PID Control Based Balancing Robot

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Abstract- *Dynamic balancing system & PID control concept is used in implementing two wheel balancing robot.*

In implementing two wheel balancing robot in inverted pendulum configuration, system balances itself and without falling. According to predetermined position the position of robot is balanced. In previous research the robot in two wheel configuration was unstable and nonlinear.

In new approach with the help of proportional integral and derivative (PID) control concept the system becomes stable & linear. Mathematical modeling is used to analyze dynamic behavior of the system. PID control is used to control the position of robot. Some tolerances are incorporated in forward and reverse direction considering mean position but after settling time the system gains its desired position.

This paper shows the concept of self balancing using PID control, with growing technology in this era researchers have developed various modifications enhancement and updation in technology.This robot system becomes attractive in education field due to its size and power requirement.

In recent trend we can modify our system and apply for various applications like defense, transportation hospital, surveillance etc.

Keywords- Inverted Pendulum, Gyroscope, accelerometer,PID Controller, PWM,Ardiuno, IMUs, MEMS etc.

I. INTRODUCTION

The Conquest of robots in human's life is in different ways like guard robots, services robots, fire-fighter robots, entertaining robots and human robots. There is an immense research going on making them cheap, efficient and reliable. An important class of autonomous wheel mobile robots is two wheeled self-balancing robots. Its mechanism is like a human that balances. It adjusts its position, when it is about to fall forward or backward to avoid the instability. Unlike conventional mobile robots, two wheeled self-balancing robots bring practical advantages as follows:

1) Movement on zero radius curves,
2) High tolerant to impulsive force,
3) Small foot print helps to move on dangerous places,
4) Greater stability over slopes.

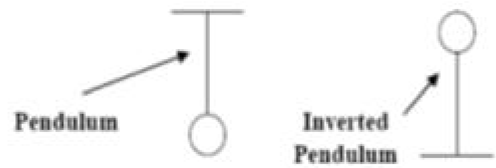

Figure 1. Inverted and Non-inverted Pendulum

Two wheeled balancing robot is a classic engineering problem based on inverted pendulum and is much like trying to balance a broom on the tip of your finger. This challenging robotics, electronics, and controls problem is the basis of our study for this project.

The word 'balance', here, means that the inverted pendulum is in equilibrium state, i.e. its position is standing upright at 90 degrees. However, the system itself is not balanced, which means it keeps falling off, away from the vertical axis. Therefore, an accelerometer-gyroscopic inertial measurement unit is needed to provide the angular position or tilt of the robot base with respect to the vertical and input it to the microcontroller, which is programmed with a balancing algorithm. The microcontroller will provide a type of feedback signal through Pulse Width Modulation (PWM) control to the MOSFET reinforced L293D motor driver's H-Bridge circuit to turn the motor clockwise or anticlockwise with appropriate speed and acceleration, based on the Proportional-Integral-Derivative (thus balancing PID) control, the robot.

The code will be written in C software and compiled for the Atmel ATMega168 microcontroller through Arduino software. The main goal of the microcontroller is to fuse the wheel encoder, gyroscope and accelerometer sensors through a method called Kalman Filtering, to estimate the attitude of the platform and then to use this information to drive the wheel in the direction to maintain an upright and balanced position.

The basic idea for a two-wheeled dynamically balancing robot is pretty simple: move the actuator in a direction to counter the direction of fall. In practice this requires two feedback sensors: a tilt or angle sensor to measure the tilt of the robot with respect to gravity, an accelerometer to calibrate the gyro thus minimizing the drift. Two terms are used to balance the robot. These are 1) the tilt angle and 2) its first derivative, the angular velocity. These two measurements are summed together through Kalman Filtering and fed back to the actuator which produces the counter torque required to balance the robot through PID.

Thus the robot can be classified into the following parts:

- Mechanical Model
- Inertial sensors
- Logical processing unit
- Actuators

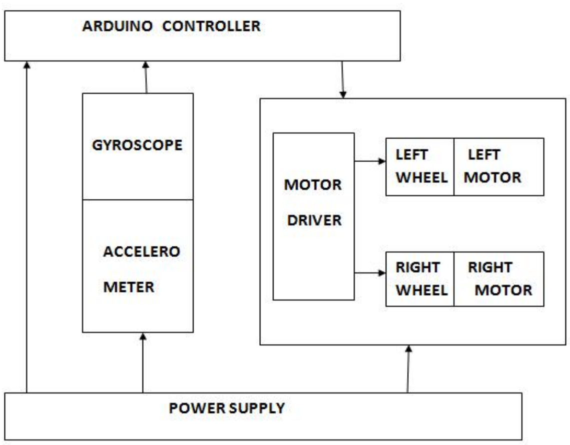

Figure 2. Block Diagram of System

II. METHODOLOGY

The basic idea for a two-wheeled dynamically balancing robot is pretty simple: drive the wheels in the direction that the upper part of the robot is falling. If the wheels can be driven in such a way as to stay under the robot's center of gravity, the robot remains balanced. To balance itself, balancing robot requires feedback from accelerometer and gyroscope. To achieve stability PID control algorithm will be applied to robot.

In building this two wheeled balancing robot locomotion the work will be divided in two parts:

Part 1: Assembly of mechanical and electrical part of robot. this include listing and identifying the robot components such as motors, wheels , body parts, steel part, actuator, circuit design, ardiuno implementing, sensors and others.

Part 2: The development of the robot programming using ardiuno microcontroller and the full testing of the robot functionality.

III. PID CONCEPT

A. What is PID?

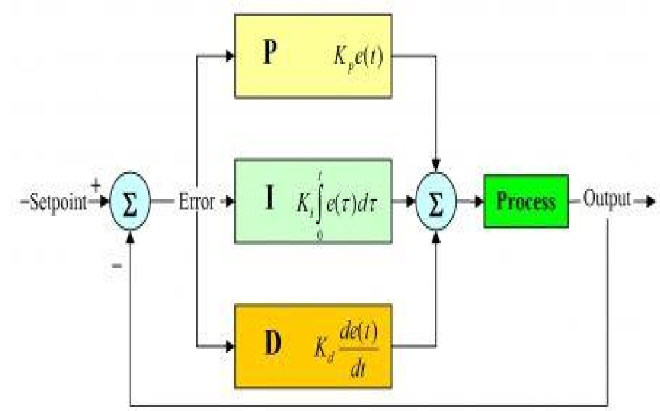

Figure 3. Block Diagram of PID

PID stands for Proportional Integral and Derivative. It is a popular control loop feedback control extensively used in industrial controls systems.

B. The terms associated with PID-

- Target – It is the position you want the line follower to always be(or try to be),that is, the center of the robot.
- Current Position – It is the current position of the robot with respect to the line.
- Error - It is the difference between the current position and the target. It can be negative, positive or zero.
- Proportional – It tells us how far the robot is from the line like the robot has been on the line in the last few moments or not.
- Derivative – It is the rate at which the robot oscillates to the left and right about the line.
- Integral – It gives the accumulated error over time. It tells us if position right.

Kp, Ki and Kd are the constants used to vary the effect of Proportional, Integral and Derivative terms respectively.The three gains, kP, kI and kD are tunable parameters and must be adjusted according to the specific hardware used. There are very many ways to tune these parameters to an optimal value. We used the manual method to do this. First, we set all the gains to 0. Then kP is increased until the response oscillates. Then kP is set to half its value. kI is now increased until the steady state error is corrected in sufficient time. Finally, kD is increased to minimize overshoot.

IV. RESULTS AND DISCUSSIONS

An accelerometer is a device that measures proper acceleration. The proper acceleration measured by an accelerometer is not necessarily the coordinate acceleration (rate of change of velocity). Instead, the accelerometer sees the acceleration associated with the phenomenon of weight experienced by any test mass at rest in the frame of reference of the accelerometer device. For example, an accelerometer at rest on the surface of the earth will measure an acceleration g= 9.81 m/s2 straight upwards, due to its weight. By contrast, accelerometers in free fall or at rest in outer space will measure zero. Another term for the type of acceleration that accelerometers can measure is g-force acceleration.

Single- and multi-axis models of accelerometer are available to detect magnitude and direction of the proper acceleration (or g-force), as a vector quantity, and can be used to sense orientation (because direction of weight changes), coordinate acceleration (so long as it produces g-force or a change in g-force), vibration, shock, and falling in a resistive medium (a case where the proper acceleration changes, since it starts at zero, then increases). Micromachined accelerometers are increasingly present in portable electronic devices and video game controllers, to detect the position of the device or provide for game input.

Accelerometers have multiple applications in industry and science. Highly sensitive accelerometers are components of inertial navigation systems for aircraft and missiles. Accelerometers are used to detect and monitor vibration in rotating machinery.

Accelerometers are used in tablet computers and digital cameras so that images on screens are always displayed u– to the right, to the extreme right, to the left or a little to the left. Proportional is the fundamental term used to calculate the other two.

V. MEMS GYROSCOPE

MEMS gyroscopes use the Coriolis Effect to measure the angular velocity. When a mass (m) is moving in direction v and angular rotation velocity Ω is applied, then the mass will experience a force as a result of the Coriolis force. And the resulting physical displacement caused by the Coriolis force is then read from a capacitive sensing structure.

Most available MEMS gyroscopes use a tuning fork configuration. Two masses oscillate and move constantly in opposite directions When angular velocity is applied, the Coriolis force on each mass also acts in opposite directions, which result in capacitance change. This differential value in capacitance is proportional to the angular velocity Ω > and is then converted into output voltage for analog gyroscopes or LSBs for digital gyroscopes.When linear acceleration is applied to two masses, they move in the same direction. Therefore, there will be no capacitance difference detected. The gyroscope will output zero-rate level of voltage or LSBs, which shows that the MEMS gyroscopes are not sensitive to linear acceleration such as tilt, shock, or vibration.

Digital cameras use gyroscopes to detect hand rotation for image stabilization. A yaw rate gyroscope can be used in cars to activate the electronic stability control (ESC) brake system to prevent accidents from happening when the car is making a sharp turn. And a roll gyroscope can be used to activate airbags when a rollover condition happens.

A yaw rate gyroscope can be used in cars to measure the orientation to keep the car moving on a digital map when GPS signal is lost. This is called car dead-reckoning backup system.
The yaw rate gyroscope can also be used for indoor robot control. and legs for body tracking and monitoring.

The IMU can also be used for air mouse application, motion gaming platforms and personal navigation devices with the integration of magnetometer and GPS receiver.Multiple inertial measurement units (IMUs) can be mounted on arms.

VI. APPLICATIONS

1. Motorized wheelchair.
2. A small cart which allows humans to travel short distances instead of car that is more polluting
3. Self balancing Robot Bicycle.
4. Surveillance mapping.
5. Telepresence.

VII. FUTURE SCOPE

1) In future the two wheeled bicycle could be made to move not only forward and backward, but also steer sideways.
2) One Wheeled Vehicle (OWV).

3) Two wheeled robot can be Upgraded to a line follower.

VIII. CONCLUSION

The two wheeled balancing robot, which is based on the Inverted pendulum concept can be balanced using a closed loop control system along with the PID control algorithm. The robot can be improved further by using encoders for determining the current position. More no. of sensor can be used to get a stronger feedback to improve stability.

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