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An Obstacle Avoidance Self-Balancing Line Follower Robot

Miss Ranjana Ray[1], Mr. Souvik Saha[2], Mr. Rupak Ghosh[3], Mr. Biltu Bala[4], Mr. MD Asraful[5], Mr. Rajdeep Banerjee[6]

[1]*Assistant Professor, Department of ECE, JIS College Of Engineering, Kalyani, Nadia, West Bengal, IN*

[2,3,4,5,6] *UG Student, Department of ECE, JIS College Of Engineering, Kalyani, Nadia, West Bengal, IN*

***Abstract*—An autonomous self-balance line following robot is system of two wheeled balancing robots offers a competitive advantage in future locomotion for everyday robots. The unique stability control and follow line or track that required to keep upright to differentiate and properly follow track or line it traditional of robotics. For stability of system and follow right path properly is controlled by PID controller. Using opensource micro-controller Arduino and MPU6050 gyroscope the balancing of robot, motor drive with quite high rpm and IR array sensors to follow track. And we can able to control it through a controller and it can be switched to avoid the object and balanced properly goods or object and follow tracks to move goods from one place to another place. Its innovative capacity allows for responsive, timely stability control, a unique feature that sets it apart from traditional robotics. Its help for various industrial uses and household jobs and applicable gardening, shopping malls, defence systems. This system, developed through careful consideration of various aspects, provides ongoing improvements and potential faults.**

***IndexTerms*—self-balance, IR array sensors, microcontroller, line follower, PID controller, robot**

I. INTRODUCTION

There are many tasks that demand a bounty of manpower, time and attention. In Industries the load carried around by men reduces their time and effort to do other useful things. In large manufacturing factories use heavy objects that need to move from one place to another place. In hospitals, harmful disease patients used clothes and pathological testing kits also lot of wastes are all disposed of further by people who are rather vulnerable to the infection it still contains. Even the job serving restaurants, which often requires extreme multitasking abilities, can sometimes get simply hard as it is next to impossible to attend everyone at the same time. These and dozens of other tasks applicable indoor call for the same sort and prerequisites that could be fulfilled without consuming this much manpower. All these reasons and more, inclined us towards finding one of the best possible solutions is An Obstacle Avoidance Self-Balancing Line Follower Robot.

These two-wheeled robots are independent on the principles of an inverted pendulum, which describes a system, where in an inverted pendulum has to be maintained upright by moving the wagon It is attached to under its centre of mass. This idea was extended to design self-balancing robot which can balance itself on two wheels by driving its base support under the centre of mass and thus align itself perpendicular to the floor.

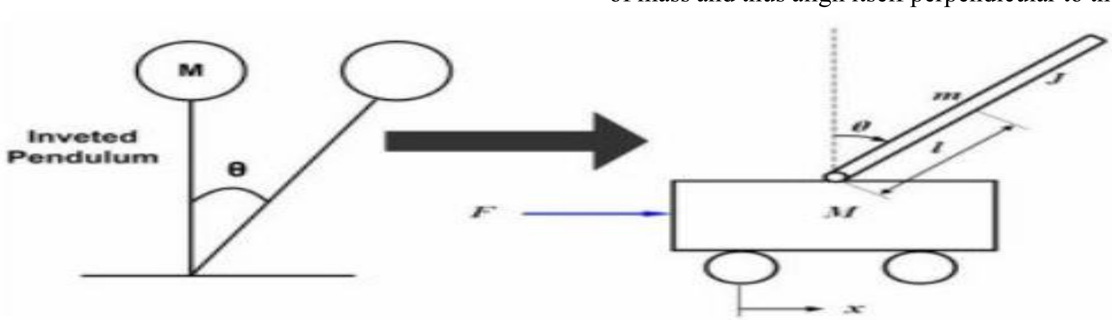

Fig:1 Inverted pendulum analogy for self-balance robot

A PID controller is the control algorithm used in this active self-balancing robot. PID as the name stands for has three parameters like Proportional(P), integral(I), derivative(D). It utilizes a closed-loop feedback system that called a negative feedback system. The reason PID is welcomed largely is because of its wide varieties of operating conditions and operations which can be done simplest manner.

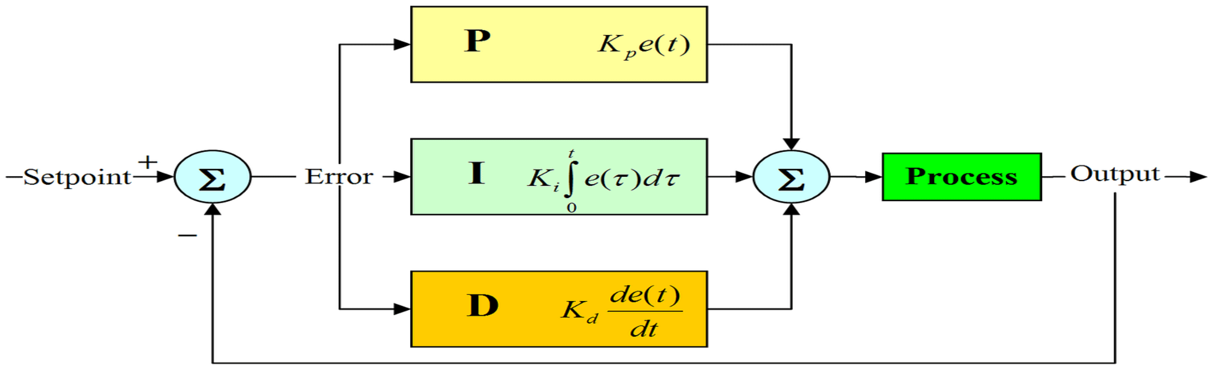

Fig:2 PID control Algorithm

In this robot system we are using sensor for obstacle avoidance that uses ultrasonic wave determines distance between two objects and converts the reflected sound into electrical signal. For following a track or path we used array IR sensor. This array IR sensor makes with photodiode or LED that emitting infrared light and detecting its reflection to sense track or path (Path is black colour line). Another important contribution to this made by a Kalman Filter, which is used for merging two outputs of different sensors and reducing the noise of the same by appropriating its weightage. This filter is also beneficial that reduce memory consumption in the processor. The self-balancing robot is adjusted on two wheels which gives the necessary hold for appropriate contact. To keep the vertical axis straight, two things need to be done, one is to estimate the inclination point and the other is to control the motors to maintain 0˚ angle with the vertical axis by pushing them forward or backward. To measure the angle, two sensors, an accelerometer and a gyroscope are used. The accelerometer can sense the static or dynamic force of acceleration and the gyroscope measures the angular velocity.

The aim and objective of our project to design and implement An Obstacle Avoidance Self-Balancing Line Follower Robot attribute and aspects of robot on it. It would be a fully automatic system that will vary direction and position automatically follow path or track so that can reach the right destination and interact with obstacles it will move another direction and whenever it will be like going unstable it will make itself stable with the help of sensor and controllers.

II. METHODOLOGY

1. Hardware Details:

A) Arduino UNO: Arduino Uno is a popular microcontroller development board based on 8-bit ATmega328P microcontroller. Along with ATmega328P MCU IC, it consists of other components such as crystal oscillator, serial communication, voltage regulator, etc. to support the microcontroller.

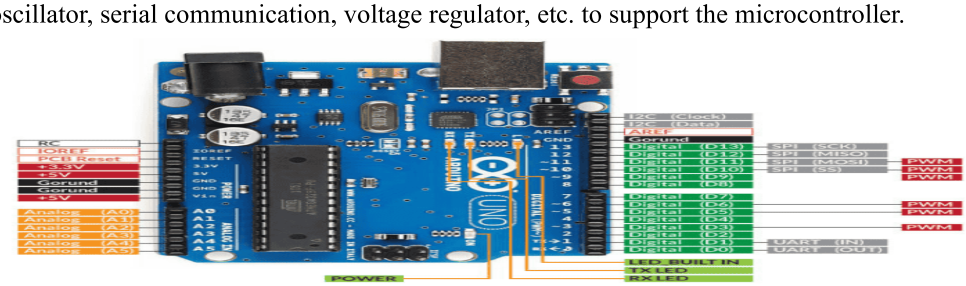

Fig:3 Arduino UNO Pinout

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Microcontroller	ATmega328P – 8bit AVR family microcontroller
Operating Voltage	5V
Recommended Input Voltage	7-12V
Input Voltage Limits	6-20V
Analog Input Pins	6 (A0 – A5)
Digital I/O Pins	14 (Out of which 6 provide PWM output)
DC Current on I/O Pins	40 mA
DC Current on 3.3V Pin	50 mA
Flash Memory	32 KB (0.5 KB is used for Bootloader)
SRAM	2 KB
EEPROM	1 KB
Frequency (Clock Speed)	16 Hz

B) Ultrasonic Sensor: An HC-SR04 ultrasonic distance sensor actually consists of two ultrasonic transducers. One acts as a transmitter that converts the electrical signal into 40 KHz ultrasonic sound pulses. The other acts as a receiver and listens for the transmitted pulses. When the receiver receives these pulses, it produces an output pulse whose width is proportional to the distance of the object in front. This sensor provides excellent no contact range detection between 2 cm to 400 cm (~13 feet) with an accuracy of 3 mm. Since it operates on 5 volts, it can be connected directly to an Arduino or any other 5V logic microcontroller.

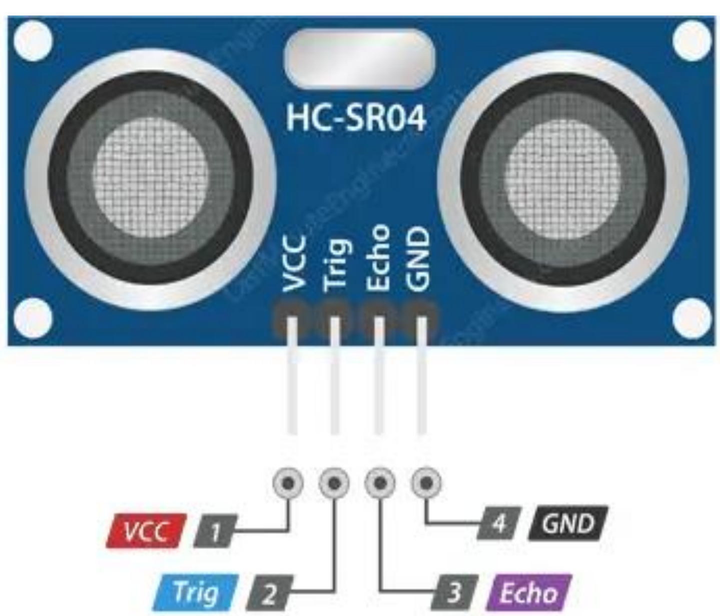


Fig:4 Ultrasonic Sensor HC-SR04

Operating Voltage	DC 5V
Operating Current	15mA
Operating Frequency	40KHz
Max Range	4m
Min Range	2cm
Ranging Accuracy	3mm
Measuring Angle	15degree
Trigger Input Signal	10µS TTL pulse
Dimension	45 x 20 x 15mm

C) Gyroscope Sensor: The MPU6050 module is a Micro Electro-Mechanical Systems (MEMS) which consists of a 3-axis Accelerometer and 3-axis Gyroscope inside it. This helps us to measure acceleration, velocity, orientation, displacement and many other motions related parameter of a system or object.

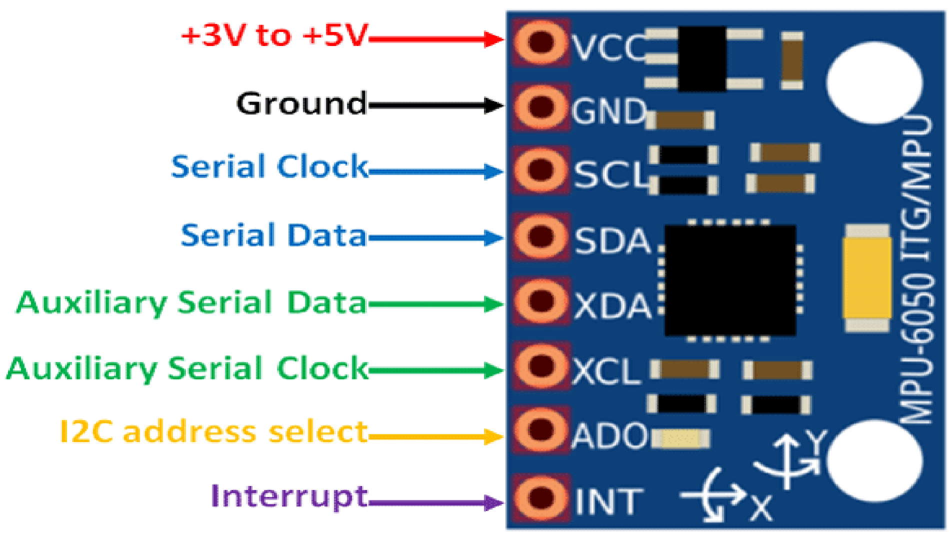
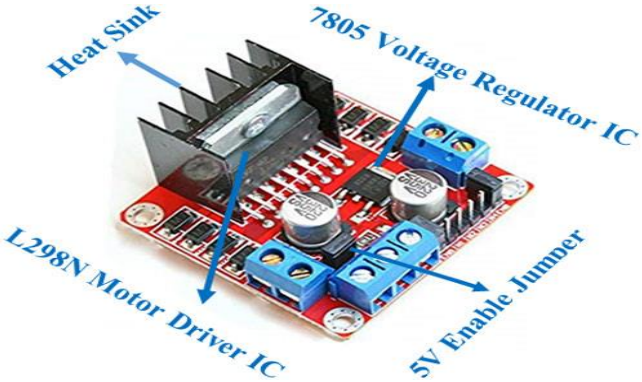


Fig:5 Gyroscope Sensor (MPU-6050)

- Features:

I. MEMS 3-aixs accelerometer and 3-axis gyroscope values combined
II. Power Supply: 3-5V
III. Communication: I2C protocol
IV. Built-in 16-bit ADC provides high accuracy
V. Built-in DMP provides high computational power
VI. Can be used to interface with other IIC devices like magnetometer
VII. Configurable IIC Address
VIII. In-built Temperature sensor

D) Motor Driver: L298N module is a high voltage, high current dual full-bridge motor driver module for controlling DC motor and stepper motor. It can control both the speed and rotation direction of two DC motors. This module consists of an L298 dual-channel H-Bridge motor driver IC. This module uses two techniques for the control speed and rotation direction of the DC motors. These are PWM – For controlling the speed and H-Bridge – For controlling rotation direction. These modules can control two DC motor or one stepper motor at the same time.



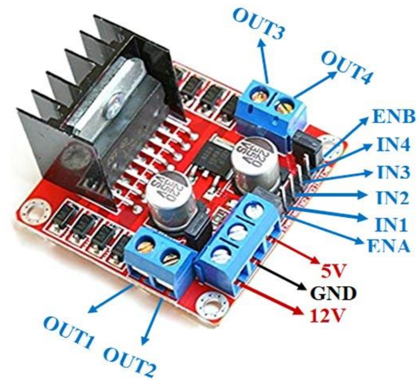


Fig:6 Motor Driver (L298N)

PWM (Pulse Width Modulation) Techniques

L298n motor driver module uses the PWM technique to control the speed of rotation of a DC motor. In this technique, the speed of a DC motor can be controlled by changing its input voltage. Pulse Width Modulation is a technique where the average value of the input voltage is adjusted by sending a series of ON-OFF pulses. The average voltage is proportional to the width of the pulses, these pulses known as Duty Cycle. If the duty cycle higher, then the average voltage is applied to the DC motor (High Speed), and the lower the duty cycle, the less the average voltage being applied to the dc motor (Low Speed).

Operating Voltage	5V – 46V
Operating Current	2A
Logic Voltage	5V
Logical Current	0-36mA
Maximum Power (W)	25W
Driver Chip	L298 dual-channel H-Bridge motor driver IC
LED lights indicators	Power-On LED indicator
Drives motor	Drives up to 4 motors (2 for each motor output terminal block) or One Stepper Motor
Module Dimensions	44 x 44 x 28 (L x W x H) mm

E) 5 Array IR Sensor: The 5-Channel IR (Infrared) Sensor is an electronic device capable of detecting infrared light across five distinct channels. This sensor is commonly used in line-following robots, edge detection, and object sorting based on reflective properties. It is particularly popular in educational robotics and automation projects.

Powering the Sensor**:** Connect the VCC pin to a 3.3V or 5V power supply and the GND pin to the ground of your circuit.

Connecting to a Microcontroller**:** Connect each OUT pin to a digital input pin on your microcontroller, such as an Arduino UNO.
Calibration**:** Adjust the onboard potentiometers to set the detection distance for each channel.

Reading the Sensor**:** Monitor the digital input pins. A HIGH signal typically indicates that the IR light is being reflected back to the sensor, while a LOW signal indicates no reflection.

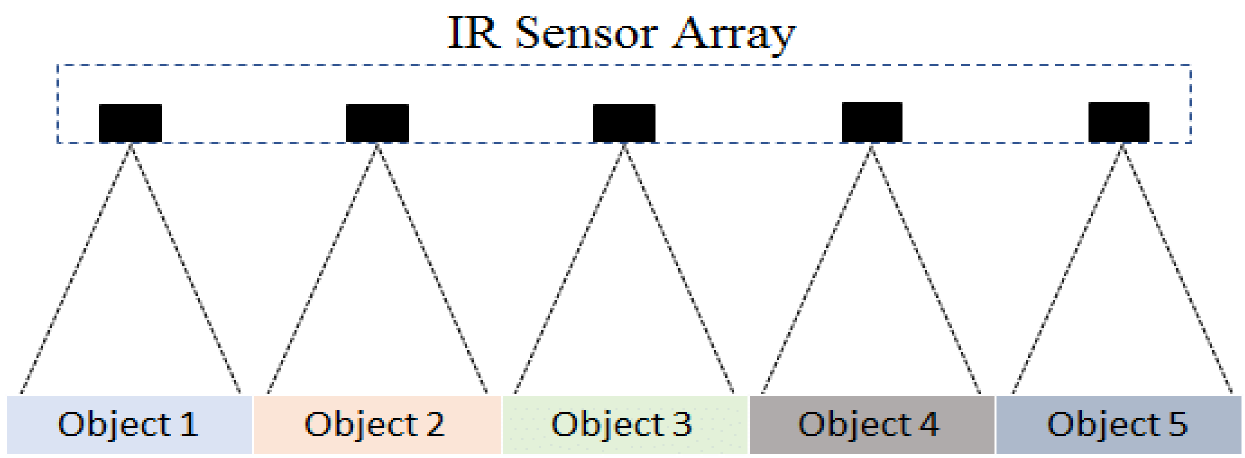


Fig:7 IR Array Sensor

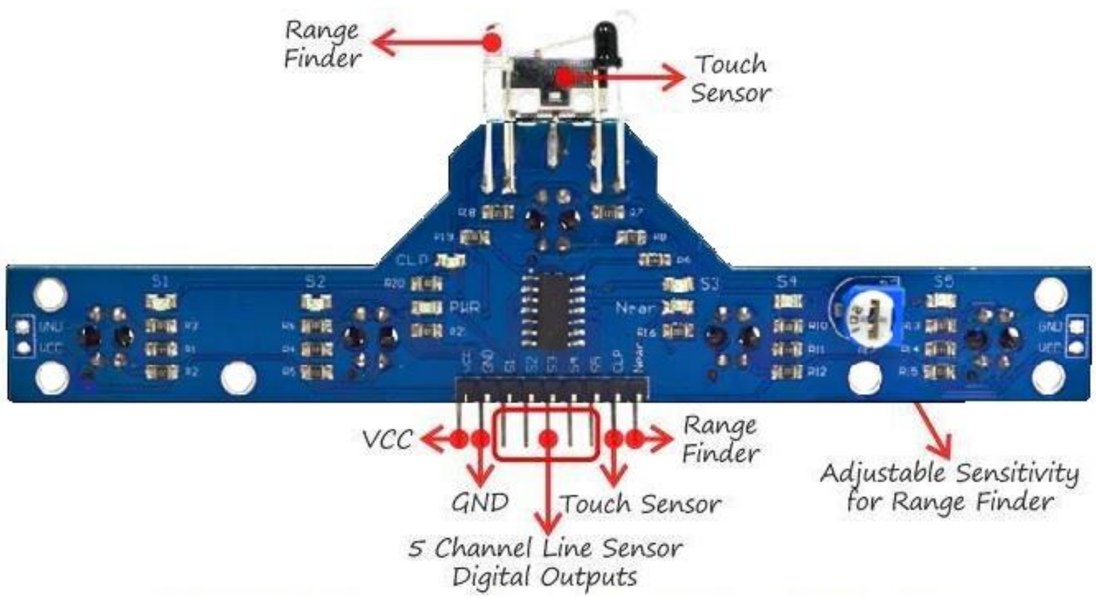


Fig:8 IR Sensor Pinout

- Features:

I. Operating Voltage: 3.3V to 5V DC
II. Current Consumption: 10-20mA per channel
III. Output Channel: 5 digital outputs, one for each IR sensor
IV. Detection Distance: 2cm to 15cm (adjustable via onboard potentiometers)
V. Ambient Light Resistance: Built-in daylight filter for outdoor use

F) Gear Motor Wheel:

The Gear motor DC 130 3-12V is a type of small electric motor and dual shaft that used in various application, Projects including robotics.

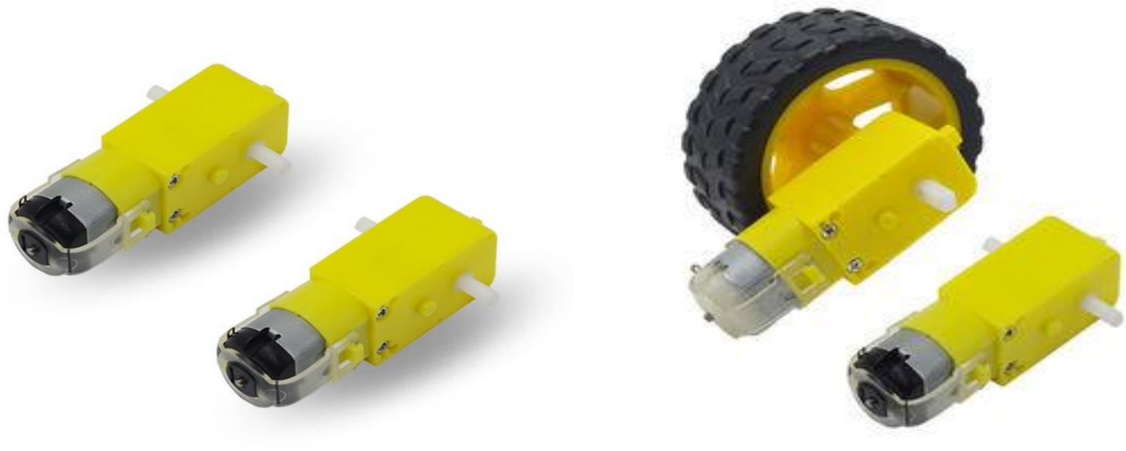


Fig:9 Gear Motor with wheel

- Features:

I. Plastic spur gearbox
II. Dual shaft
III. 130 metal brush or carbon brush motor
IV. 3v-12v voltage range
V. 0.5-5W output power
VI. Wire soldering available

2. Software:

A) Arduino IDE: It is Arduino Integrate Development Environment or Arduino Software (IDE) contains a text editor for writing code, a message area, a text console, a toolbar with buttons for common functions and a series of menus. It connects to the Arduino hardware to upload programs and communicate with them. It serves as the backbone of the robot's software environment, enabling the execution of various applications, programs and algorithm. Arduino IDE provides stable and efficient platform to run control logic, process sensor data and interface with hardware components like motor and sensors. Its light- weight nature and support for libraries like C and C++ make it ideal for robotics project.

B) Kalman Filter: The Kalman Filter is an advanced mathematical algorithm used for sensor fusion and data filtering. In this project, the Kalman filter process noisy data from the MPU6050 sensor, which accelerometer and gyroscope readings and array IR sensor readings. It combines the measurement to estimate the tilt angle of the robot high precision and the state of a system by fusing noisy sensor data, leading to more accurate and robust performance. Kalman Filter plays critical role in ensuring smooth and stable balancing and path or track following of the two wheeled robot, even when disturbances occur.

- Algorithm:

I. PID Controller Algorithm: The PID controller corrects tilt and assisting the bot stay on the track using three components:

Proportional (P) Corrects based on the magnitude of the correct error

Integral (I) Accumulates past errors to eliminate steady state offset

Derivative (D) Predicts future errors by analyzing the rate of error changes

Formula:

$$u(t) = K_{\mathrm{p}} e(t) + K_{\mathrm{i}} \int_0^t e(\tau)\,\mathrm{d}\tau + K_{\mathrm{d}} \frac{\mathrm{d}e(t)}{\mathrm{d}t},$$

where K p Ki and Kd all non-negative, denote the coefficients for the proportional, integral, and derivative terms respectively (sometimes denoted *P*, *I*, and *D*)

II. Error Calculation: The error calculation block determines the deviation of the robots current tilt angle from the desired value: Angle Reading: The tilt angle obtained for the complementary filter. Set Value: The target tilt angle (typically 0 degree for perfect balance).

The error is computed as:

Error = Angle reading – Set Value

The error serves as the input to the PID controller.

III. Angle Reading: Angle reading block processes tilt angle data using:

Gyro-sensor angle: The raw angular velocity and tilt angle are measured using a Gyroscope.

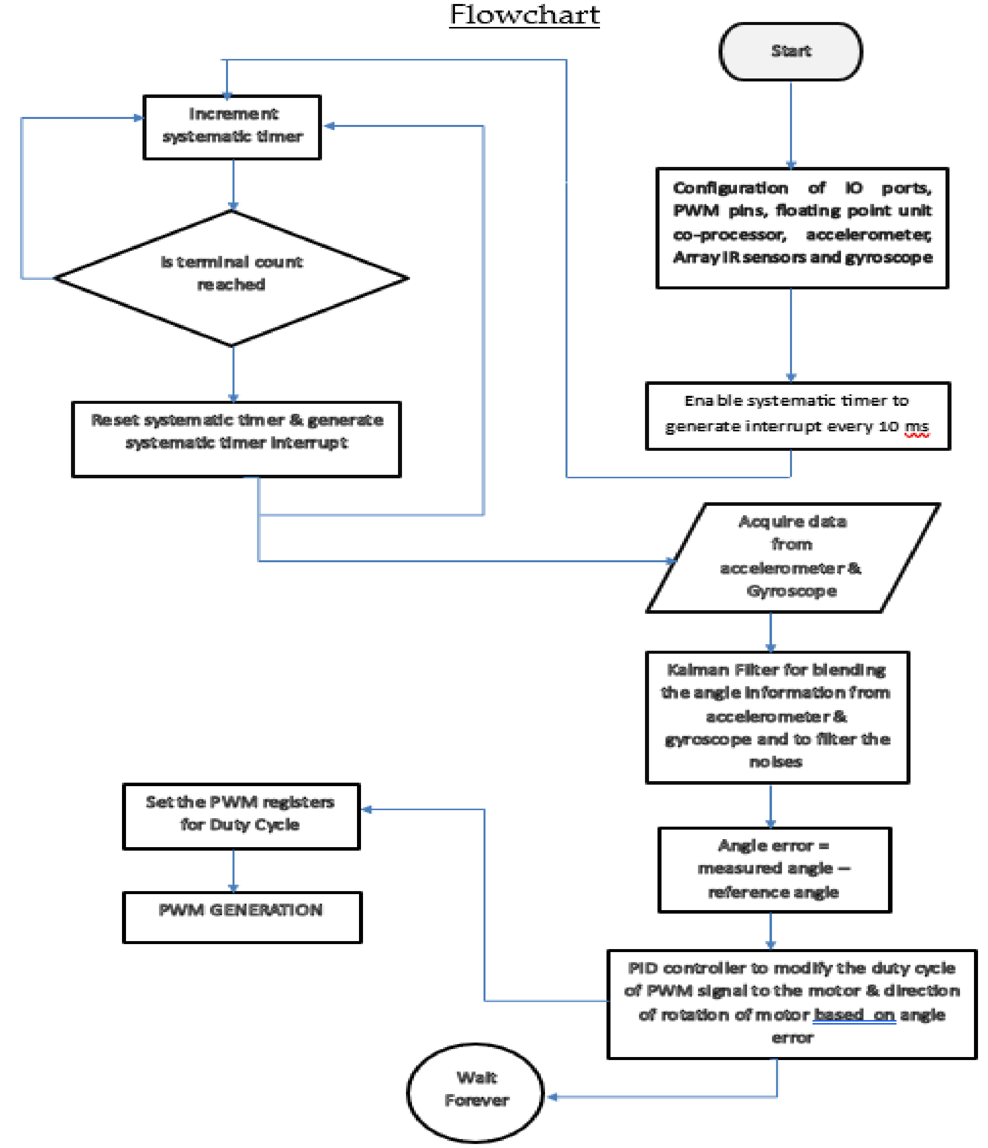
Complementary Filter: A filtering technique combines gyroscope and accelerometer data to smooth the reading and reduce noise.

IV.

V. Motor Operation Control: The blocks apply to the PID output to control the motors:

PWM Controls: The PID output is converted into Pulse Width Modulation (PWM) signals to motor speed and direction. The motors respond dynamically to the correction signal to maintain balance.

Flowchart



III. RESULT & DISCUSSION

The output we have achieved is the obstacle avoidance self-balancing line follower robot succeeding in the balance and line following and able to avoid objects within its range in three directions (Front, right, left). Unlike other robots

Which avoid obstacle is way more costly than our project so as mentioned as better quality we used to reduce robot cost which is less than the other robots Which can be bought in market. The outcome of our project is to make the robot move automatically avoid the object which h operates through lithium-ion batteries which can energies through an ordinary module charger on a self-balancing line following robot has a self-balancing, obstacle avoidance, line following which can keep operator from any kinds of fall harm.

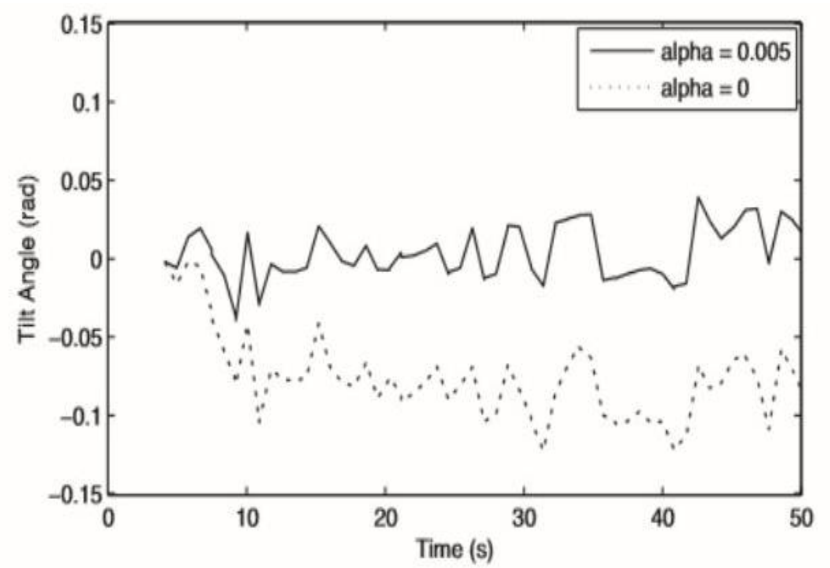


Fig:10 impact of selecting complementary filter coefficient

Using the accelerometer to remove the bias in the gyroscopes estimate of the current angle as a result of nonzero staring conditions and measurement drift

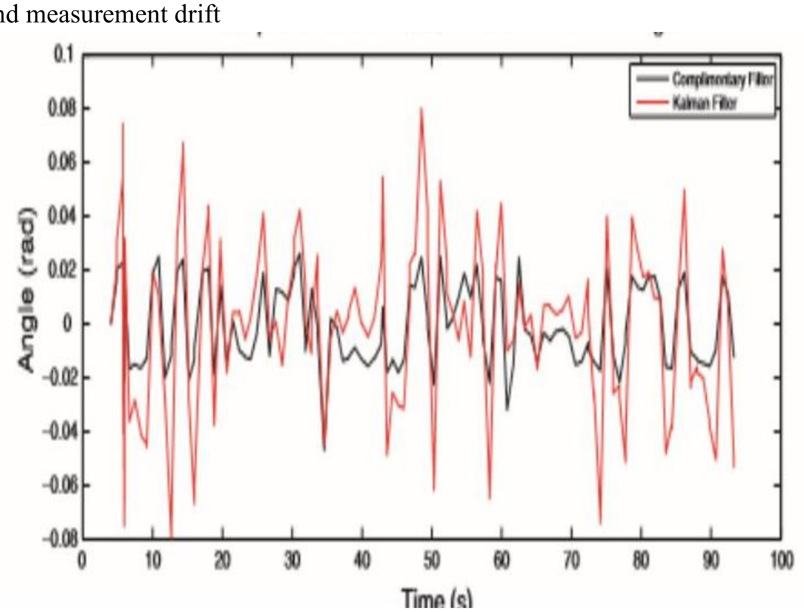


Fig:11 Comparison of state reconstruction filters: Tilt angle

Tilt angle generated by Kalman and complementary filter respectively

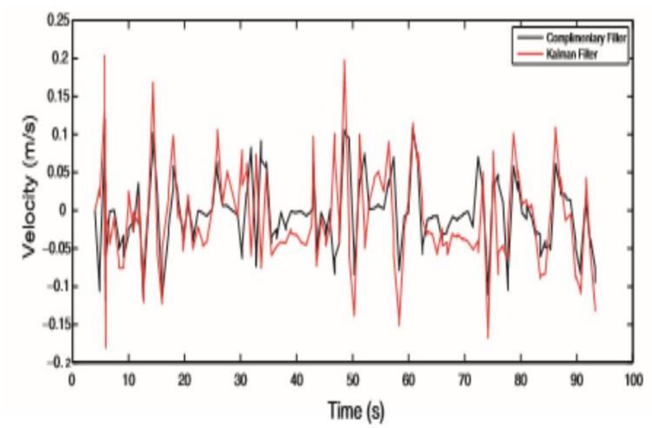


Fig: 12 Comparison of state reconstruction Filters: Horizontal Velocity

Linear velocity state generated by Kalman and complementary filter respectively. Note that the complementary filter uses on extra sensor to achieve its reconstruction.

IV. CONCLUSION

This paper has represented a design and implements is An Obstacle Avoidance Self-Balancing Line Follower Robot (OASBLFR) which can avoid obstacles, self-balance, line or track follow. This was done using Arduino, and other off the shelves parts to make it affordable, easier for maintenance and improvement. This robot can make a balance and controlled body in the first and marking can avoid the object in three direction and follow path. We have designed the robot in the manner can carry it to anywhere easily and the main application off this project we have made is to work as a servant robot.

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