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Research and application of PID controller for self-balanced two-wheel vehicles.

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Abstract: *The article deals with the research problem of building a self-balancing two-wheeled robot model based on the theoretical foundation of the inverted pendulum model. Learn car models, self-balancing 2-wheel robots, and balance basics. Learn car models, self-balancing 2-wheel robots, and balance basics. Learn car models, self-balancing 2-wheel robots, and balance basics. Learn car models, self-balancing 2-wheel robots, and balance basics.*
Keywords: *Robot, balance car, PID controller.*

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I. Pose the problem

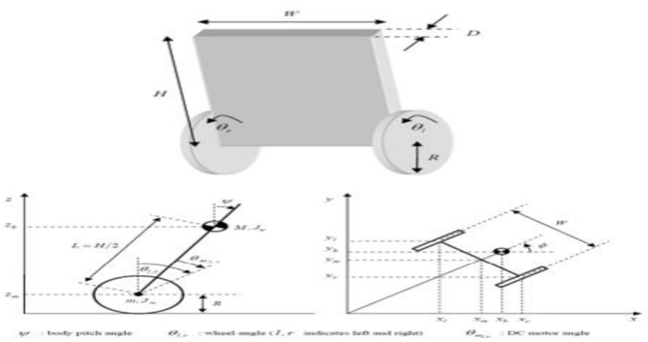
In the field of automation - automatic control in general and cybernetics in particular, the inverted pendulum model is one of the typical research objects and is characterized by the unstable dynamic characteristics of the model, so the control controlling this object in fact poses as a challenge.

If a lot of weight is placed on the rudder, the robot will be unstable and easy to fall, and if put on many tail wheels, the two main wheels will lose their ability to grip. Many robot designs can move well on flat terrain but cannot move up and down on convex or inclined surfaces. When moving up the hill, the robot's weight is on the rear of the vehicle, causing it to lose its ability to grip and slip.

II. Modeling self-balancing 2-wheel robot on flat terrain

Building a system of state equations describing a self-balancing two-wheeled robot system. Using the Euler-Lagrange method to build the kinetic model. Suppose At time t = 0, the robot moves in the positive x-axis direction, we have the equations:

$$\begin{bmatrix} q \\ f \end{bmatrix} = \begin{bmatrix} \frac{1}{2}\left(q_l + q_r\right) \\ \frac{R}{W}\left(q_l - q_r\right) \end{bmatrix}$$



Where the average coordinates of the robot in the frame of reference:

$$\begin{bmatrix} x_m \\ y_m \\ z_m \end{bmatrix} = \begin{bmatrix} \int \dot{x}_m \\ \int \dot{y}_m \\ \int \dot{z}_m \end{bmatrix}$$

Left wheel coordinates in the frame of reference:

$$\begin{bmatrix} x_l \\ y_l \\ z_l \end{bmatrix} = \begin{bmatrix} x_m - \frac{W}{2}\sin\phi \\ y_m + \frac{W}{2}\cos\phi \\ z_m \end{bmatrix}$$

III. Calculating the parameters of the robot

The equation of kinetic energy of rotation:

$$T_2 = \frac{1}{2}J_w\dot{\theta}_l^2 + \frac{1}{2}J_w\dot{\theta}_r^2 + \frac{1}{2}J_\psi\dot{\psi}^2 + \frac{1}{2}J_\phi\dot{\phi}^2 + \frac{1}{2}n^2J_m\left(\dot{\theta}_l - \dot{\psi}_l\right)^2 + \frac{1}{2}n^2J_m\left(\dot{\theta}_r - \dot{\psi}_r\right)^2$$

With $\frac{1}{2}n^2J_m\left(\dot{\theta}_l - \dot{\psi}_l\right)^2, \frac{1}{2}n^2J_m\left(\dot{\theta}_r - \dot{\psi}_r\right)^2$ is the rotational kinetic energy of the left and right motor armatures.

Taking the derivative L with respect to the variables we get:

$$\left[(2m + M)R^2 + 2J_w + 2n^2J_m\right]\ddot{\theta} + \left(MRL\cos\psi - 2n^2J_m\right)\ddot{\psi} - MRL\sin\psi = F_\theta$$

$$\left(MRL\cos\psi - 2n^2J_m\right)\ddot{\theta} + \left(ML^2 + J_w + 2n^2J_m\right)\ddot{\psi} - MgL\sin\psi - ML^2\dot{\phi}^2\sin\psi\cos\psi = F_\psi$$

$$\left[\frac{1}{2}mW^2 + J_\phi + \frac{W^2}{2R^2}\left(J_w + n^2J_m\right) + ML^2\sin^2\psi\right]\ddot{\phi} + 2ML^2\dot{\phi}\dot{\psi}\sin\psi\cos\psi = F_\phi$$

Dynamic torque produced by DC motor:

$$F_l = nK_ti_l + f_m\left(\dot{\psi} - \dot{\theta}_l\right) - f_w\dot{\theta}_l$$

$$F_r = nK_ti_r + f_m\left(\dot{\psi} - \dot{\theta}_r\right) - f_w\dot{\theta}_r$$

$$F_w = -nK_ti_l - nK_ti_r - f_m\left(\dot{\psi} - \dot{\theta}_l\right) - f_m\left(\dot{\psi} - \dot{\theta}_r\right)$$

$$\begin{bmatrix} F_\theta \\ F_\psi \\ F_\phi \end{bmatrix} = \begin{bmatrix} F_l + F_r \\ F_\psi \\ \frac{W}{2R}(F_l - F_r) \end{bmatrix}$$

And

Using the PWM method to control the motor should switch from motor current to motor voltage:

$$L_m\dot{i}_{l,r} = v_{l,r} + K_b\left(\dot{\psi} - \dot{\theta}_{l,r}\right) - R_m i_{l,r}$$

Considering the relatively small armature inductance (near zero), which can be neglected, deduce:

$$i_{l,r} = \frac{v_{l,r} + K_b\left(\dot{\psi} - \dot{\theta}_{l,r}\right)}{R_m}$$

From there, the torques are generated:

$$F_\theta = \alpha\left(v_l + v_r\right) - 2\left(\beta + f_w\right)\dot{\phi} + 2\beta\dot{\psi}$$

$$F_\psi = -\alpha\left(v_l + v_r\right) - 2\beta\dot{\theta} - 2\beta\dot{\psi}$$

With $\alpha = \frac{nK_t}{R_m}, \beta = \frac{nK_tK_b}{R_m} + f_m$

$$F_{\phi} = \frac{W}{2R}\alpha\,(v_l + v_r) - \frac{W}{2R}(\beta + f_m)\dot{\phi}$$

The kinematic equation describing the motion of the robot is obtained as follows:
[(2□ + □)2 + 2□□ + 2□2□□]□̈ + (□□□□□□□ - 2□2□□)̈ - □□□□̇ 2□□□□□ =
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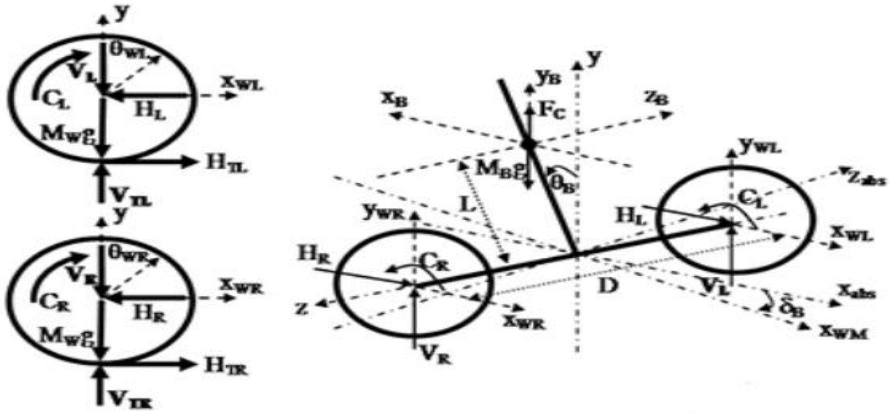
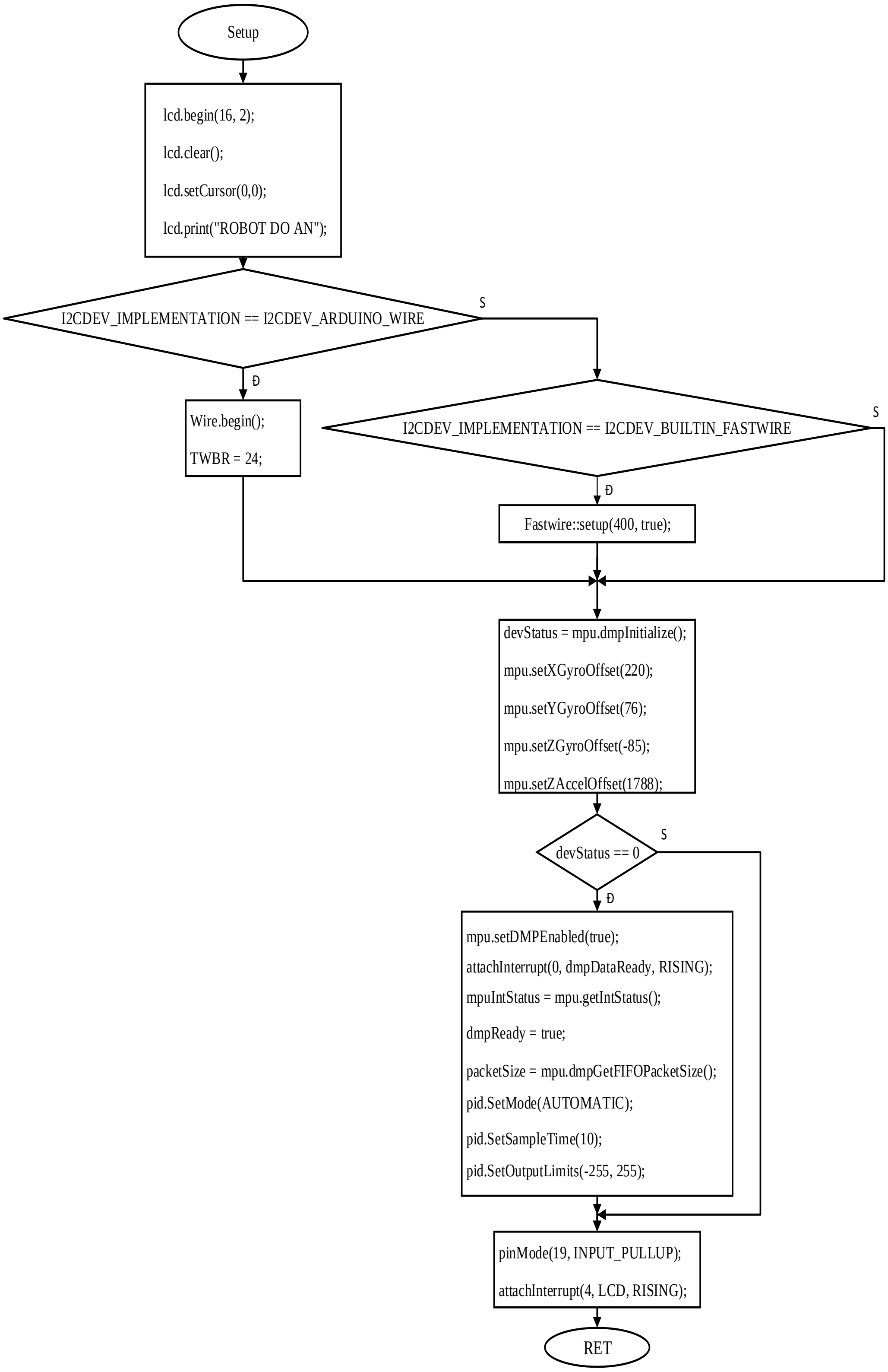
□□) + 2□□̇ - 2□□̇

$$\left[\frac{1}{2}mW^2 + J_\emptyset + \frac{W^2}{2R^2}(J_w + n^2 J_m) + ML^2\sin^2\psi\right]\ddot{\phi}^2$$
$$+ 2ML^2\dot{\psi}\dot{\phi}\sin\psi\cos\psi = \frac{W}{2R}\alpha(v_r - v_l) - \frac{W^2}{2R^2}(\beta + f_w)\dot{\phi}$$

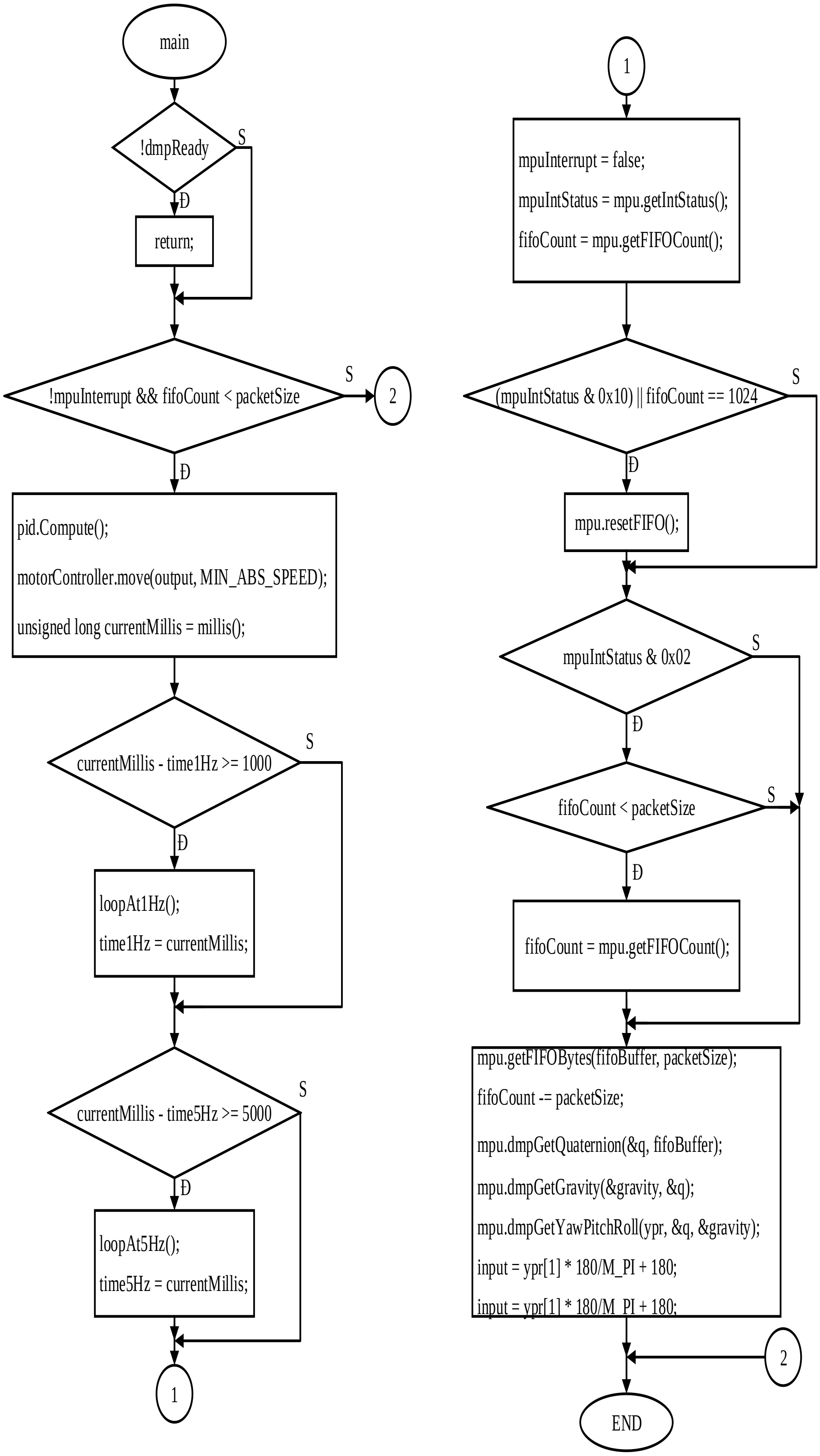


IV. System design

Algorithm flowchart



Main program



V. Conclusion

The article refers to the research problem, complete design, complete the self-balancing 2-wheel robot model. Set up mathematical model, state function of model and simulate successfully on Matlab Simulink.

Active Circuit Components and Microcontrollers: Active Circuit Components and Microcontrollers. The H-bridge circuit operates stably without overloading and overheating. Read the encoder correctly without bias. The control vo works stably. The microcontroller works stably, does not reset or disconnect itself.

Self-balancing two-wheeled robot is not a new topic but poses many challenges in research and manufacturing. To be able to design a complete, more flexible, self-balancing 2-wheel robot model and serve as a basis for building a self-balancing 2-wheeled vehicle that can carry people, it is necessary to accurately calculate the mechanical structure, as well as get really accurate parameters about the motor, encoder, sensor and an adaptable controller like neural network.

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