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The design, modeling, construction and implementation of Self-balancing robot

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Abstract: This paper proposes a self-balancing robot using the concept of inverted pendulum. Self-balancing of the robot can be achieved by adjusting its Centre of gravity by the means of acceleration and torque applied on its wheels. The self-balancing robot is designed using motors, sensors and microprocessor. This type of robot has earned interest and fame among researchers and engineers of worldwide as it based on such a control system that is used to stabilize an unstable system using efficient micro controllers and sensors. These robots provide exceptional robustness and capability due to their smaller size and power requirements. These types of implementations find applications in several purposes such as surveillance & transportation. This project is based on development of a self-balanced two wheeled robot. In particular, the focus is on the electro-mechanical mechanisms & control algorithms required to enable the robot to perceive and act in real time. Similar concept can be applied in various control system with complex implementation such as humanoid robot, industrial robots, etc

I. INTRODUCTION

The self-balancing robot has gained fame and interest among researchers and engineers around the globe in last few decades. A robot which is intelligent enough to the calculations to be in its upright (vertical) position balancing itself only on two wheels. It is capable of adjusting the position and alignment of its wheels on its own even upon application of external force. The two wheels are situated below the base and allow the robot chassis to maintain an upright position. It does so by moving in the direction of tilt, either forward or backward, in an attempt to keep the centre of the mass above the wheel axles. The wheels also provide the locomotion thus allowing the robot to transverse across various terrains and environments.

THEORY OF INVERTED PENDULUM:
An inverted pendulum is a pendulum that has its center of mass above its pivot point. It is unstable and without additional help will fall over. In order to stabilize a pendulum in this inverted position, a feedback control system can be used, which monitors the pendulum's angle and moves the position of the pivot point sideways when the pendulum starts to fall over, to keep it balanced.

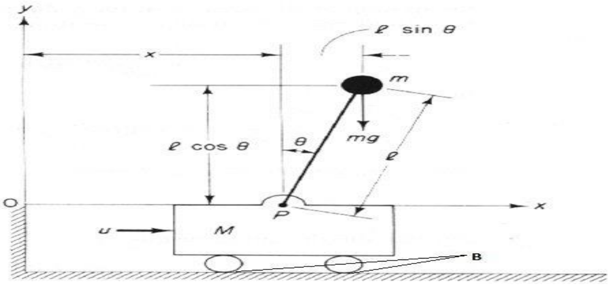

Fig1:

II. LITERATURE REVIEW:

In a literature review a lot of papers were searched and reviewed. We used references like research gate. We referred papers which had information about the components used like gyroscope and sensors and mathematical model of self-balancing robot. Although the self-balancing robot has proven to be a popular topic, and therefore a lot of research is been done in this area, after examining the articles in depth, 10 articles were reviewed. Each of these demonstrated different methods on how to achieve balance from a two wheeled robot.
The literature reviewed examined the hardware used in the design of the robot, the software. Although the self-balancing robot has proven to be a popular topic, and therefore a lot of research was obtained, after examining the articles in depth, 10 articles were reviewed. Each of these
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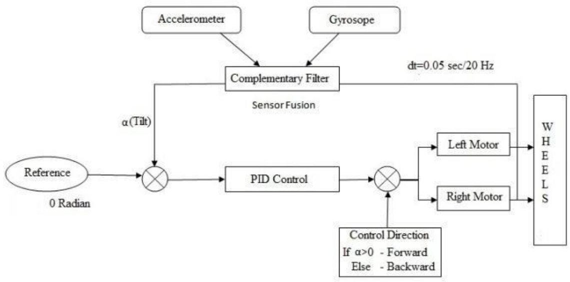
Since, this topic is quite famous among engineers and researchers there were many papers on this project. We made use of 4 research papers among those:In the paper titled “Trajectory tracking control for navigation of the inverse pendulum type self-contained robot” [1] the research was made on construction and designing a robot that could independently move and navigate itself by maintaining stability and balance.
The paper “Performance Evaluation of MMA7260QT and ADXL345 on Self Balancing Robot” (Ferdinando, Khoswanto & Purwanto, 2013) research was made on components used like gyroscope and accelerometer and how to calculate the angle of tilt.
In the paper “Comparison of different control theories on a two wheeled self-balancing robot” (Rahman, Rashid, Hassan & Hossain, 2018) the researchers made use of different control theories & programs to run them.
The paper “Development of a self-balancing robot with a control moment gyroscope” (Park & Cho, 2018) research was made on point of stating that when a self-balancing robot encounters a disturbance the robot will lose its stability and must move in order to correct this.

III. DESIGN & IMPLEMENTATION:

BLOCK DIAGRAM:

controller produces a control signal μ. PID control signal then gets fed into the process under control. Process under PID control is two wheeled robot. PID control signal will try to drive the process to the desired set-point value that is 0˚ in vertical position by driving the motors in such a way that the robot is balanced.



The self balancing robot gets balanced on a pair of wheels having the required grip providing sufficient friction. For maintaining vertical axis two things must be done, one is measuring the inclination angle and other is controlling of motors to move forward or backwards to maintain 0˚angle with vertical axis. For measuring the angle, two sensors, accelerometer and gyroscope are used. Accelerometer can sense either static or dynamic forces of acceleration and Gyroscope measures the angular velocity.
The outputs of the sensors are fused using a Complementary filter. Sensors measure the process output say α which gets subtracted from the reference set-point value to produce an error. Error is then fed into the PID where the error gets managed in three ways. After the PID algorithm processes the error, the under PID
controller produces a control signal μ. PID control signal then gets fed into the process under control. Process control is two wheeled robot. PID control signal will try to drive the process to the desired set-point such a way that robot is balanced. value that is 0˚ in vertical position by driving the motors in such a way that the robot is balanced.

Components:

1.Arduino nano:
The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328P released in 2008. It is smaller in size than Arduino uno. Since, its is smaller in size and provides same connectivity and efficiency than uno so nano is most widely used. It has 14 digital I/O pins and has clock speed of 16MHz, It has operating voltage of 5V, It has flash memory of 16KB out of which 2KB is for boot loader, It has SRAM of 1KB and EEPROM of 512 bytes.

2.ACCELEROMETER& GYROSCOPE(GY521 Module):
The accelerometer measure the acceleration of the chassis and the gyroscope is used to help maintain the balancing position. Gyroscope is used to measure speed of rotation of robot. When robot is falling n gyroscope is rotating the gyroscope will read appropriate value and of spend and rotation.
3.HC-05 Bluetooth module:
HC-05 Bluetooth Module is a simple Wireless Communication device based on the Bluetooth Protocol. This module is based on BC417 Single Chip Bluetooth IC that is compliant with Bluetooth v2.0 standard and with support for both UART and USB interfaces.
4.A4988 Stepper motor drivers:

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The A4988 is a complete Microstepping Motor Driver with built-in translator for easy operation. The driver has a maximum output capacity of 35 V and ± 2 A. It can operate bipolar stepper motors in full, half, quarter, eighth, and sixteenth-step modes.

5. NEMA 17 stepper motors:

Nema 17 is a **hybrid stepping motor** with a 1.8° step angle (200 steps/revolution). Each phase draws 1.2 A at 4 V, allowing for a holding torque of 3.2 kg-cm. NEMA 17 Stepper motor is generally used in Printers, CNC machines and Laser Cutters.

CONTROL TECHNIQUE:

It is difficult to balance a robot because its naturally unstable so to overcome this we make use of PID controller. A PID controller is used to continuiosly measure the error angle from desired angle (0 degree). PID controller try to minimize error by continuously adjusting motor torque from following equation where u(t) is control variable , e(t) is current error and Kp , Ki, and Kd are coefficients

IV. CONCLUSION

Based on our research a self balancing robot was designed and established as desired with limited resources possible. It was able to balance smoothly with a maximum tilt error of 5 degrees. The robot is capable of taking payloads around 0.3 Kg. The project was challenging even though it looked simple. Self balancing robot moves smoothly on smooth surface like floor and carpets.

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