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A Review on Self-Balancing Line follower Robot

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Abstract **- Self-balancing robots contribute a factor of excellence to important aspects of robotics. These robots are often two-wheeled and work on the inverted pendulum concept. Our aim is to develop a self-balancing line follower robot, capable of bringing a revolutionary change concerning indoor tasks in commercial industries, hospitals, educational institutes, and other facilities. Here Raspberry Pi works as the brain of the robot and uses a PID control loop to maintain balance on two wheels by constantly reading the IMU data and adjusting itself to the pre-defined set-point. It is also capable of following white/black lines using infra-red sensors and also uses ultrasonic sensors and a camera module for obstacle and object detection respectively**

Keywords— The self-balancing robot, PID control loop, line follower, infra-red sensor, ultrasonic sensor, object detection, obstacle detection

1. 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 potential to do other useful things. In hospitals, especially in the light of covid-19, a lot of waste-such as used masks and PPE kits are all disposed of further by people who are rather vulnerable to the infection it still contains. Even the job of serving in restaurants, which often requires extreme multitasking abilities, can sometimes get simply hard as it is next to impossible to attend to everyone at the same time. Educational institutes could function more smoothly if there was no need to allow a person to pass every memo now and then. These and dozens of other tasks applicable indoor call for the same sort of prerequisites that could be fulfilled without consuming this much time or manpower. All these reasons and
more, inclined us towards finding one of the best possible solutions: A self -balancing bot.

These two-wheeled robots are dependent on the principles of an inverted pendulum, which means it is expected to increase acceleration every time the angle of inclination changes from that of the vertical. This prevents it from falling, the center of the mass of the robot will then experience an artificial force, which applies a torque opposite to its tilt direction, henceforth retaining its balance. A PID controller is the control algorithm used in this active self-balancing robot. PID, as the name stands for, has three parameters: Proportional, integral, derivative. It utilizes a closed-loop control system or what's 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 in the simplest manner. Another important contribution to this is 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 because of its high accuracy and reduced memory consumption in the processor.

The two-wheeled robots have an edge over three and four-wheeled robots in terms of maneuverability. Since the turn ratio is reduced to zero, we can achieve smoother rotations while changing the course of the path with accurate navigation in compact spaces. We can observe the robot losing its balancing, while it's under the condition of passively balancing and stable equilibrium. To overcome this we can mimic the human action of stepping towards the same direction of fall, an actively balanced system with unstable equilibrium conditions.

2. LITERATURE REVIEW

In [1], the goal was to develop an algorithm for a balancing bot to follow a predefined line. The microcontroller used here ATMEGA32 works as the brain of the system, where it responds to the stimulus produced from the environment causing the drifts and maintains the balance by modifying the inclination angle. It uses Infrared sensors to sense the path to be traversed and coordinates with the controller to provide the right commands to the motor drivers. A PID controller was used to implement the restoration process for getting back the setpoint while balancing and it is also integrated with the line following algorithm for a smooth transition. Overall, the system resulted in providing a dynamically stable balancing bot with line following capabilities.

In [2], the objective was to develop a balancing bot using an Arduino controller. To attain the self-balancing capability 1-axis gyroscope and 2 axis accelerometer were planned to coordinate with the motors via controller decisions. In this system drifts in the gyroscope values were found a filter instilled to make up for fluctuations. The result was observed to be a self-balancing bot that was implemented with effective usage of PID along with the LQR technique for PI-PD design. In [3], the research focuses on implementing a self-balancing bot, with a unique estimation on the state onboard for the PID controller's feedback. Usually, the balancing bot works on acquiring the estimation from IMU and the triggers from the actuators onboard. Whereas this paper presents about developing an estimation algorithm to provide the same feedback. Although the actuator feedback is robust, it creates vague situations during the process. The result showed a significant level of stability and robustness using the PID controller.

In [4], the inertial navigation system makes use of an inertial measurement unit (IMU) to measure the navigation parameters. The navigation solution is bound to shift over time because of the amount of noise sensor measurements contain. In the case of low-cost sensors, the usage of multiple IMUs improves the performance of a single unit. The paper presents the architecture of 32 multi IMU with the results for the same. A dedicated software tool that is able to address MIMU inputs, was developed to analyze the sensory data. Navigation accuracy, rejection of sensor outliers, the performance of stationary calibrations, the accuracy of coarse alignment, and effects of positioning in architecture have been examined and evaluated using various hardware and software tools. Upon increasing the number of IMUs the significant improvement in the performance can be seen at the end.

In [5], the paper presents a summary of three majorly authoritative algorithms. Where they have introduced the Kalman filter and Bayesian state estimators and filters. Particle filter, Kalman, and extended Kalman filters are explained with algorithms, analyzed its complexity, correctness, and accuracy, and finally compared the three with a practical example.

In [6], ATMega8535 was used for the implementation of a Kalman filter for the IMU along with an accelerometer and a gyroscope. The controller evaluates using smaller values once the arbitrary sampling time is chosen. The Kalman filter operates with complex matrix formulations where it can be transformed into simple quadratic equations. The covariance matrix is the one that changes the response of the filter to noise. Wherever the value is higher the results in a smooth transition, but it won't be able to give the proper estimate of angles. In the other case, if the value is small the angle will be affected by the sensitivity to noise. So the paper suggests keeping 0.0001 to 0.001 for covariance noise parameters and to include a pipeline to avoid larger time samples.

In [7], TABAR, a line follower bot was designed and implemented for a robotics competition. The objective of this bot is to identify the line drawn on the floor and traverse along with it. The path can either be a black stripe on a white surface giving a high contrast or a magnetic field, which is invisible and provided in advance. Here Infrared sensors were mounted on the robot to sense the path, where it transmits the data to the processor and the processor makes the required decisions and provides commands to the drivers based on the goal to be reached.

In [8], the objective was to develop a wheeled robot with a line following capability. An ARM cortex-3 based microcontroller called LM3S811 was used as the controller to receive the data from the line follower sensors for accurate and smooth operations. The differential drive type of locomotion system was replaced by using PID with a dynamic controller algorithm for the improvements in navigation. In the end, it is observed that the technique can be implemented under the real-time system requirements.

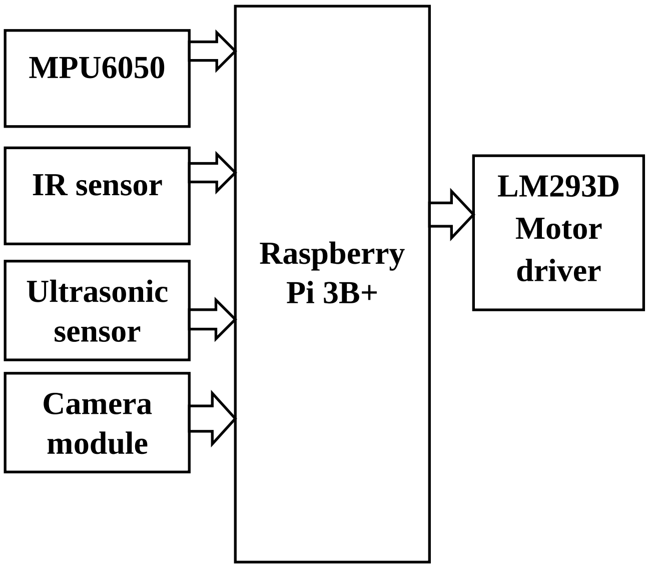
In [9], the objective was to develop an algorithm to follow a black line using a camera module mounted on the robot. Here raspberry-pi was used as the core processor and other software was constructed with C++. A significant performance was observed using this technique to follow the line, where the direction of movement of the robot gets modified based on the detected path and this technique was found to be more reliable.

In [10], the objective was to design a Motor driver using the H bridge technique. As mentioned, the motor's speed and also the rotating direction can be controlled using the H-bridge circuit, where the PWM input to the MOSFET plays a significant role in achieving the proper implementation. By dictating the PWM duty cycle they have directly controlled the motor's speed in reference to change in the motor terminal voltage. The dsPIC30f4011 microcontroller was used to control the overall circuitry, where it generates the required PWM signal necessary for the control of the terminal voltage at the motor. And the controller was tested for different levels of speed and has noticed fair results.

In [11], the paper concentrates on design and implementing a robot, which uses an ATmega328 microcontroller and uses ultrasonic sensors for obstacle avoidance. This project advances the robotic vehicle that has been built with intelligence to direct itself away from a potential obstacle. Here the obstacles are detected using the ultrasonic sensors mounted all around the robot, whenever it encounters one it sends a trigger signal to the controller and the microcontroller takes the appropriate decision on changing the course and concentrating on moving to cross the obstacle without harming the system,

In [12], the paper concentrates on detecting moving obstacles in front of the robot using a camera module mounted on it. Employing techniques like background subtraction and image differentiation in a still camera is not possible. Here it demonstrates the detection of moving objects using block-based detection, where the image picture is divided into smaller blocks and it compares each block with the consecutive image, which is fragmented in the same manner as the previous one. If a significant difference is found, then the block is tagged under the moving object. This approach of moving object detection has tested for indoor environments and found noticeable results with the robot.

3. METHODOLOGY



The heart of the system is the MPU running the PID and line following algorithms. The IMU sensor engages in real-time data acquisition required. A setpoint is predefined. The PID control loop determines how far off is the current value from the set point. According to the offset value, the motor is driven to maintain the balance. The line following algorithm depends on the IR sensor values. Depending upon the reading of different sensor values, the algorithm drives the motors accordingly. The ultrasonic sensor detects the obstacle around the robot and alerts the processor with the object's position. Then the camera module is triggered to identify the active or passiveness of the obstacle. Based on the nature of identification further action will be taken, either to take some minor deviations or activating an emergency signal.

4. RESULT & DISCUSSION

The above paper aims at building an autonomous robot with self-balancing and line following capability. The robot using a PID control loop will be able to maintain balance on two wheels by constantly reading the IMU data and adjusting itself to the pre-defined set-point. The robot follows a white/black line using IR sensors. The sensor data is continuously red, and it adjusts itself by changing motor rotation and direction. The ultrasonic and the camera module helps in detecting the obstacle and taking necessary actions. The testing of the components has been done to ensure their proper functionality.

5. CONCLUSION

From the above papers, the thing to be noted is that the perfect balance of the robot can be achieved only by proper implementation of Kalman filter using IMU, with this we can also be able to convert complex matrix calculations into ordinary equations. We can also use PI-PD over PID and a complementary filter for better stability. Integrating PID control algorithms for line following will improve navigation and unwanted changes in the path width can be avoided, by satisfying the system's real-time requirements. Making use of the PWM technique is crucial to control the speed of the motors and H-Bridge for bidirectional control of motors. We can optimize the system by replacing ultrasonic sensors with LIDAR and Block based moving object detection techniques to identify the nature of the obstacle.

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