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Международный научно-образовательный электронный журнал «ОБРАЗОВАНИЕ И НАУКА В XXI ВЕКЕ». Выпуск №62-4 (том 1) (май, 2025). Дата выхода в свет: 26.05.2025.

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Название публикации: «REAL-TIME CONTROLLED ROBOT WITH GYROSCOPE AND ACCELEROMETER»

Abstract

The development of real-time controlled robotic systems has gained significant attention due to their applications in automation, navigation, and stabilization. This research focused on designing and implementing a robot capable of maintaining balance and precise motion control using a combination of gyroscope and accelerometer sensors. The system utilized sensor fusion algorithms to process real-time data, enabling dynamic adjustments to the robot's movements. A PID (Proportional-Integral-Derivative) control mechanism was integrated to enhance stability and responsiveness. Experimental results demonstrated the effectiveness of the proposed system in maintaining equilibrium under varying external disturbances. The study highlighted the importance of sensor accuracy and control algorithm efficiency in real-time robotic applications. The findings contribute to advancements in autonomous robotics, particularly in scenarios requiring high precision and adaptability. Future research directions include optimizing computational efficiency and expanding the system's capabilities for more complex environments.

Introduction

Robotic systems with real-time control capabilities have become essential in modern automation, particularly in applications requiring stability and precise motion. The integration of inertial measurement units (IMUs), such as gyroscopes and accelerometers, has enabled robots to achieve self-balancing and adaptive navigation.

This study explored the design and implementation of a robot that leverages these sensors for real-time motion control.

The primary objective was to develop a system capable of processing sensor data instantaneously and adjusting motor outputs to maintain stability. The research addressed challenges such as sensor noise, latency in control loops, and the need for efficient filtering techniques. By combining gyroscopic and accelerometric data, the system achieved enhanced accuracy in detecting orientation and movement.

Previous studies have demonstrated the effectiveness of PID controllers in robotic stabilization. However, this research extended existing methodologies by incorporating real-time sensor fusion and adaptive control strategies. The results provided insights into the practical limitations and potential improvements for future robotic systems.

Methods and Methodology

The experimental setup consisted of a robotic platform equipped with a microcontroller, an IMU (MPU-6050), and DC motors with encoders for feedback control. The MPU-6050 provided angular velocity and acceleration data, which were processed using a complementary filter to minimize noise and drift. The filtered data were then fed into a PID control loop to adjust motor speeds dynamically.

The system architecture followed a modular approach, with separate components for sensor data acquisition, signal processing, and motor control. The microcontroller executed the control algorithm at a high frequency to ensure real-time responsiveness. Calibration procedures were implemented to account for sensor biases and misalignments.

The PID controller was tuned empirically to achieve optimal performance. The proportional term corrected immediate errors, the integral term addressed accumulated deviations, and the derivative term mitigated overshooting. The robot's stability was tested under various conditions, including sudden tilts and external pushes.

Data logging was performed to analyze the system's response time and stability margins. The results were compared against theoretical models to validate the control strategy. The methodology emphasized reproducibility, with all parameters documented for future reference.

Results and Discussion

The experimental results demonstrated that the robot successfully maintained balance under controlled disturbances. The complementary filter effectively reduced sensor noise, providing a stable orientation estimate. The PID controller exhibited robust performance, with minimal oscillations during stabilization.

One key observation was the trade-off between response speed and stability. Aggressive PID gains led to faster corrections but introduced instability, while conservative gains resulted in sluggish responses. The optimal tuning balanced these factors, ensuring reliable performance.

Sensor fusion proved critical in compensating for the gyroscope's drift and the accelerometer's susceptibility to vibrations. The complementary filter's weighting factor was adjusted to prioritize gyroscopic data for short-term accuracy and accelerometric data for long-term stability.

Challenges included latency in the control loop due to computational delays. Future improvements could involve higher-speed microcontrollers or parallel processing techniques. Additionally, environmental factors such as uneven surfaces introduced variability, suggesting the need for adaptive control algorithms.

Conclusion

This research successfully implemented a real-time controlled robot using gyroscope and accelerometer sensors. The system demonstrated effective stabilization through sensor fusion and PID control. The findings highlighted the importance of accurate sensor data and efficient control algorithms in robotic applications.

Future work should explore advanced filtering techniques, such as Kalman filters, to further enhance precision. Additionally, machine learning approaches could be investigated for adaptive control in unpredictable environments. The study provided a foundation for further advancements in autonomous robotic systems.

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