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Design and Development of Self Balancing Two Wheeler

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Abstract: *The Self-balancing robots represent a fascinating intersection of technology and practical application. This project aims to design and develop a self-balancing two- wheeler robot capable of maintaining stability and balance autonomously. Drawing inspiration from principles observed in human balance and locomotion, the robot employs a combination of sensors, actuators, and control algorithms to achieve its objective. The project begins with an in-depth literature survey, exploring existing research and methodologies in the field of self-balancing robotics. Leveraging insights from key publications, the project outlines fundamental principles, sensor fusion techniques, advanced control methodologies, and challenges inherent in self-balancing robot design. Key components including an Arduino Uno board, accelerometers, gyroscopes, DC motors, batteries, and optional reaction wheels are carefully selected and integrated into the robot's hardware architecture. A systematic approach to hardware selection, assembly, sensor integration, microcontroller programming, and motor control ensures a coherent and functional design. Throughout the development process, emphasis is placed on rigorous testing, calibration, and iterative improvement. The robot is subjected to various environmental conditions and scenarios to validate its stability and performance. Calibration procedures refine sensor accuracy and control algorithms, enhancing the robot's ability to maintain balance under dynamic conditions. The project culminates in the creation of a comprehensive documentation package, detailing schematics, code explanations, assembly instructions, and testing methodologies. Additionally, a presentation showcases the robot's functionality, design rationale, and potential applications. By meticulously following the outlined steps and leveraging insights from existing research, this project aims to contribute to the advancement of self-balancing robotics and serve as a foundation for future exploration and innovation in this exciting field*

Keywords: Self-balancing robots

I. INTRODUCTION

In the realm of robotics, the pursuit of autonomy has always been a paramount goal. Among the myriad challenges in this pursuit, achieving stability and balance stands as a fundamental prerequisite for the seamless operation of robotic systems. Inspired by the elegant mechanics of nature and human locomotion, self-balancing robots emerge as a testament to the ingenuity of engineering, blending sophisticated sensors, intelligent control algorithms, and precise actuation to emulate the graceful equilibrium observed in living organisms. The aim of this project is to embark on the design and development journey of a self-balancing two-wheeler robot, an embodiment of technological prowess and mechanical finesse. Such a robot, akin to its human counterparts, endeavours to maintain its equilibrium without human intervention, navigating its surroundings with poise and precision. Within the landscape of robotics, the allure of self-balancing robots extends far beyond mere technological fascination. These versatile machines find application across diverse domains, ranging from education and research to entertainment and industrial automation. Their ability to uphold stability in dynamic environments opens avenues for innovation and exploration, serving as platforms for experimentation with cutting-edge control systems and robotics methodologies. As we delve into the intricacies of self-balancing robotics, it becomes apparent that a multidisciplinary approach is essential. Drawing insights from fields such as control theory, sensor fusion, and mechanical engineering, we embark on a journey marked by innovation and collaboration. Through meticulous planning, systematic experimentation, and iterative refinement, we strive to unlock the full potential of self- balancing two-wheeler robots, ushering in a new era of autonomous machines. In the following sections, we embark on a comprehensive exploration of the principles, methodologies, and technologies underpinning the design and development of our self-balancing robot. Through a synthesis of existing research, practical experimentation, and creative problem- solving, we endeavour to realize a robot that not only embodies stability and balance but also serves as a testament to the boundless possibilities of robotics in the modern era.

II. EXISTING SYSTEM

Several existing systems and platforms demonstrate the capabilities of self-balancing two-wheeler robots across various domains. For instance, Segway-Ninebot offers a range of personal transporters, utilizing gyroscopic sensors and advanced algorithms for balance maintenance. Boston Dynamics' Handle, designed for logistics, showcases autonomous navigation and task handling abilities. In the consumer space, WowWee's MiP robot combines entertainment with balancing tech, controlled via gestures or apps. Additionally, companies like Toyota and WHILL have innovated self-balancing wheelchair platforms for enhanced mobility. DIY and open-source platforms, such as Arduino-based kits, further foster exploration and development in the self-balancing robotics domain, highlighting its diverse applications and continuous advancement.

III. RELATED WORK

Design of Two-Wheeled Self-Balancing Robot Based on Sensor Fusion Algorithm Jianhai Han, Xiangpan Li∗, and Qi Qin A two-wheeled, self-balancing robot is proposed using 6- axis MEMS sensors MPU6050 to measure its posture. The sensors integrated with a 3-axis gyroscope and a 3-axis accelerometer, can output the inclination of the robot based on sensor fusion algorithm. A handheld remote controller sends out commands to the robot such as forward, back, and turning around. According to the inclination and orientation commands, a 16-bit MCU using the PID control algorithm calculates the required control voltage for the motors, to adjust the robot's posture and keep the body balanced. In this paper, the principle of the sensor fusion algorithm is fully described, and its effects are verified through related experiments. The experimental results show that the proposed robot is practical and able to balance using inexpensive MEMS sensors.

Design and control of a two-wheel self-balancing robot Alex Mathew, R Ananthu, P Binsy, Abdul Vahid, Ciby Thomas and S Sidharthan. Designing the self-balancing two wheeled mobile robots and stabilizing it has gained a lot of momentum in research areas. Instead of complex control system that are mostly scene in these research papers this paper introduces a new design of two wheeled robot structure which fulfils the required level of stabilization without any complex control system. To achieve this, the structure is designed with a vertical straight-line motion. After deriving the mathematical model, the model is simulated in Matlab Simulink. The simulation is carried for step, ramp and uneven terrain input conditions.

Model Predictive Control for a Two Wheeled Self Balancing Robot Mohammad Mahdi Azimi In this paper, a model predictive control is presented and applied to a two wheeled self-balancing robot. This robot is known as a three-degree-of- freedom mobile robot with multivariable underactuated dynamics. The dynamic equations of the system are first introduced and the inputs and outputs are assigned. Then, by using a compensator block in sequential closing loop method, the original system is transformed into two subsystems. The model predictive controller is designed for maintaining robot in balance despite the external disturbances. The robustness of the method is evaluated in the presence of sinusoidal and step-like disturbances. The simulation results are also presented and discussed using Matlab software.

Model-Based LQR Control of Two-Wheeled Balancing Robot Khin Wai Hlaing Phyo, 2 Aung Kyaw Nyein Two-wheeled balancing robot has working principle like inverted pendulum that the controller in the mobile robot plays a critical role in self- balancing and stabilizing. This paper inscribes the design, construction and control of a two-wheeled balancing robot. There are two DC geared motor, MPU 6050 and Arduino Uno in this system. The focus of this paper is to control the twowheeled balancing robot by using Linear-Quadratic Regulator (LQR) controller. In order to measure the angle of robot, MPU 6050 is used and its measurement data noise is filtered using complementary filter. With the help of encoder feedback, the control of two-wheeled balancing robot uses LQR controller included with adjusting motor speed and spinning direction. Kinematic and electrical parameters are determined experimentally, LQR control modelling based upon the linearized equations of motion. The experimental results show that the two-wheeled balancing robot is able to maintain robot position at its balanced condition.

A PD SLIDING MODE CONTROLLER FOR TWO- WHEELED SELF-BALANCING ROBOT Nguyen Gia Minh Thao, Duong Hoai Nghia, Phan Quang An. This paper presents a method to design and control a two-wheeled self-balancing robot. It focuses on hardware description and PD sliding mode controller design. The signals from angle sensors are filtered by a discrete Kalman filter before being fed to the PD sliding mode controller. The objectives of the proposed controller are twofold: regulation of the pitch angle and tracking the desired position. The proposed controller has two loops. The first loop is a sliding mode pitch angle regulator. The second loop is a PD position tracking controller. Simulations and experimental results show that the proposed controller has good performance and robust against disturbances.

Self-balancing robot: modeling and comparative analysis between PID and linear quadratic regulator Lu Bin Lau, Nur Syazreen Ahmad, Patrick Goh A two-wheeled self-balancing robot (TWSBR) is an underactuated system that is inherently nonlinear and unstable. While many control methods have been introduced to enhance the performance, there is no unique solution when it comes to hardware implementation as the robot's stability is highly dependent on accuracy of sensors and robustness of the electronic control systems. In this study, a TWSBR that is controlled by an embedded NI myRIO-1900 board with LabVIEW-based control scheme is developed. We compare the performance between proportional-integral- derivative (PID) and linear quadratic regulator (LQR) schemes which are designed based on the TWSBR's model that is constructed from Newtonian principles. A hybrid PID-LQR scheme is then proposed to compensate for the individual components' limitations. Experimental results demonstrate the PID is more effective at regulating the tilt angle of the robot in the presence of external disturbances, but it necessitates a higher velocity to sustain its equilibrium. The LQR on the other hand outperforms PID in terms of maximum initial tilt angle. By combining both schemes, significant improvements can be observed, such as an increase in maximum initial tilt angle and a reduction in settling time.

IV. PROBLEM STATEMENT

The proposed system is a self-balancing two-wheeler robot designed to autonomously maintain stability and balance while navigating its environment. At its core, the system integrates an Arduino Uno board as the central control unit, orchestrating the operation of various components. These include an Inertial Measurement Unit (IMU) comprising an accelerometer and gyroscope sensor, providing real-time data on the robot's orientation and motion. Motorized wheels, powered by DC motors and motor drivers, enable locomotion and directional control, with precise motor control ensuring smooth movement and responsiveness to external stimuli. The system is powered by a rechargeable battery pack, facilitating untethered operation and prolonged usage periods. Structurally, the robot features a robust chassis and frame, providing stability and support for mounting components. Functionally, the system incorporates self-balancing control algorithms, such as PID control, to continuously adjust the robot's position and velocity for stability. It also includes safety features like emergency braking and fall detection to mitigate risks. Optionally, wireless communication capabilities, such as Bluetooth or Wi-Fi, can be integrated for remote control and data transmission. A user- friendly interface allows users to monitor the robot's status, adjust control parameters, and initiate commands remotely. The system finds applications in education, research, prototyping, entertainment, and demonstrations, showcasing the potential of autonomous two-wheeler robots in diverse contexts.

V. METHODOLOGY

In this chapter, we detail the methodology and implementation plan for designing and developing our self- balancing two-wheeler robot. We outline the systematic approach to hardware selection, sensor integration, control algorithm development, and testing procedures. By following this methodology, we aim to realize a functional prototype that embodies stability, autonomy, and efficiency.

Hardware Selection and Integration The first step in the implementation process is selecting and integrating the necessary hardware components. This includes microcontrollers, sensors, actuators, and power systems. For our self-balancing robot, we opt for an Arduino Uno board as the primary microcontroller due to its versatility and ease of programming. We integrate accelerometers and gyroscopes to measure orientation and angular velocity, respectively, providing essential feedback for balance control. DC motors with encoders are chosen for actuation, allowing precise control of wheel rotation. Additionally, we select suitable batteries to power the system and ensure sufficient runtime.

Sensor Calibration and Fusion Once the hardware components are assembled, we proceed with sensor calibration and fusion to ensure accurate and reliable data acquisition. Calibration procedures involve removing bias and scaling errors from sensor readings, enhancing their accuracy and consistency. Sensor fusion techniques, such as complementary filtering or Kalman filtering, are employed to integrate data from multiple sensors and derive more robust estimates of the robot's state, including orientation, angular velocity, and linear acceleration.

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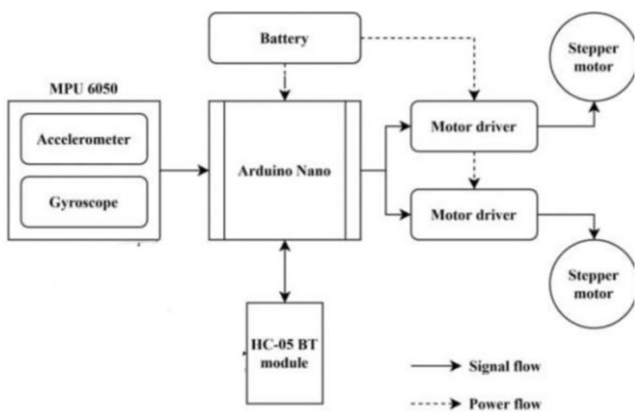
Control Algorithm Development The heart of the self- balancing robot lies in its control algorithms, which govern its dynamic behavior and stability. We develop a control algorithm based on PID (Proportional-Integral-Derivative) principles, leveraging feedback from sensors to adjust motor speeds and maintain balance. The PID controller continuously computes control signals based on the error between the desired orientation and the measured orientation, applying corrective actions to keep the robot upright. Tuning of PID parameters is performed iteratively through experimentation and analysis of system response to ensure optimal performance.

Motor Control and Actuation Effective motor control is essential for achieving smooth and stable locomotion in the self-balancing robot. We implement motor control algorithms that translate control signals from the PID controller into precise adjustments of motor speed and direction. By utilizing pulse- width modulation (PWM) techniques, we regulate the power supplied to the DC motors, enabling fine-grained control of wheel rotation. Additionally, feedback from motor encoders is used to monitor wheel position and velocity, facilitating closed- loop control and dynamic adjustments to maintain balance.

Testing and Iterative Improvement Throughout the implementation process, rigorous testing and iterative improvement are conducted to validate system functionality and enhance performance. We subject the robot to various scenarios and environmental conditions, including changes in terrain, external disturbances, and user interactions. Testing procedures involve assessing stability, responsiveness, and energy efficiency under different operating conditions. Feedback from testing informs adjustments to hardware configurations, sensor calibration parameters, and control algorithms, driving continuous refinement and optimization of the robot's behavior.

Documentation and Presentation Finally, we compile comprehensive documentation detailing the design, implementation, and testing of the self-balancing robot. This documentation package includes schematics, code explanations, assembly instructions, calibration procedures, and testing methodologies, providing a comprehensive resource for replication and further development. Additionally, we prepare a presentation to showcase the robot's functionality, design rationale, and potential applications, disseminating our findings and insights to a broader audience



VI. CONCLUSION

The project Block diagram to interface the components between them. To know the functions of all the components in the project and to know the importance of each component and their working procedure.

In conclusion, our project has successfully culminated in the creation of a self-balancing two-wheeler robot, showcasing a blend of technological innovation. Through hardware selection, sensor integration, and control algorithm development, we have achieved a robust platform capable of maintaining stability and balance autonomously .This section describes in detail the results of the project. It provides a qualitative assessment as well as quantitative data to support that assessment

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VII. FUTURE SCOPE

Self-balancing two-wheeler robots have a promising future with advancements in navigation, autonomy, mobility, AI integration, energy efficiency, specialization for specific tasks, and a focus on safety and regulatory compliance.

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