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Self Balancing Robot

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Abstract*: Robotic mobility technology over the past few years have gained much more popularity in both government and commercial sectors. .In last few decades, the open source community has expanded to make it possible for people to build complex product at home. A quick look at the range of mobile robots in existence system reveals an enormous change diversity in shape, form, and modes of mobility. The most common is the passively balanceness (i.e. state of stable equilibrium).. The main goal of our project is to design and implement a discrete control system that will provide robotic stability. There has been varieties of technique to increase the robotic stability on dynamic environments .One such popular technique used for mobile robots is an inverted pendulum based model. A robot that implements the inverted pendulum is usually a tower shaped structure, usually standing on two-wheels and autonomously commanding the motors such that it can keep itself upright while also travelling guided by the user input .Complementary are implemented which is associated with the noise of the signal .Thus the purpose of complementary filter if to simplify the noise by passing it to low pass and high pass filter. We are demonstrating a method which presents the stability by reading the robots tilt from sensors and computing commands for the motors and is analysed using different filter coefficients using PID algorithm as the control strategy. Self balancing robots are designed for variety of user types. The role of the self-balancing is to interpret small muscular activations and high level commands and execute them. Such platforms typically employee techniques from artificial intelligence, such as path-planning.
***Keywords*: Self balancing robot; inverted pendulum; complementary filter; PID; mpu6050**

I. INTRODUCTION

The proposed system Self Balancing Robot is based on Artificial Intelligence domain of Robotics and is an efforts to provide complete automation of the activities involving in houses, restaurants, hospitals and companies. The system would use a Complementary filter and PID control algorithm for sensors and motor controller which provides integrated values and helps in maintaining stability. The inverted pendulum has been the most popular benchmark, among others, for teaching and research in control theory and robotics. The problem regarding 4 wheel or 4 legged robots is that it is more space consuming thus to overcome this problem we built two wheel self-balancing robot which consume less space and can be easily used for transportation(hospitals, companies, restaurants).Besides learning about the theoretical aspects, the project also incorporates the practical side .Complementary filter was also a motivation to develop the self-balancing robot which fuses the data from two sensors such that a better estimation of tilt angle is obtained. Hence, this system would also be designed in such a way that it optimizes the use of energy and satisfies human needs.

II. INVERTED PENDULUM MODEL

The self-balancing robot is based on the concept of inverted pendulum concept. The main key factor of self balancing robot is the stability. The inverted pendulum system is naturally unstable. Therefore, a suitable control system technique and method needs to be investigated to control the system. The two wheel balancing robot is an application of the inverted pendulum that requires a controller to maintain its upright position. To achieve this, a controller needs to be designed and implement on the robot to balance the inverted pendulum. The goal of the project is to adjust the wheels' position so that the inclination angle remains stable within a pre-determined value. In this the robots moves back and froth but in an inverted manner. The angle on inclination is measured and the approximate values are calculated. MPU6050 plays a keen role is calculating the acceleration and angular velocity of the robot. The inverted pendulum concept in the simplest form, consists of a cart moved by two DC motors, to control the position of the inverted pendulum tending to rotate about a fixed position on the cart. The process is nonlinear and unstable with one input signal and several output signals.

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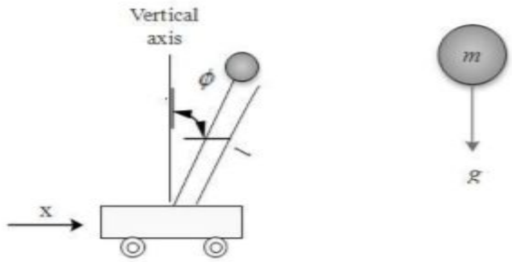

Fig 1: Inverted pendulum on a cart.[4]

In the following analysis of the pendulum cart system by Siebert [8],[4], we mathematically obtain the transfer function of the pendulum-cart system.

The torque produced about the pivoting point at an angle Ø due to gravitational acceleration, g

$$T = mgl\sin(\phi)$$

Based on (1), we derive the following two equations for the vertical and horizontal rotational accelerations

$$\ddot{\phi}_g = \left(\frac{g}{l}\right)\sin(\phi) \qquad (1)$$

$$\ddot{\phi}_x = \left(\frac{\ddot{x}}{l}\right)\cos(\phi) \qquad (2)$$

From (1) and (2), we combine them to get the final rotational acceleration acting on the system.

$$\ddot{\phi} = \ddot{\phi}_g + \ddot{\phi}_x = \left(\frac{g}{l}\right)\sin(\phi) - \left(\frac{\ddot{x}}{l}\right)\cos(\phi)$$

Finally applying Laplace operator to this, we get the following equation :

$$\frac{\phi(s)}{X(s)} = \frac{-s^2}{ls^2 - g} = \frac{\frac{-s^2}{g}}{(\tau s + 1)(\tau s - 1)}$$

III. BLOCK DIAGRAM

A. Hardware

The diagram consists of mainly:

1) Accelerometer
2) Gyroscope
3) PID controller
4) Motors

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˚ .This it will maintain the center of gravity of the In the block diagram shown in the Fig. 2 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 a voltage regulator regulates the supply and gives it to the Arduino UNO 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.

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robot thus balancing the whole system. For measuring the angle, two sensors, accelerometer and gyroscope are used. The operation is then done using wireless joystick. Where the wired joystick is converted into wireless joystick using transceiver module and Arduino UNO.

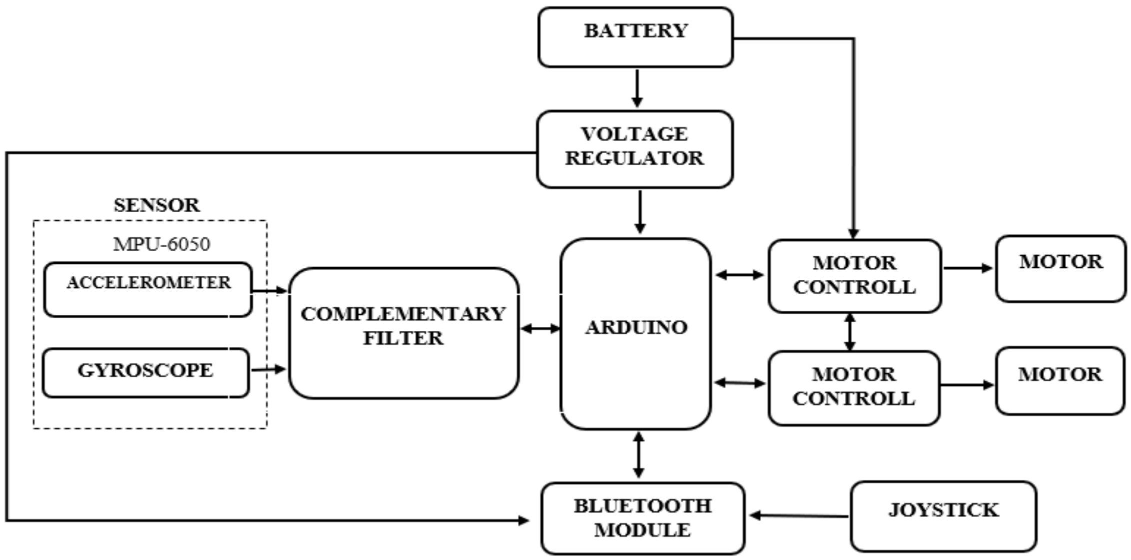

Fig 2 : Block Diagram

B. Arduino

1) *Arduino Uno:* Arduino UNO is used for main programming in self balancing robot. The Arduino Uno is a 8 bit microcontroller board grounded on the ATmega328.It has 14 digital pins and 6 analog pins and additional power pins such as, GND, VCC. It takes 14 digital input/output pins (of which 6can be castoff as PWM outputs), six analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header, and a reset button. It has SRAM 2kb plus flash memory 32kb. EEPROM with 1KB. Arduino is undefended source hardware board with numerous open source libraries to interface it on board microcontroller with numerous other external components like LED, motors, IR sensors and various other things one want to interface with Arduino board. Arduino is a complete board which include all things to connect with exterior peripheral and to program through computer. The Arduino circuit acts as an interface between the software part and the hardware part of the project.
2) *Arduino Pro Mini:* This is a 5V Arduino running the 16MHz bootloader. Arduino Pro Mini does not come with connectors populated so that you can solder in any connector or wire with any orientation you need. We recommend first time Arduino users start with the Uno R3. It's a great board that will get you up and running quickly. The Arduino Pro series is meant for users that understand the limitations of system voltage (5V), lack of connectors, and USB off board.

C. Mpu 6050 Gyro & Accelerometer

The IMU sensor, MPU-6050, MEMS based, manufactured by InvenSense technologies was used. The module consists of 3-accelerometers and 3-Gyroscopes making the unit a 6 DOF (Degrees of freedom) sensor. The sensor works at a voltage level of 3.3v and I2C protocol as means of communication with the microcontroller.

D. Motor Driver

The DRV8825 stepper motor driver carrier is a breakout board for TI's DRV8825 micro stepping bipolar stepper motor driver. The module has a pinout and interface that are nearly identical to those of our A4988 stepper motor driver board, so it can be used as a higher-performance drop-in replacement for those boards in many applications. The DRV8825 features adjustable current limiting, overcurrent and overtemperature protection, and six micro step resolutions (down to 1/32-step). It operates from 8.2 – 45 V and can deliver up to approximately 1.5 A per phase without a heat sink or forced air flow (rated for up to 2.2 A per coil with sufficient additional cooling).

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E. Li Polymer Battery

A lithium polymer battery, or more correctly lithium-ion polymer battery (abbreviated variously as LiPo, LIP, Li-poly and others), is a rechargeable battery of lithium-ion technology using a polymer electrolyte instead of the more common liquid electrolyte. High conductivity semisolid (gel) polymers form the electrolyte for LiPo cells that are being used in tablet computers and many cellular telephone handsets.

F. Complementary Filter

The need for an alternative to Kalman filter arises from the fact that the Kalman filter is very cumbersome, difficult to understand and challenging to implement on a smaller 8-bit microcontroller. Thus a complementary filter serves this purpose of simplifying the difficulties faced while implementing simple first order high pass and low pass filters. Complementary filters do not act on the signals. They are in fact filters to be associated with noise of the signal present. Thus the task of the filter is to estimate a stable angle from multiple sources containing erroneous data and which exhibit noise with different frequency content [9].

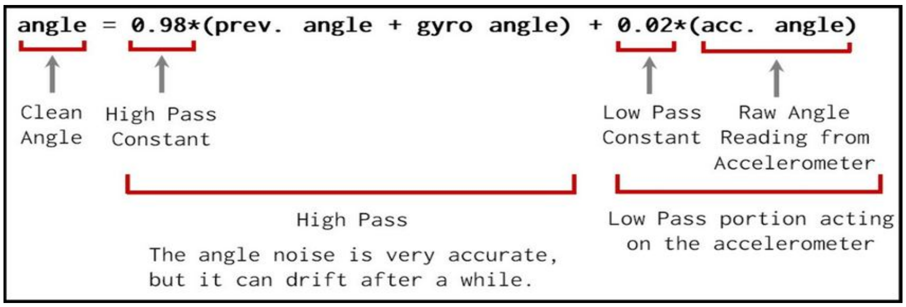
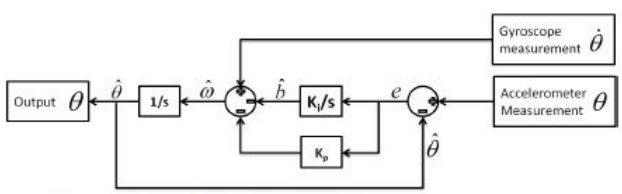


Fig 3 : Complementary Equation Description[4]

Complementary filters do not act on the signals. They are in fact filters to be associated with noise of the signal present. Thus the task of the filter is to estimate a stable angle from multiple sources containing erroneous data and which exhibit noise with different frequency content [8].The complementary filter is a frequency domain filter. Mathematically, it can be seen as the use of two or more transfer functions which are complements of each other. Thus, if one data from the first sensor is represented by the transfer function G(s), then the other data from the second sensor is I-G(s) with the sum being the identity matrix I [8]. If the high frequency noise from one sensor and the low frequency from the second one are compliments of each other then, the complementary filter is applicable. The signal is passed through both high and low pass filter to remove the noise and final reconstruction takes place.



θ = measured angle of accelerometer
$\dot{\theta}$ = measured angular velocity of gyroscope
$\hat{\theta}$ = estimated angle of balancing robot
e = estimation error between $\hat{\theta}$ and θ measurement
$\hat{b}$ = estimated gyro bias
$\hat{\omega}$ = estimated angular velocity
k_p = proportional gain
k_i = integral gain

Fig 4 : Complementary Filter Block Diagram[1]

In theory the Kalman filter should provide the best output and does not work in the frequency domain. But on the other hand the practical implementation of complementary filter does not vary much or rather is almost same as the Kalman filter. What makes the difference in the two is the implementation. The software implementation of the complementary is very easy with the use of just a digital high pass and a low pass filter. The filter consists of two filter coefficients and the following is the complementary filter equation[1]

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FAngle = c*(FAngle+GyroA*dt) + (1-c)*AccA
Where,
FAngle= Final filtered angle
c= High pass filter coefficient
GyroA=Angle obtained from the gyroscope
AccA=Angle obtained from acceleration
dt=loop time since last iteration

IV. CONCLUSIONS

Through this project we were able to make a two wheel self balancing robot by using an inverted pendulum concept. We have also concentrated on the space consuming effect and the stability of two wheel self balancing robot is maintain by using the complementary filter algorithm which plays an important role in our project. We have also covered the hardware and the software aspect, as well as overall architecture and tanning process. The operating process of robot will be handled by a wireless joystick. Future work on this project will be devoted to make the robot more effective, efficient and usable, By using it as obstacle avoidance robot, spy robot etc. and by using more an more sensor to improve the performance to a better level and also make the robots human friendly.

V. ACKNOWLEDGMENT

Firstly, I would express my gratitude to the faculty of engineering, especially computer engineering department faculty for accepting our project idea and giving our opportunity to work on it and bring success in it. This project would not have been possible without the help and guidance by our prof. Siddhesh Bhagat who always helped our bursting his new ideas and suggestions for our to make up with something new.
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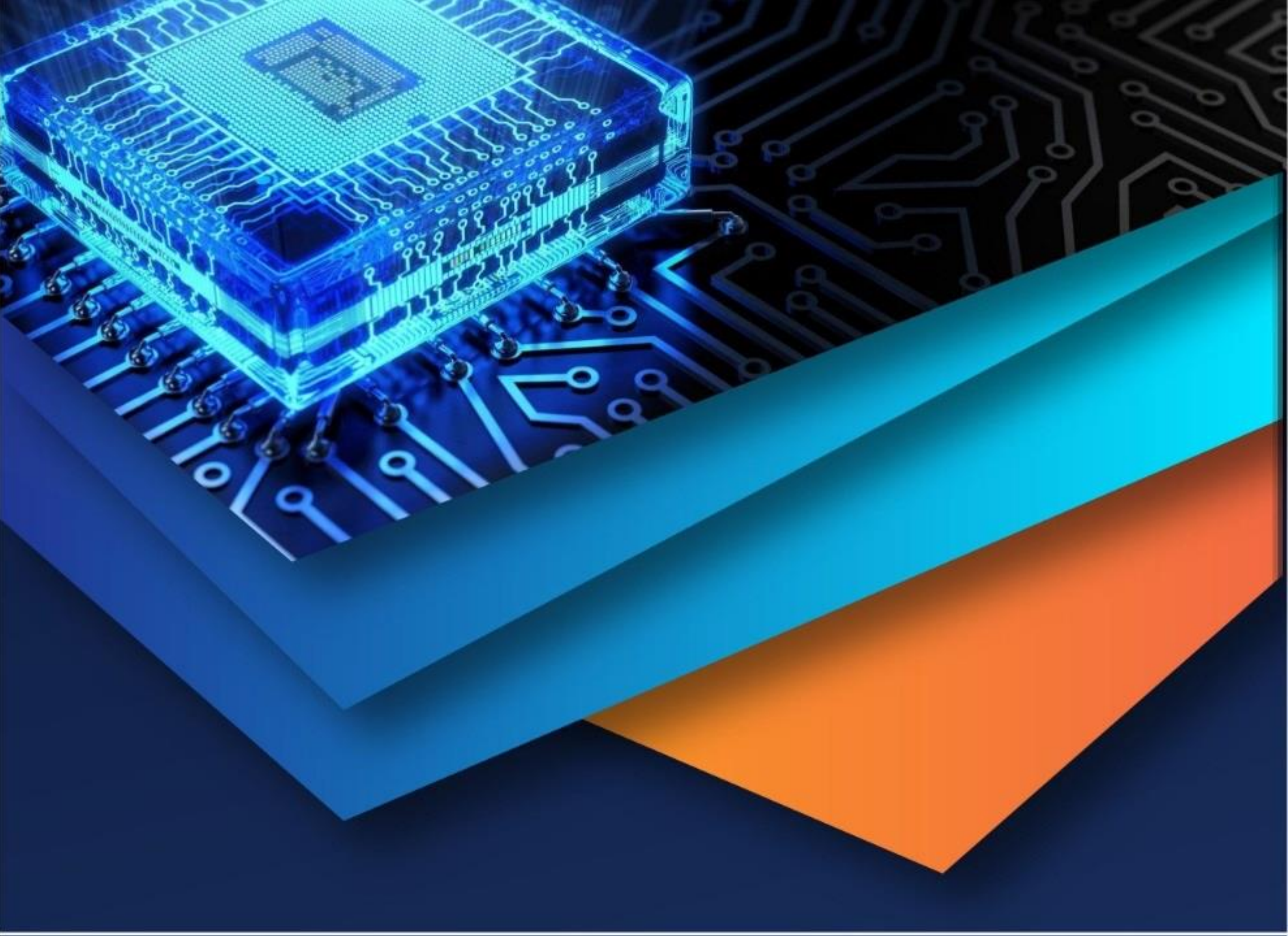

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