screen with this. The display was used for the user convenience to show the user during testing what was angle required for the proper placing of the disc on to the desired location. Also the number of the disc left in the stacks was displayed in the display.
n. BUZZER: As soon as the disc was finished from the stacks the buzzer starts buzzing and tells the user to load the new stack of the disc. The buzzer is used because not every time the robot is controlled by the manual operator. Thus to tell the maintenance person to load the new stack. Also during the disc launching the user will not every time look at the display to determine the number of disc left, thus these buzzer also tells the user to move back the robot to loading zone.

2. DESIGN PARAMETERS

Light weight: Our Robot needs to travel through very complicated places and where they are required to maintain its center of gravity, and many more parameters. Thus in order to satisfy these conditions the robot needs to be light weight. Also, more the inertia more was the power required to control the robot and it becomes difficult for the robot to travel through off terrain.
Fast actuation: More fast the robot it becomes very easy to do the task in time and thus benefits the user to multiple task in minimum rate.
Mobile: The robot should be mobile thus it was required to provide it with the wheels to the controller or to displace the robot in all terrains.
Multi degree of angle: It should have wide range of resolution and should shoot the Frisbee in any range and direction.

3. DESIGNING OF CHASSIS

The chassis was developed with the help of the commercial grade aluminum material. These material was selected because of the light weight and good machinability. The structure was decided only because of the strength and stability of the robot. The motors were mounted on the chassis with the help of the motor clamp, the motor used for the base chassis were planetary DC geared motor with encoder. The special type of the wheel was used for the displacing the robot in various direction. The wheel used was OMNI wheel. The wheel was coupled with the motor using the flexible coupling and the wheel was supported with the bearing house from both the sides and allows the weight distribution over the chassis equally. It does not allow the weight of the chassis to fall on the motor shaft and hence the motor only delivers the torque to the wheels. The chassis is used for carrying the whole load of the body. The chassis structure was designed in multi-section in order to avoid the bending of the chassis.

4. DESIGN OF TRIGGERING MECHANISM

The loading mechanism was nothing but the slider crank mechanism. This mechanism consist of the one motor and three linkages. These linkages were mounted such that when the motor takes one complete turn then it loads one disc in the launching mechanism. The motor used in this mechanism was planetary geared motor with encoder. This mechanism is having the rate of loading 5 discs in one minute. This mechanism was very fast and actuated due to the high RPM motor and less friction between the sliding parts. This mechanism eliminates the complicated pneumatic mechanism and it’s demerits are leakage, large reservoirs, and control of the arm in intermediate position. This mechanism was developed using the light weight material called aluminium. The axis of the motor was perpendicular to the direction of the sliding linkage.

5. DESIGN OF LAUNCHING MECHANISM

The launching mechanism consist of high speed amp flow motor, the specialty of this motor was to maintain its torque and speed even at the different loading conditions. This mechanism was used to throw the disc at any given condition over a wide range. The mechanism contains the central wheel, curve path. It consists of a curve path which enables the disc to gain momentum. It contains the centrally mounted wheel coupled with the amp flow motor of 2900 rpm. With the help of this wheel the disc gets the required linear as well as angular momentum. The wheel was covered with a rubber. In order to avoid the friction between the wheel shaft and motor shaft with the curve surface chassis the bearing was installed to the mechanism. The motor was coupled to the wheel shaft with the Oldham coupling. The wheel was pivoted with the help of the wheel shat and does not allow to touch the lateral surface of the curve chassis in order to avoid the friction and which results in speed reduction of the wheel, but as we have used the amp flow motor it maintains its speed by consuming more power. Thus we had pivoted the wheel with the shaft. The clearance between the wheel and the curve surface chassis was very minimum so that the wheel just gets lifted from the base. The wheel was made up of Acrylic material with centrally placed holes in order to reduce the weight and inertia of the wheel. This increases the speed and reduces the power consumption and increases the battery life.. The rotation speed of the motor was controlled using the PWM signals. This signals were transferred from the controller which primarily senses the distance between the robot and the desired point where it needs to place the disc and then judge the speed of the motor required to provide the momentum to the disc. During the manual mode the speed directly falls on the LCD display where the user sets it manually and then the required momentum for the disc was acquired. More important thing involved in the launching the disc is the smoothness of the curve surface of the launching mechanism, because the momentum gets reduced due to frictional surface, which subsequently changes its trajectory. In this way the launching mechanism works.

6. DESIGN OF STACK

The stack mechanism was built on the basis of the law of gravitation. There was no special stack mechanism used for the stack, but the container used for the storing the multiple disc and release the disc one by one as the triggering mechanism loads the disc into the launching mechanism. The stack was designed according to the disc size and shape. It was used for holding minimum 20 disc at a time and can be modified to store up to 30 to 40 discs at a time based on the size and shape of the disc. The specialty of this mechanism was to build the pressure on the disc continuously with the help of the spring. As soon as the triggering mechanism loads the disc for launching and come backs to its original position, the stack mechanism inserts the disc in front of the triggering mechanism that allows the mechanism to be ready for the next round. Stack was arranged above and perpendicular to the launching mechanism to avoid the complication in the angle changing mechanism. The material of the stack was of acrylic mold in the form of a cylinder. The spring was used for creating a little pressure on the disc in order to avoid difficulty in removing the disc from the stack. In this way the stack mechanism works. It was placed accordingly to maintain its center of gravity of the robot during the displacement of the robot.

7. DESIGN OF ANGLE CHANGING MECHANISM

The angle mechanism was used for creating the elevation platform for the launching of the disc. The mechanism consist of the chain and sprocket drive. The sprocket was used to drive the chain in either direction. The two mechanisms of the same type were used for these angle changing mechanism. The first mechanism was used for changing the pitch angle of the mechanism and the second one was used for the roll angle of the mechanism. The required angle was defined by the camera used and thus the data capture by the camera was sent to the microcontroller.

CALCULATION

When the point mass was projected then it follows the projectile motion, this projectile motion is given by the following equation, To find every point on a trajectory we use the equation 1. Where,

$$y = x\tan(\theta) - \frac{g\,x^2}{2(\cos(\theta)U)^2}\,(1)$$

$\theta = angle\ of\ elivation$
$y = displacement\ in\ y\ direction$
$x = displacement\ in\ x\ direction$
$g = gravitational\ acceleration$
$U = initial\ velocity$
$R = range\ of\ the\ projectile$
$H = maximum\ height\ of\ the\ projectile$

In order to find the range of the projectile we use the formula of range which was given by the equation 2.

$$R = \frac{U^2 \sin(2\theta)}{g} \qquad (2)$$

In order to find the height of the projectile we use the formula of height which was given by the equation 3.

$$H = \frac{U^2 (\sin\theta)^2}{2g} \qquad (3)$$

The disc was a circular plate with specific dimension. If we relate it with the aerodynamic model it bears same forces as that of the aerodynamic body, such as drag and lift forces. If we draw the free body diagram of the disc then we get that various types of forces acts on it in practice.

1. LIFT FORCE

$$Fl = \frac{\rho \,.\, Cl \,.\, A .\, U^2}{2} \qquad (4)$$

where,

$Fl = Lift\ Force$

$\rho = Density\ of\ Air$

$Cl = \ Lift\ Coefficient$

$A = \ Reference\ Area$

2. DRAG FORCE

$$Fd = \frac{\rho \,.\, Cd \,.\, A .\, U^2}{2} \qquad (5)$$

Where,

$Fd = Lift\ Force$

$Cd = \ Drag\ Coefficient$

GYROSCOPIC ACCELERATION

$$Ax = \frac{-\rho\ Cd\ A\ .\ U^2 x}{2\ \cos(\theta).\ M} - \frac{\rho\ U^2 x\ A\ Cl\ \sin(\theta)}{2\ M\ \cos^2(\theta)} \qquad (6)$$

$$Ay = -g - \frac{-\rho\ Cd\ A\ .\ U^2 y}{2\ \sin(\theta) M} - \frac{\rho\ U^2 y\ A\ Cl\ \cos(\theta)}{2\ M\ \ \sin^2(\theta)} \qquad (7)$$

$Ax = \ X\ component\ of\ accleration$

$Ay = \ Y\ component\ of\ accleration$

$M = \ Mass\ of\ the\ Disc$

MODEL

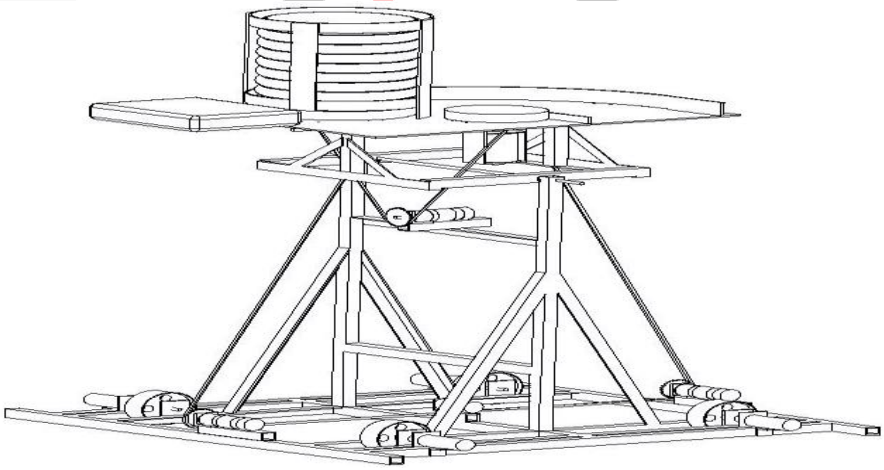

Figure 2: Isometric view

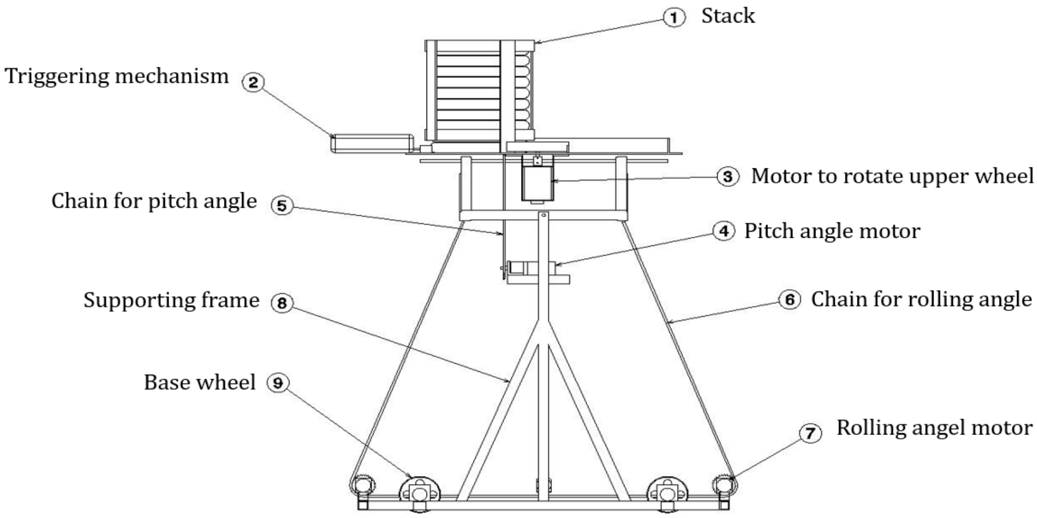

Figure 3: Front View

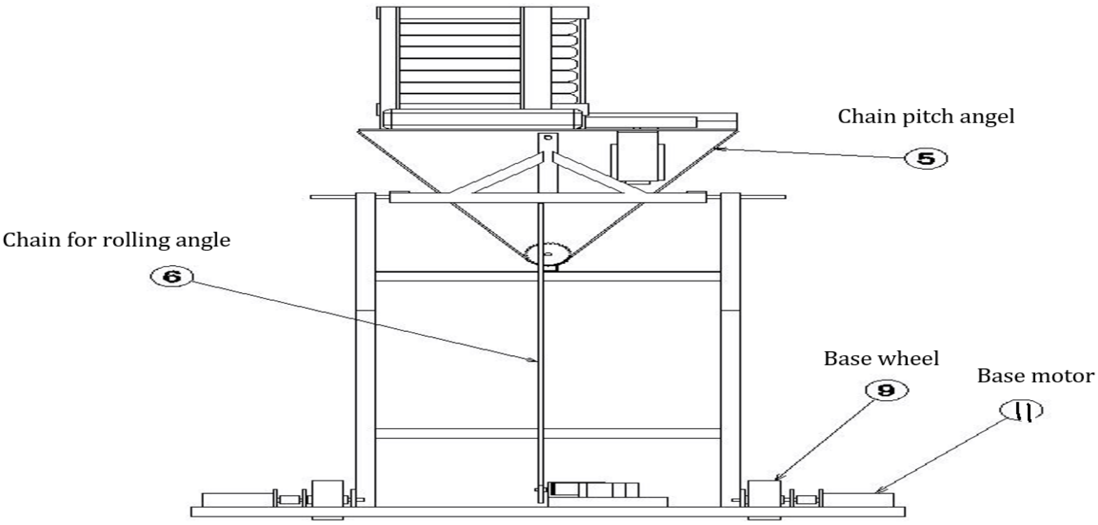

Figure 4: Side View

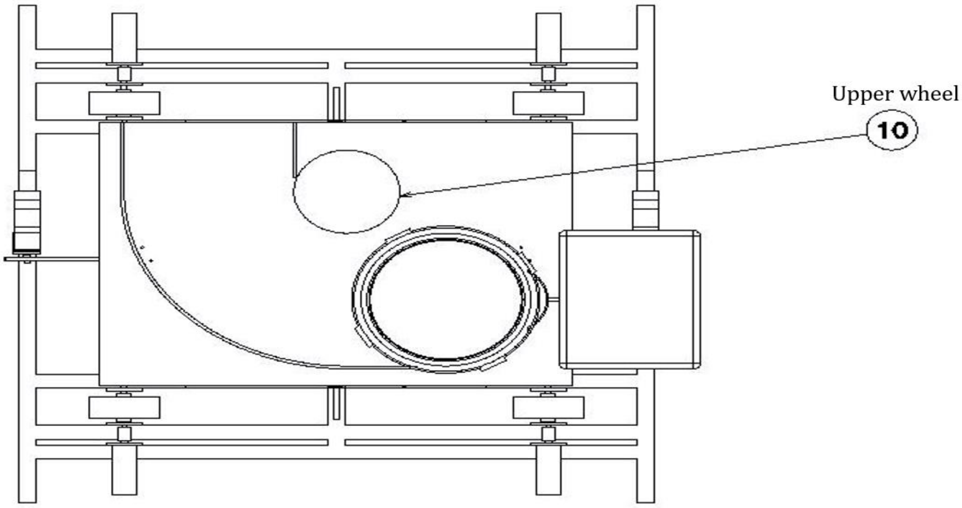

Figure 5: Top View

Figure 2 shows the complete isometric view of the robot and its parts located at specific position. The actual experimental setup is similar to the figure 2. The figure 2 does not show the electronic component attached to the figure. The overall setup of the robot is mostly made from the commercial grade aluminium material with most of the plate structure made acrylic material. Figure 3 shows various parts used in the model such as part 1 as stack, part 2 as Triggering mechanism, part 3 as upper wheel rotating motor used for creating rotational motion on the disc, part 4 as pitch angel changing motor situated beneath the upper platform used for stack and triggering mechanism holding, part 5 as chain for pitch angel which is driven by the part 4, part 6 as the rolling angel chain used for changing the rolling angel which is driven by the part 7, part 7 as rolling angel changing motor, part 8 as the frame structure used to support the structure, part 9 as base wheel used to create the yawing motion and displace the robot without friction on the floor, part 10 as the upper wheel used to rotate the disc with the help of the motor part 3 the wheel is couple with the motor part 3 rigidly, part

11 as the base motor used for driving robot. Figure 4 shows the side view of the robot with some major parts such as part 5, 6, 9, 11. Figure 5 shows the top view of the robot with the part 10 upper wheel mounted on it. Figure 6 is the actual experimental setup of the disc throwing robot. The setup was manufactured in the in-house facility. The whole structure was tested and the results are given below and discussed.

Figure 6: Actual Experimental Setup

RESULT

Table 1: Results of the experiment

Distance (m)	2	5	6	8	10
Wheel (rpm)	706	1310	1471	1765	2059
Rolling Angle (degrees)	11	16	16	23	23
Pitch Angle (degrees)	45	48	48	56	56
Yawing Motion (degrees)	0	5	5	15	20
Height Achieved (m)	1	1.5	1.5	1	1

Table 1 shows the results of the experiment. The rolling angle, the yawing motion and the pitch angle was given in terms of degrees. Whereas the height and the distance (Range) was given in terms of meters. The respective results were obtained on the basis of the experiments perform. The results were obtained based on experiments in the laboratory. It may vary if the experiments are carried out on-site.

DISCUSSION

I. It can be stated from the above table that as pitch angle is directly proportional to the elevation height required.

II. It can be also stated that as during the throwing of the disc in order to increase the stability of the disc we need to increase the rolling angle of the plat form.

III. As the limit of the disc throwing is reached we can increase the translational motion and achieve the target.

IV. We can say that as the distance increases for throwing the disc the RPM of the Upper motor is also increases.

V. Weight of the disc is directly proportional to the bouncing effect of the disc.

VI. Material and shape of the disc plays a very crucial role in throwing the disc to destination and to main its stability.

VII. Height achieved and distance covered is inversely proportional to each other. i.e. as height increases the range decreases and vice versa.

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