International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

Semi-Autonomous bot with PID controlled line following algorithm and Omnidirectional Drive with Electro-Pneumatic Mechanical subsystems

Divyashree Rachakonda[1], Arnold Sequeira[2], Vivek Viswanathan[3], Vedant Vyawahare[4], Androse Fernandes[5], Rajesh Maharana[6],Yogesh Gholap[7]

[1-4]BE student, Department of Electronics and Telecommunication, Don Bosco Institute of Technology, Mumbai, India- 400070
[5]TE student, Department of Mechanical Engineering, Don Bosco Institute of Technology, Mumbai, India- 400070
[6]SE student, Department of Mechanical Engineering, Don Bosco Institute of Technology, Mumbai, India- 400070
[7]Professor, Department of Electronics and Telecommunication, Don Bosco Institute of Technology, Mumbai, India- 400070

Abstract - *The project encompasses techniques used for the design and implementation of a Semi-Autonomous Rugby bot with capabilities of Omnidirectional drive with Automated systems such as Line Following using PID Algorithm with collision avoidance system and encoder motors. It is capable of switching between automatic and manual control modes. Machine designed using Electro-Pneumatic based subsystem following the guidelines given by ABU-Robocon 2020.The mechanical subsystems involved are Picking, Throwing and Kicking. The Kicking mechanism is a spring-based system which is loaded using pneumatic cylinder and latch assembly to achieve desired range. The mechanism for picking and throwing are designed to quicken the ejection process of the ball. It uses mechanical leverage which helps us to achieve the desired projectile. Increase in reliability and safety has been achieved by design of power management system and custom boards for controllers.*

***Key Words*: Pneumatic Systems, Omni-Directional Drive, Line Follower, PID Algorithm, Automated Drive.**

1. INTRODUCTION

As technology progresses in today's world, we can see how Robotic Automation is under the lime light, paving its way into every business sector opening their doors to a plethora of possibilities. Automation provides an increase in quality, consistency, speed, accuracy , reduces direct human labour cost and many more. The aim of this project is to create a Semi-Autonomous bot with PID controlled line following algorithm with Omnidirectional Drive and Electro-Pneumatic Mechanical subsystems.

2. PROPOSED SYSTEM

The skeletal body of the bot is made using L-rods of mild steel of width 25mm and thickness 2mm. Mild Steel provides rigidity and good tensile strength. The entirety of the bot has been Arc-welded together, eliminating the failures due to vibrations and vectored forces of kicking system and throwing pistons. The estimated weight of the PR bot is 24 kg (with the batteries and pneumatic tanks).

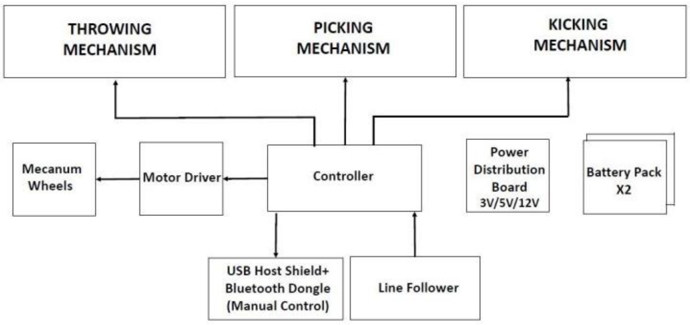

Fig -1: System Block Diagram

It is of semi-autonomous type. The overall maximum dimension at the PRSZ is 759x785x1122mm(lxbxh). During the game, the maximum dimension is extended to 904x785x1122(lxbxh). A spring-based kicking mechanism is designed which is loaded using pneumatic cylinder and latch assembly. Initially in the retracted position, the extension spring is loaded to provide elastic potential on the tension arm.

Fig – 2: Pass Robot CAD Model

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

To loop the process, a pneumatic cylinder loads the spring and latches until desired distance and angle from the ball is met with the constraints, using the sensor system and algorithms. These grabbing fingers are controlled using servo motors. A small jerk using an auxiliary cylinder knocks the ball onto the grabbing fingers and with linear actuation of the Picking cylinder, the pneumatic force is converted into the angular velocity resulting in the ejection of the ball.

3. IMPLEMENTATION

3.1 Ball Pick and Pass

Mechanical leverage concept builds up the throwing mechanism. The throwing arm is connected to aluminium structure (length=940mm, thickness = 150mm, material = Stainless steel (SS)). It consists of grabbing fingers (lxbxh)=270x10x15mm; aluminium material) driven by a servo motor, two support rods, throwing piston (ø32 x200mm) attached to a pivot point at a height of 155mm and a picking piston. The bot is manually driven to the try ball rack is precisely aligned by taking feedback using a Tiny Lidar Sensor. Once it gets aligned, the bot slightly moves ahead. Picking is executed using grabbing fingers which are attached to two support rods. These gripping arms are controlled using servo motors. A small jerk using auxiliary cylinder knocks the ball onto the grabber finger, with linear actuation of the piston converted into angular velocity which ejects the ball. The velocity of the piston was experimentally calculated using image processing.

$V_p = 1.08 m/s$; $r_1 = 0.15m$
$V_p = r_1 \times w$
Therefore, $w = 7.2$ rad/s
$V_B = r_2 \times w$; where $r_2 = 0.940m$
Therefore, $V_B = 6.768 m/s$

$$R = \frac{u^2 \sin 2\theta}{g} = 3m$$

Where,
u=initial velocity;
R = range;
g = gravity acceleration=$9.8 m^2/s$;
Θ = angle of projection = 70°
Vp=velocity of piston stroke
V_B= velocity of ball

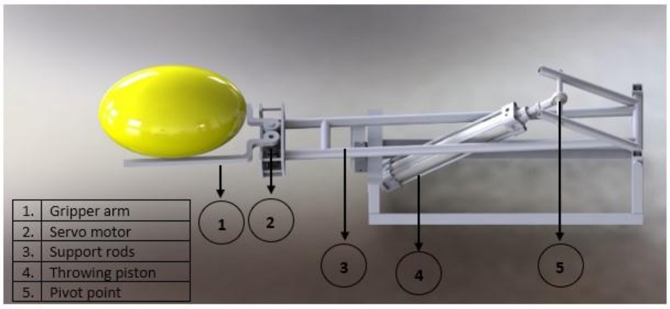

Fig – 3: Pick and Throw Mechanism

3.2 Kicking Mechanism

A spring-based system is loaded using pneumatic cylinder and latch assembly. The rocker arm (fig2.3) consists of 2 parallel aluminium square tubes (40mmx40mm) of length 650mm.It is divided into 2 parts: the tension arm and load arm. The tension arm(150mm), has a spring loading cylinder attached to it. As the Rocker arm takes on the position to kick, the spring is extended to provide the required elastic force. It merely loads the arm and upon latching, retracts back to its closed state. The latch assembly is a 2-part system with a Pneumatic slider on the support structure of the kicking mechanism and spring return latch on the rocker arm. As the rocker arm retracts the latch due to the presence of spring slips on the lip of the slider to get latched. The load arm(450mm) contains a cylindrical foot designed to minimize the area of contact with the ball to increase the impact force. Stacked wood sheets form the foot. On successfully positioning with the ball using the sensor system, the slider is retracted to release the rocker arm to kick the ball. Solving for distance of 9m from the goal and end trajectory as 2m, velocity needed to be attained by ball is u =12.875ms-1[Eqn. 1]. By practical iterative analysis measured k for designed spring are as follows [Eqn. 2]. Force of spring is calculated for the change in displacement [Eqn. 3], appropriate piston(Bore:ø50mm Stroke:150mm) is selected to counter the force efficiently[Eqn. 4]. Work energy principle is applied to find the velocity at spring connection [Eqn. 5], which provided us the angular velocity of the rocker arm [Eqn. 6]. Appropriately the length of the arm was iteratively varied to obtain the required resultant velocity at the Kicking foot.[Eqn.7].To compensate for the inelasticity of the ball coefficient of restitution of ball is substituted for transfer of momentum[Eqn 8].

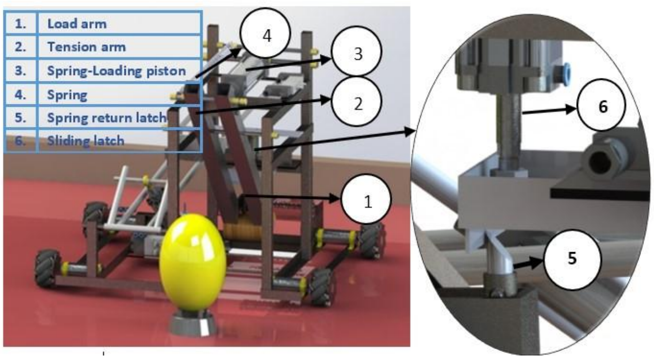

Fig - 4: Kicking mechanism

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 07 Issue: 06 | June 2020 www.irjet.net p-ISSN: 2395-0072

1.	$y = x\tan(\theta) - \frac{gx^2}{2u^2\cos^2\theta}$ Hence, $u = 12\cdot875\ ms^{-1}$	θ=Angle of Projectile=30° u =Initial Velocity y = Height of goal post x= Distance from kicking zone 2 y= 2m and x=9m k =Springs Constant x = displacement of the spring V_c=Velocity at spring contact = 6.18 m/s ω = Angular Velocity of Kicking Leg= 41.2 rad/s v_{BALL} =Ball velocity G = Shear modulus of material d=Diameter of wire D=Diameter of each coil of spring N=Number of turns or coils in the springs
2.	$k = \frac{G\,d^4}{8D^3N}$ $k = \frac{1.115 * 10^7 * 0.118^4}{8 * (0.59055)^3 * 133}$ $= 1733.93\ Nm^{-1}$	
3.	$F_{SPRING} = k * x = 390.012N$	
4.	F PISTON=1177.5 N (6 bar)	
5.	$w = \Delta kE \Rightarrow \frac{1}{2}kx^2 = \frac{1}{2}mv_c^2 = 43.89J$ $v_c = 9\cdot369\ ms^{-1}$	
6.	$v_c = \omega r_c; r_c = 0.15mm$ $\omega = 62\cdot46 rad\,s^{-1}$	
7.	$v_k = \omega r_k; r_k = 0.45m$ $\Rightarrow v_k = 28.107ms^{-1}$	
8.	By coefficient of restitution: $e = 0.75 = \frac{v_{BALL}}{v_k}; v_{BALL}$ $= 21.08ms^{-1}$	

3.3 Line Follower

The line following capability of the bot provides the autonomous characteristic for its movement. To achieve this we are using the Advanced Auto-Calibrating Line Sensor (LSA08) which is capable to operate in three different modes: digital, analog and serial. We used four LSA08 sensors in serial mode. These four LSA08 sensors are mounted in the center of the base profiles on all the four sides. We have a controller (Arduino Mega 2560) in the center. A PID(Proportional-Integral-Derivative) based algorithm is fed to the central controller where the output from each LSA08 acts as the input data to this controller. The PID algorithm involves finding the deviation of the robot with respect to the line,while correcting its alignment by changing the speed and direction of the motors connected to the 4 wheels. The algorithm specifically takes the error into consideration and works towards minimizing it by calculating the appropriate motor speed, hence correcting the path it follows. The robot always tries to adjust itself to center at the set point. LSA08 supports a range of 0-70 in the analog mode, so the value 35 was decided as the set point and the aim of the PID controller was to make sure that it achieves the value 35 in the shortest time possible.
We are using Mecanum wheels which are omnidirectional in nature. According to the output of the respective LSA08 sensor, the controller will setup the motor drivers to give the required rotation to all the four Mecanum wheels so as to achieve a quick response.

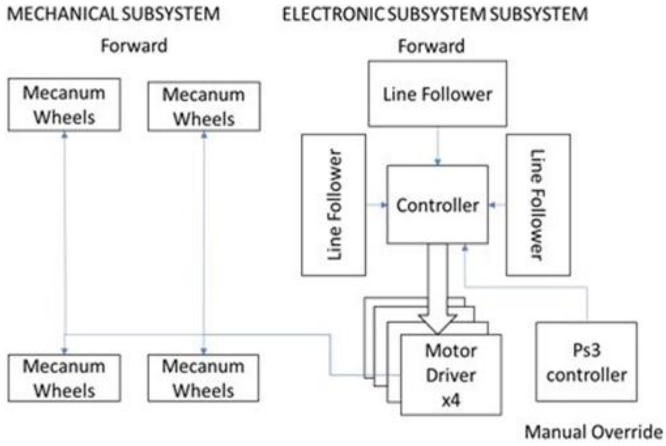

Fig -5: Line Follower System Block Diagram

With this approach we are able to explain and understand the concept of AGV(Autonomous Guided Vehicle). To increase efficiency in the design we are using only two serial buses to establish communication with all four LSAs. Serial bus 1 is used for communication with Forward and Right LSA, while the serial bus 2 is used for Left and Back LSA. The JPULSE is used for junction detection where a pulse will be generated every time LSA08 will cross a junction. This JPULSE value can be used to provide instruction to automate certain steps in the bot. UEN is the UART output enable pin which helps us to initiate serial communication between the peripherals and the central controller. This design increases the efficiency by increasing the speed of line detection, consequently the adjustment of the respective motor speed and direction of rotation.

3.4 Omni-Directional Drive

The bot is built upon mecanum wheel as the wheels and encoder motor as the drive. The use of hall effect sensor integrated within the encoder motor is used to calculate the ticks on wheel rotation. The independent rotation of each wheel gives the bot the ability to obtain true omni-directional capabilities. The Bot has 2 methods of operation with the help of PS3 controller for manual override and automated movement based on pre-fed coordinates along with LIDAR sensor as safety system.

3.4.1 Manual Override:

The analog values from the Left stick and Right stick are mapped onto PWM values for respective movements. The Left stick is responsible for forward, backward and sideways movement. The Right stick is responsible for spot turns. Precise turns can be taken by using both the joy stick to drive, i.e Left stick for forward or backward velocity vector and Right stick for left or right velocity vector which is handled by the developed algorithm.

3.4.2 Automated Drive:

The hall effect sensor generated pulses which are connected to hardware interrupts onto the controller. To account for wheel slip and inertia for the bot, the algorithm consist of PID tuning which enables the bot to have better controlled movement. Coordinates for movement can be fed into the program which are sequentially followed by the system. Use of tinyLIDAR provides us the safety measures to avoid the bot from colliding onto objects or people.

4. RESULTS AND DISCUSSIONS

4.1 Pick and Throw

The design proved to be faster and depended upon gravity to have the ball positioned for throwing. By the appropriate design of picking arm, the falling motion of ball could be predicted. Tests were conducted with a piston of stroke length 250mm which was longer than our required stroke length. Due to its longer length we were able to achieve only half projectile range of 1.5m .This was the test from which we practically concluded that by using piston of shorter stroke length a larger distance could be achieved. The final cylinder of ø32 x200mm gave us a complete projectile. Thus easily covering the distance of 2.5-3m.Also the use of quick exhaust valve in the throwing action helped in increasing the range as the rotation motion was increased with the linear actuation speed on the cylinder.

4.2 Kicking

The design being based on proper calculations was robust and reliable. Initial test rigs were created for the calculated values and parameters which were successfully achieved with the use of custom designed springs and latching mechanism. The CAD designed model was then integrated along with other mechanisms to utilize minimum space and follow the underlying weight restrictions. This design resembles to the kicking in humans.

4.3 Line Follower

Line Follower system with sensor on all four sides of the bot was installed. Initial wiring was done on four different serial ports of the controller,on further testing to better utilize port they were all shifted onto two serial ports.PID tuning enabled the bot to hold the line better. Due to change in ambient lighting calibration needed to be carried out for every change, use of LSA cover shielded the IR detector from ambient light variations.

4.4 Omni-Directional Drive

We were able establish wireless communication using Bluetooth dongle CSR4.0 with a range of 10m.This communication didn't prove to be reliable due to connectivity issues. The encoder motor system was successfully implemented but due to unequal load distribution on the wheels the Bot pulls to a side. On prior testing the Bot *overshot the given coordinates by the user. With the use of PID algorithm and appropriate tuning, better results were obtained with marginal error.*

5. CONCLUSIONS

Our efforts to develop a low-cost integrated system to implement Semi-Autonomous movement as well as understanding and integrating an Electro-Pneumatic mechanical subsystem which can be designed as per the requirements that the task demands has resulted into a well integrated and tested system. The software stack has been developed for movement, and detection of objects. Automation of the Bot ensured its functions without any human intervention, thus eliminating human errors. After following an iterative testing methods for multiple algorithms, the bot is ready with a centralised safety system that can be adjusted according to its environment.

5. REFERENCES

[1] Firoz Alam, Aleksandar Subic, Simon Watkins, Jamal Naser, "An Experimental and Computational Study of Aerodynamic Properties of Rugby Balls" School of Aerospace, Mechanical and Manufacturing Engineering, RMIT University, Faculty of Engineering and Industrial Sciences, Swinburne University of Technology and Faculty of Sciences, Engineering and Health, Central Queensland University (Australia).

[2] Franco Normani,"User Manual For Projectile Motion Simulator In Excel", February 17, 2011..

[3] Neil Bezodis, Alexandra Atack, Sandy Willmott, Grant Trewartha," Kicking foot swing planes and support leg kinematics in rugby place kicking" in European Journal of Sport Science, September 2018.

[4] T. Butnaru, F. Gˆırbacia, F. Tˆırziu and D. Talab "Mobile Robot System Controlled Through Mobile Communications" Product Engineering, Springer, 2004

[5] Chinnu Augustine, Chinnu Thampi, Maria George, "Pick and Place Robotic Arm Implementation using Arduino", IOSR Journal of IEEE, Volume 12, Issue 2, Ver.III, April 2017, PP 38-41.

[6] Tutorial by Cytron. (2015). Line-Following Robot Using LSA08 in Serial Mode with PID Controller. (//tutorial.cytron.io/2015/07/31/linefollowing- robot-using-lsa08-in-serial-mode-with-pid-controller/)

[7] S.N.Teli, AkshayBhalerao ,Sagar Ingole ,Mahesh Jagadale, Kiran Kharat, "Design and Fabrication of Pneumatic Robotic Arm" in IJSER, ISSN 2229-5518, Vol. 8, Issue 3, March-2017