International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 05 Issue: 09 | May 2019 www.irjet.net p-ISSN: 2395-0072

Design & Development of Two-Wheeled Self Balancing Robot

Mr. Pramod R. Sonawane[1], Ayesha H. Shaikh[2], Aditya S. Shah[3], Pranita N. Phadtare[4]

[1,2,3,4]Dept. of Electronics and Telecommunication Engineering, Pimpri Chinchwad College of Engineering, Pune, India

***

Abstract:- Two wheeled self-balancing robot, which is based on an inverted pendulum system, is dynamically stable but statically unstable. The robot involves various physics and control theories. This project describes the modeling of the two wheeled self-balancing robot, designs the robot controller using PID and Kalman filter and implements the controller on the robot. In this project, an inertial measurement unit (IMU) is used, which combines accelerometer and gyroscope measurement in order to estimate and obtain the tilt angle of the robot. The PID controller is applied to correct the error between the desired set point and the actual tilt angle and adjust the dc motor speed accordingly to balance the robot. The result obtained shows that the PID controller is able to balance the robot acceptably but with some limitations. The simulation result of the model is compared with the developed hardware and the performance of the controller is analyzed and discussed. In addition, the PID tuning using heuristic method is also performed and an improvement can clearly be seen in terms of the robot balancing.

Key Words: **Self balancing, Inverted Pendulum Systems, PID controller, Kalman Filter, MPU6050, Arduino, TB6612FNG, Bluetooth, Tuning.**

1. INTRODUCTION

The self balancing robot is based on the classic mechanical model of 'Inverted Pendulum Systems'. The robot is a two wheeled system which balances itself about the axis which is along the line connecting the two wheels from their centers. The robot consists of a PID based Kalman Filter controller, which will carry out the balancing action. The robot consists of:

1) Arduino Mega2560:
This is the main processor to which all other peripherals will be connected.

2) Sensor Module MPU6050:
MPU6050 is an integrated 3 axis accelerometer and 3 axis gyroscope. This module senses the robot position thus measuring the tilt angle and acceleration value which are given to the Arduino foe further processing.

3) Dual Motor Drive TB6612FNG:
This dual motor drive drives the two encoder motors thus, accelerating them in forward or backward direction to achieve self-balancing.

4) Encoder Motors:
Geared DC encoder motors have been used with a gear ratio of 1:34. The rpm values are read by the encoder which are given to the drive.

5) Bluetooth Module 5.0:
The robot will be controlled using an Android application. The connectivity between robot and Android device is via Bluetooth.

6) Power Source:
The power source used is a 12 V Lithium-Polymer battery which is connected to the Arduino via a switch.

1.1 Controllers:

To maintain the robot upright, the most commonly used controllers are Proportional-Integral-Derivative (PID) and the Linear Quadratic Regulator. Other theses have also explored the use of Linear-Gaussian Control (LQG), Fuzzy Logic and Pole-Placement; however, in some cases they were never implemented in a robot and were only experimented in simulations. In these where the robot displacement is also controlled, either LQG is used or combination of controllers. For example, LQR is used to maintain the robot upright and PID is used for controlling displacement, or a cascaded PID controller. PID and LQR are the explored controllers, thus further details will only be provided for them.

PID is perhaps the most used controller, as stated by VanDoren “More than 60 years after the introduction of proportional-integral-derivative controllers, they remain the workhorse of industrial process control.” The algorithm is described by the following equation:

$$u(t) = Kp\ (t) + Ki\int e(t)\ dt + Kd\frac{d}{dt}e(t)$$

Where, u(t) is the output of the controller, e(t) is the error and Kp, Ki and Kd are the tuning parameters. It is relatively easy to implement and does not require a model of the system. Tuning of the parameters can be done with trial and error. Using this simple method, robots have been controlled to remain upright.

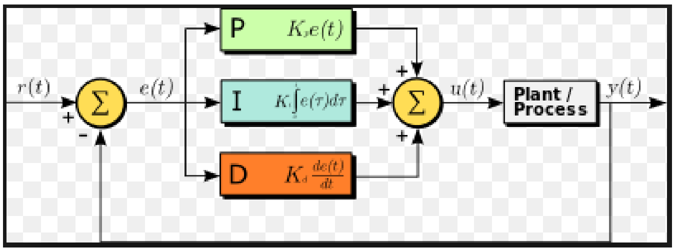

Fig no.1 : PID Controller

1.2 Sensors

A common agreement in literature is that using either a gyroscope or an accelerometer, on their own, to obtain the tilt angle is not very reliable. This primarily arises from the fact that both of these devices have a bias in the measurements, are affected by white noise and the bias is affected by temperature. Hence, we fuse both the terms in order to estimate the tilt angle. The gyroscope measures angular velocity 'thieta symbol' in radians per second or degrees per second. Intuitively, by integrating the angular velocity the tilt angle can be calculated. The accelerometer measures the acceleration relative to free fall. Thus when the object is tilted, the force is divided into components in the x, y, and z directions of the object.

1.3 Kalman Filter

Kalman Filter is used to fuse the data from gyroscope and accelerometer in order to calculate the tilt angle. The Kalman Filter implements a form of feedback: first, a process state estimate is made using the time update equations and then using the measurement update equation a form of measurement estimation is obtained.

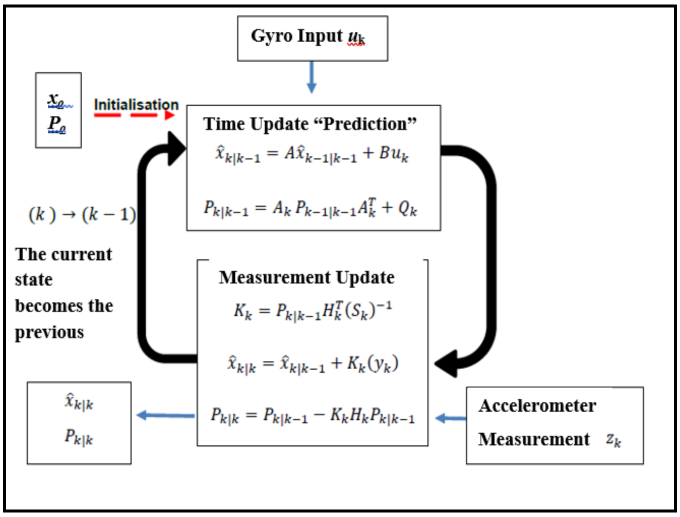

Fig no. 2: Ongoing Discrete Kalman Filter Cycle

1.4 Tuning

A good Control System will have low rise time, settling time, peak overshoot and steady state error. Therefore, the Kp, Kd, Ki need to be finely tuned to adjust the contribution of the above factors in order to acquire a good Control System.

2. PROPOSED SYSTEM

2.1 Working:

Two wheeled balancing robots are based on inverted pendulum configuration which relies upon dynamic balancing systems for balancing and maneuvering. In self balancing robot, if the bot gets tilted by an angle, this value will be sent to the Arduino processor. The Arduino will process these values using PID based Kalman Filter algorithm, and give instructions in the form of new rpm values, positive or negative, depending on the direction of tilt, to TB6612FNG motor drive to instruct the motors to cover up the tilt angle. Thus, the center of mass of the bot will experience pseudo force which will apply a torque opposite to the direction of tilt.

2.2 Algorithm

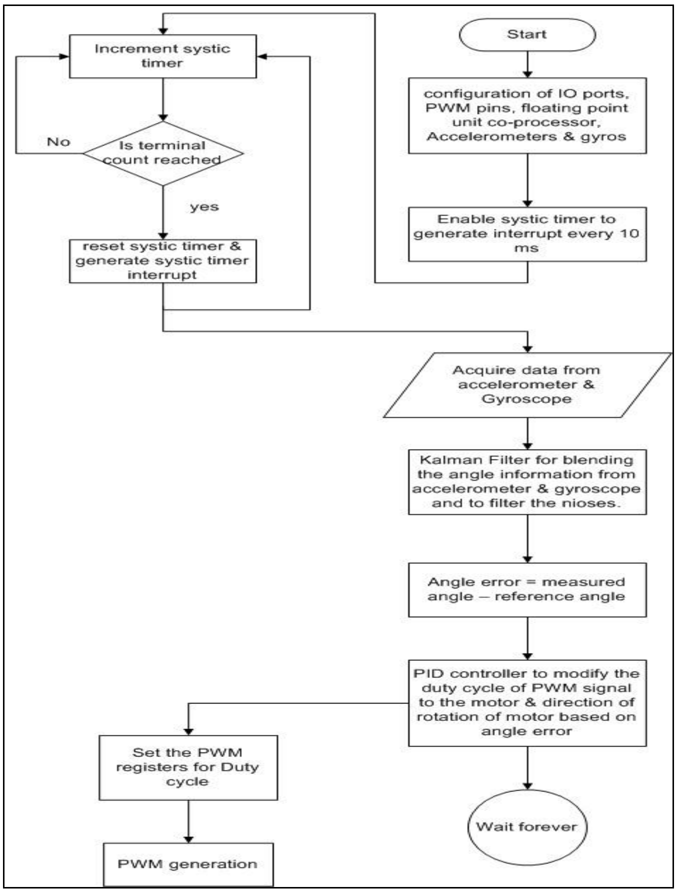

Fig no.3 : Self Balancing Algorithm

2.3 Representation of the Proposed Model

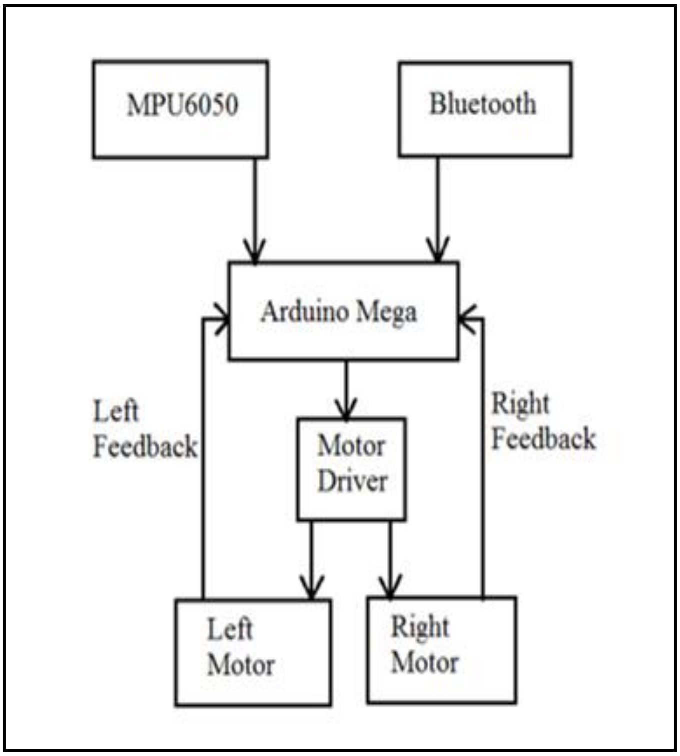

Fig no. 4 : Working of the proposed system

The whole bot gets balanced on two wheels having the required grip providing sufficient friction. In order to obtain the verticality of robot two things must be done, in one hand the angle of inclination must be measured, and in the other hand motors must be controlled to move forward or backwards to make an angle 0˚ . We observe that when the supply is initiated the robot gets active and initially is in a slightly tilted position. Here the supply is given by the battery and gives it to the Arduino MEGA and also to the MPU sensor which consist of mainly two sensors that is the gyroscope and the accelerometer. The accelerometer is used to measure the angle of tilt and the gyroscope will provide the angular velocity to the wheels of the robot via the Arduino which will further give it to the motor- driver to drive the wheels of the robot. The wheels of the robot move in the direction in which the robot is falling thus preventing it falling. The direction of the movement of the robot is provided by the Bluetooth control by which we can control the complete movement of it. This will be controlled by an application made by us so it can be made to use at any place where we want it to work and on any surface. Thus we see that all the components are interfaced and are working together in a synchronous manner.

2.4 System Architecture

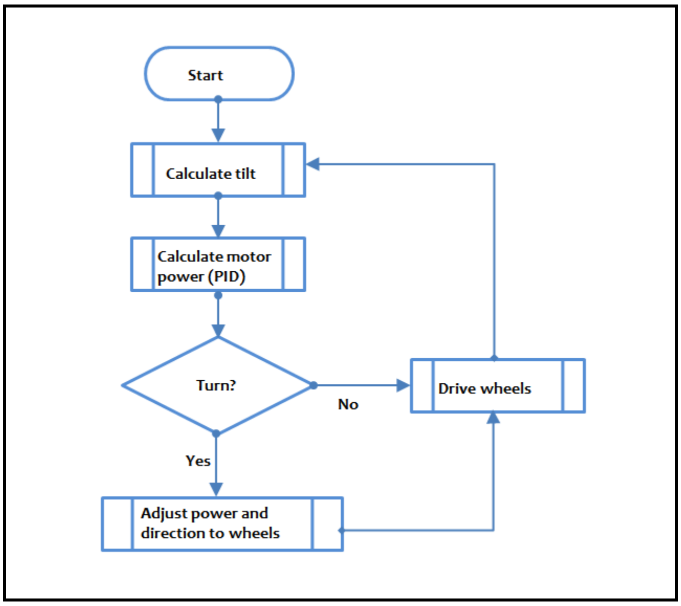

Fig no. 5: System Architecture

3. CONCLUSION

The objectives set in the beginning of the project were met, with the exception of making the robot balance by itself using PID and Kalman Filter. The open loop speed provides a very smooth line with only a few unexpected values. The PID Algorithm is also working fine providing a very low settling time of the motor. The motor's PID Algorithm was tested under various voltages keeping the reference speed constant. The voltage change does not change the speed of the motor showing that the PID Algorithm is working fine. Ultimately, it can be summarized that a learning platform was developed through the designing and development of an optimally performing self-balancing robot.

REFERENCES

[1] IEEE International Power Engineering and Optimization Conference (PEOCO2012), Hybrid Servo Motor Drives for Robotic Application.
[2] KRISHNAN R.: 'Electric motor drives: modelling, analysis and control' (Pearson Education, India, 2003).
[3] NED MOHAN, TORE M. UNDELAND, WILLIAM P. ROBBINS: 'Power Electronics', Third Edition, John Wiley and Sons, New Delhi, 2011
[4] L. Szamel: The special characteristics of stepping motor drives, ENELKO, Alba Iulia, Romania, 2012
[5] 3rd International Conference on Electric Power and Energy Conversion Systems, Servo Motor Driver Design for High Performance Applications, 2013
[6] A.J. Blauch, M. Bodson, and J. Chiasson, "High-speed parameter estimation of stepper motors," IEEE Transactions

on Control Systems Technology, vol. 1, no. 4, pp. 270- 279, December 1993.
[7] G. Baluta, "Microstepping mode for stepper motor control," in International Symposium on Signals, Circuits and Systems , Iasi, Romania, 2007.
[8] Peter Cox and Guido Remmerie, "Driver ICs elevate design of stepper-motor control," Power Electronics Technology, August 2007.
[9] Brlian Henryranu Prasetio,"Ensemble Kalman Filter and PID Controller Implementation on self Balancing Robot", International Electronics Sympusium(IES),2015.
[10] Fengxin Sun, Zhen yu, Haijiao Yang, "A design for two-wheeled self-balancing robot based on Kalman filter and LQR", International conference on mechatronics and control(ICMC),2014.
[11] B.S.B. Vamsi Krishna, P. Mallikarjuna Rao, "Implementation of two wheel self balancing platform", International Research Journal of engineering and Technology(IRJET),2016.