Design and Build Two Wheel Balancing Robot Simulation with Fuzzy PID

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Abstract: This research produces a two-wheeled equilibrium robot with Fuzzy PID as its motion control. Generate designs and simulations of robotic systems namely gyroscope, PID, Fuzzy simulation, and motor control. In the PID simulation the stability values are obtained at Kp = 100, Ki = 200, Kd = 10, and from the gyroscope simulation results obtained a minimum value of 0.074616, a maximum value of 0.110321, an average value of 0.092469, a standard deviation of 0.025247, sum of data (sum) 0.184937, mean 0.092469. The results of this study are expected to be developed using a stepper motor, improving the complement or Kalman filter algorithm to produce a gyroscope sensor signal that is clean from noise interference, as well as adding an input membership function to get a better motion response.

1 INTRODUCTION

The development of robotics technology has made the quality of human life even higher. Currently the development of robotics technology has been able to increase the quality and quantity of production in various industries(Tugaev & Kulibaba, 1986; Weik, 2000). Robotics technology has also reached the side of entertainment and education for humans. One way to increase the level of intelligence of a robot is to add sensors, control methods and even provide artificial intelligence to the robot. Robots that have intelligence One of them is a self-balancing robot (Frankovský et al., 2017; Gonzalez et al., 2017; Mai et al., 2019; Santoso & Mursyid, 2017). balance robot (balancing robot) is a robot that has two wheels on the right and left which will not be balanced without a controller. This balance robot is the development of an inverted pendulum model that is placed on a wheeled train (Odry & Fuller, 2018; Xin et al., 2011). Balancing a two-wheeled robot requires a good hardware circuit and a reliable control method to maintain the robot's position perpendicular to the earth's surface. The concept of a balance robot has been used as a means of transportation called a segway(Yun et al., 2019). To be able to see the performance response of a system with various combinations of input signals and control actions is a difficult thing. to perform these steps required high accuracy and the depiction is often less accurate. because the transfer function in a system is in the s region or in the laplace function, to analyze a system response it is necessary to perform the inverse laplace function or change from the s region to the t region. Of course, this is very inefficient and time consuming. Therefore, software is used, to make it easier to understand, analyze, and get the desired system response.

2 LITERATURE REVIEW

2.1 Inverted Pendulum

The equilibrium robot applies an inverted pendulum model, with the ability to maintain an upright position with respect to an object(Huang et al., 2011; Odry & Fuller, 2018). The process of equilibrium is usually called stability control (Yıldırım & Arslan, 2018). Two wheels are placed on the ground surface and allow the robot body to maintain an upright position and move forward, backward, rotating in an effort to maintain the center of mass above the axles (Huang et al., 2011).

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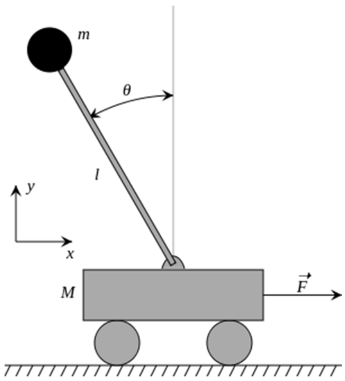


Figure 1: Schematic of an inverted pendulum.

As a result of the earth's gravitational force, an inverted pendulum which is initially perpendicular then begins to form a tilt angle of theta (θ) and over time it will fall. Therefore, in maintaining and maintaining the pendulum's position at a point, a force action is needed that can restrain the pendulum's movement. The method used to produce this force is by making the train go forward in the direction in which the pendulum will fall (Fahmizal et al., 2017).

2.2 Two-Wheeled Robot Kinematics

In the case of a two-wheeled robot, as presented in Figure 2, each wheel is controlled by an independent motor. XG and YG represent the global framework, while XL and YL represent the local framework. The speed of the robot is determined by the linear and angular velocity, which is a function of the linear and angular speed of each wheel and the distance L between the two wheels, is the linear and angular speed of the right wheel, is the linear and angular speed of the left wheel, θ is robot orientation and (ω) are the radius of the left and right wheels

$$V_{robot}(t)\omega_{robot}(t)\omega_i(t)V_r(t)\omega_r(t)V_l(t)\omega_l(t)r_l r_r \quad (1)$$

The linear speed of each wheel is determined by the relationship between the angular velocity and the radius of the wheel(Chhotray et al., n.d.).

$$V_r(t) = \omega_r(t)r_r, V_l(t) = \omega_l(t)r_l \quad (2)$$

The speed of the robot consists of the center mass linear velocity and the angular velocity generated by the difference between the two wheels.

$$V_l(t) = V_{robot}(t) - \left(\frac{L}{2}\right)\omega_{robot}(t), V_r(t) = V_{robot}(t) + \left(\frac{L}{2}\right)\omega_{robot}(t) \quad (3)$$

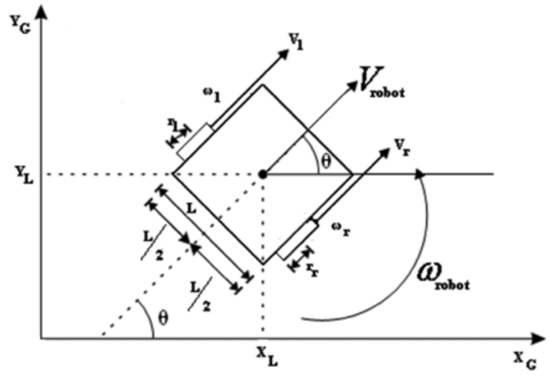


Figure 2: Two-wheeled robot kinematics.

2.3 PID

The PID controller is a combination of three types of controllers, namely proportional controllers, integral controllers, and derivative controllers. The purpose of combining the three types of controllers is to improve system performance where each controller will complement and cover each other's weaknesses and strengths. proportional, integral, and derivative terms are added up to calculate the output of the PID controller. By defining a controller output, the final form of the PID algorithm is:

$$u(t) = P(t) = K_p e(t) + K_i \int_0^t e(\tau)d\tau + K_d \frac{de(t)}{dt} \quad (4)$$

K_p: Proportional gain, tuning parameters
K_i: Integral Gain, tuning parameters
K_d: Derivative Gain, tuning parameters
e: Error = $Y_{sp} - Y_m$
Y_{sp}: Setpoint
Y_m: Process variable
t: Time
τ: Integration variable; the value is taken from time zero to t

$$L(s) = K_p + K_i/s + K_d s \quad (5)$$

with
S: The frequency of complex numbers

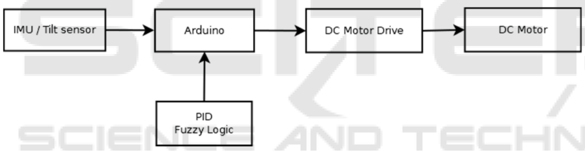
2.4 Fuzzy Logic

Fuzzy logic is a way of mapping the input space into the output space, with continuous values(Zadeh, 2009, 2015). Fuzzy expressed in degrees of membership and degrees of truth. Therefore something can be said to be partly right and partly wrong at the same time. In fuzzy logic are fuzzification, rule evaluation (inference) based on rule base, and defuzzification(Medynskaya, 2015; Sadegh-Zadeh, 1999).

3 DESIGNS

The proposed system design is shown in Figure 3. PID Fuzzy control is the main control used in this system. The main input parameter used in PID control is the error value or the difference between the system output value (process variable) and the expected value (set point).(Bimarta et al., 2015). The addition of Fuzzy control is expected to help improve the performance of the equilibrium robot. With the addition of fuzzy logic for the magnitude of the coefficient value of the PID and combined with the setpoint of the sensor data value, errors and error differences will be obtained, to be used as fuzzy logic input values, the control results will be fed to the controller to then produce PWM, the value of the PWM will control DC motor movement(Mai et al., 2019; Yu et al., 2017).

Figure 3 Balancing robot block diagram



3.1 A Two-Wheeled Balanced Robot

The design of the balancing robot is built using two wheels, the Arduino controller is placed between the two wheels, the support circuit is arranged to produce a balanced pressure between the two wheels, the sensor circuit is placed on top of the robot, in order to produce maximum power change, accepted by Arduino as input data (position) is processed in fuzzy logic and PID, to then be fed to the DC motor drive circuit by controlling the PWM to be kept constant according to the desired value setting, the coefficients will be displayed on the LCD display, changes in position x, y, z(Anitha et al., 2019; Cameron, 2019; Odry & Fuller, 2018; Pan & Zhu, 2018).

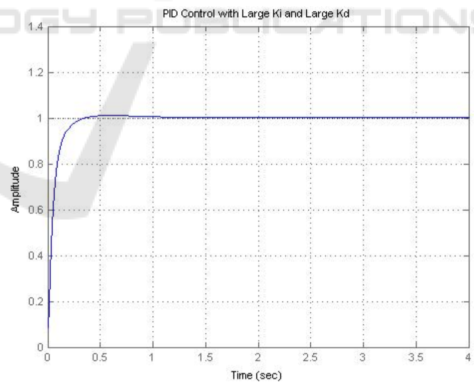
4 RESULTS AND ANALYSIS

Using two motors, an L298 motor control, arduino uno, virtual serial (compin), and virtual terminal, the software is built on the Arduino IDE, simulation is carried out by setting pin IN1=0, IN2=1, IN3=0, IN4=1 , ENA=1, ENB=1, the motor speed is set by setting the value of ENA, ENB from the lowest value 0 to the highest value 255(Frankovský et al., 2017; Hsu & Lee, 2011).

4.1 PID Simulation

PID control will produce a response that is influenced by the parameters Kp, Ki and Kd(Mai et al., 2019; Odry & Fuller, 2018). The test is carried out by changing the parameters and paying attention to the results of the robot's movement, the value and shape of the signal are obtained as follows:

(a)



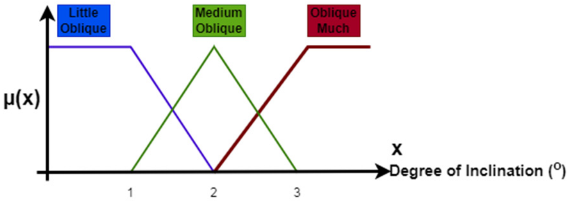
(b)

Figure 4 (a) Kp=100, Ki=200, Kd=1, (b) Kp=100, Ki=200, Kd=10

Figure 4 (b) shows the step response graph has a long value to be stable, this is because the integral gain value is small (Ki = Small), so it takes a long time for the unification action and reduces the fixed condition error, with the addition of the Ki value the process can be accelerated, Figure 4(a). With the addition of the Ki value, the steady-state error can be reduced faster than before, but also increasing the spikes, with the addition of the Kd value will reduce the spikes, shown in Figure 4(b).

4.2 Fuzzy Logic Simulation

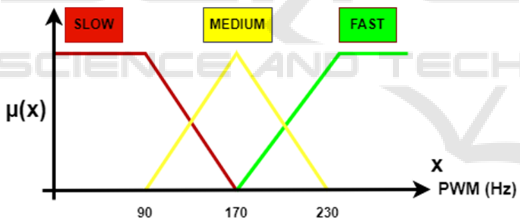
Fuzzy control will produce a final value according to a predetermined value, in this study the angle value is obtained from the IMU MPU6050 sensor.



(a)

Fuzzy Logic Rules		OBLIQUE ANGLE DATA OF CURRENTLY		
		Little Oblique	Medium Oblique	Oblique Much
OBLIQUE ANGLE DATA OF PREVIOUSLY	Little Oblique	Slow	Slow	Slow
	Medium Oblique	Slow	Medium	Fast
	Oblique Much	Fast	Fast	Fast

(b)



(c)

Figure 5 (a) Angle change input membership function, (b) PWM output membership function, (c) Correlation of angle change to PWM value

From Figure 5 (d) it can be seen that the pwm value increases as the angle changes, the pwm value is 0-120, at an angle movement between 0-5 degrees, the pwm is stable at 130, at an angle movement of 4.7-13 degrees, the pwm increases at angle change between 14-20 degrees.

4.3 Gyroscope Simulation

The simulation was made using the proteus program, by simulating three signals from the gyro sensor with three variable resistors, and connected to A0, A1, and A2 from the Arduino. The received value data is randomized, and forwarded to Matlab for storage and signal plots.

5 CONCLUSIONS

The results of testing the balancing robot using angle value data according to the variable input previously mentioned, it can be seen that the robot graph is able to balance with a balance range between (-3 to 3 degrees) on a flat plane even with fairly constant noise or error. From the simulation results, the minimum value is 0.074616, the maximum value is 0.110321, the average value is 0.092469, the standard deviation is 0.025247, the sum of data (sum) is 0.184937, the mean is 0.092469.

REFERENCES

Anitha, T., Gopu, G., Nagarajapandian, M., & Devan, PAM (2019). Hybrid Fuzzy PID Controller for Pressure Process Control Applications. 2019 IEEE Student Conference on Research and Development (SCORED), 129–133. https://doi.org/10.1109/SCORED.2019.8896276

Bimarta, R., Putra, AE, & Dharmawan, A. (2015). Balancing Robot Using Derivative Integral Proportional Control Method. IJEIS (Indonesian Journal of Electronics and Instrumentation Systems), 5(1), 89. https://doi.org/10.22146/ijeis.7157

Cameron, N. (2019). Robot Car. In N. Cameron, Arduino Applied (pp. 467–497). Apress. https://doi.org/10.1007/978-1-4842-3960-5_24

Chhotray, A., Pradhan, MK, Pandey, KK, & Parhi, DR (nd). Kinematic Analysis of a Two-Wheeled Self-Balancing Mobile Robot. 8.

Fahmizal, F., Setyawan, G., Arrofiq, M., & Mayub, A. (2017). Fuzzy Logic in Two-Wheeled Inverted Pendulum Robot. Journal of Information Technology and Computer Science, 4(4), 244. https://doi.org/10.25126/jtiik.201744484

Frankovský, P., Dominik, L., Gmiterko, A., Virgala, I., Kurylo, P., & Perminova, O. (2017). Modeling of Two-Wheeled Self-Balancing Robot Driven by DC Gearmotors. International Journal of Applied Mechanics and Engineering, 22(3), 739–747. https://doi.org/10.1515/igame-2017-0046

Gonzalez, C., Alvarado, I., & Peña, DML (2017). Low cost two-wheel self-balancing robot for control education. IFAC-PapersOnLine, 50(1), 9174–9179. https://doi.org/10.1016/j.ifacol.2017.08.1729

Hsu, C.-F., & Lee, B.-K. (2011). FPGA-based adaptive PID control of a DC motor driver via a sliding-mode approach. Expert Systems with Applications, 38(9), 11866–11872. https://doi.org/10.1016/j.eswa.2011.02.185

Huang, C.-H., Wang, W.-J., & Chiu, C.-H. (2011). Design and Implementation of Fuzzy Control on a Two-Wheel Inverted Pendulum. IEEE Transactions on Industrial Electronics, 58(7), 2988–3001. https://doi.org/10.1109/TIE.2010.2069076

Kecskés, I., & Odry, P. (2014). Optimization of PI and Fuzzy-PI Controllers on Simulation Model of Szabad(ka)-II Walking Robot. International Journal of Advanced Robotic Systems, 11(11), 186. https://doi.org/10.5772/59102

Mai, TA, Dang, TS, Anisimov, DN, & Fedorova, E. (2019). Fuzzy-PID Controller for Two Wheels Balancing Robot Based on STM32 Microcontroller. 2019 International Conference on Engineering Technologies and Computer Science (EnT), 20–24. https://doi.org/10.1109/EnT.2019.00009

Matsui, N., & Shigyo, M. (1992). Brushless DC motor control without position and speed sensors. IEEE Transactions on Industry Applications, 28(1), 120–127. https://doi.org/10.1109/28.120220

Medynskaya, MK (2015). Fuzzy set theory. The concept of fuzzy sets. 2015 XVIII International Conference on Soft Computing and Measurements (SCM), 30–31. https://doi.org/10.1109/SCM.2015.7190402

Noga, S. (2006). Kinematics and dynamics of some selected two-wheeled mobile robots. Archives of Civil and Mechanical Engineering, 6(3), 55–70. https://doi.org/10.1016/S1644-9665(12)60241-6

Odry, A., & Fuller, R. (2018). Comparison of Optimized PID and Fuzzy Control Strategies on a Mobile Pendulum Robot. 2018 IEEE 12th International Symposium on Applied Computational Intelligence and Informatics (SACI), 000207–000212. https://doi.org/10.1109/SACI.2018.8440947

Pan, T., & Zhu, Y. (2018). Using Sensors with the Arduino. In T. Pan & Y. Zhu, Designing Embedded Systems with Arduino (pp. 45–100). Springer Singapore. https://doi.org/10.1007/978-981-10-4418-2_3

Perdukova, D., Fedor, P., & Fedak, V. (2019). A Fuzzy Approach to Optimal DC Motor Controller Design. 2019 International Conference on Electrical Drives & Power Electronics (EDPE), 48–53. https://doi.org/10.1109/EDPE.2019.8883896

Sadegh-Zadeh, K. (1999). Advances in fuzzy theory. Artificial Intelligence in Medicine, 15(3), 309–323. https://doi.org/10.1016/S0933-3657(98)00060-8

Santoso, S., & Mursyid, S. (2017). PROPORTIONAL INTEGRAL (PI) CONTROL ON LINE FOLLOWER ROBOT. Journal of Science and Informatics, 1(1), 10–10.

Tugaev, VD, & Kulibaba, V. Ya. (1986). Introduction of an industrial robot in a machine shop. Metallurgist, 30(10), 380–381. https://doi.org/10.1007/BF00741414

Weik, MH (2000). Manipulating industrial robots. In MH Weik, Computer Science and Communications Dictionary (pp. 972–972). Springer US. https://doi.org/10.1007/1-4020-0613-6_11017

Xin, Y., Xu, B., Xin, H., Xu, J., & Hu, L. (2011). The Computer Simulation and Real-Time Control for the Inverted Pendulum System Based on PID. In M. Ma (Ed.), Communication Systems and Information Technology (Vol. 100, pp. 729–736). Springer Berlin Heidelberg. https://doi.org/10.1007/978-3-642-21762-3_95

Yıldırım, Ş., & Arslan, E. (2018). ODE (Open Dynamics Engine) based stability control algorithm for six legged robots. Measurements, 124, 367–377. https://doi.org/10.1016/j.measurement.2018.03.057

Yu, G.-R., Leu, Y.-K., & Huang, H.-T. (2017). PSO-based fuzzy control of a self-balancing two-wheeled robot. 2017 Joint 17th World Congress of International Fuzzy Systems Association and 9th International Conference on Soft Computing and Intelligent Systems (IFSA-SCIS), 1–5. https://doi.org/10.1109/IFSA-SCIS.2017.8023296

Yun, H., Bang, J., Kim, J., & Lee, J. (2019). High speed segway control with series elastic actuator for driving stability improvement. Journal of Mechanical Science and Technology, 33(11), 5449–5459. https://doi.org/10.1007/s12206-019-1039-x

Zadeh, LA (2009). Toward extended fuzzy logic—A first step. Fuzzy Sets and Systems, 160(21), 3175–3181. https://doi.org/10.1016/j.fss.2009.04.009

Zadeh, LA (2015). Fuzzy logic—A personal perspective. Fuzzy Sets and Systems, 281, 4–20. https://doi.org/10.1016/j.fss.2015.05.009