Speed Control System Design in Bicycle Robot by Low Power Method

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Abstract

This paper presents compare results performance between two conventional controllers for bicycle robot. The bicycle speed control system was a highly nonlinear model, multivariable and absolutely unstable. It has used for testing various design control techniques for low power. The objectives of this paper had to developed speed control which derived the mechanic model and experiment. Controllers are Proportional-Integral-Derivatives (PID) and on-off dynamic control. The dynamic system which also includes not stable friction effects the linear zed system model is used as a basis for the design to apply to speed. Computer simulation and experiment have been done, controller are capable to control output speed wheel control system successfully. The results show PID controller better then on-off dynamic controller

Keywords: Bicycle robot, Proportional-Integral-Derivatives (PID), On-Off control

1. Introduction

The bicycles are transportation device, sport without any environmental However, bicycle is unstable in itself and it will fall down without rider like steering handle or moving upper body. In these days, electric motor power assistance bicycles are used practically, but all of those bicycles merely assist human with pedal driving and there are no bicycles that help to stabilize its position. Hence, stabilizing the unstable and realizing stable driving of a bicycle have been researched. One important is efficiency about save energy for DC power supply designer will be design many way for solve this problem The Controller design can be solve them

This paper presents speed control design compare between ON-OFF and PD, PID controller. Dynamic model of running bicycle is complicated and it's hard to recognize. However, assuming that the rider doesn't move upper body, dynamics of bicycle is represented in equilibrium of gravity and centrifugal force. Centrifugal force is risen out from the running velocity and turning radius determined steering angle. Under these conditions, it is possible to stabilize bicycle posture by controlling its steering.

2 Force

2.1 External forces

Gravity the rider and all the bicycle components toward the earth almost effect there are ground reaction forces with both horizontal and vertical components. The vertical components mostly counteract the force of gravity, but also vary with braking and accelerating. The horizontal components, due to friction between the rubber wheels and the ground, including rolling resistance, are in response to propulsive forces, braking forces, and turning forces. At general bicycling speeds on level ground, dynamic drag is the largest force resisting forward motion.[

2.2 Internal forces

Internal forces are general caused assume by the friction and rider. The rider can apply torques between the steering and rear frame, and between the rider and the rear frame. Friction exists between any parts that move against each other: in the drive train, between the steering mechanism and the rear frame, general bicycles have front and rear suspensions, on bicycles with rear suspensions, feedback between the drive motor and the suspension is an issue designers propose to handle with various linkage configurations and dampers.

2.3 Movement and Balance

Lateral motions include balancing, leaning, steering diver, and turning. Motions in the central plane of symmetry include rolling forward angle, of course, but also stop brake diving, and most suspension activation. An uncontrolled bicycle is laterally unstable when stationary and can be laterally self stable when moving under the right conditions or when controlled by a rider.

Fig. 1 bicycle prototype

Balancing bicycles remains upright when it is steered so that the ground reaction forces exactly balance all the other internal and external forces it experiences, such as mass distribution, and forward speed of the bicycle. A rider can balance a bicycle by the same principle. While performing a track stand, the rider can keep the line between the two contact Forward motion can be generated simply by control motor. The rider can take advantage of an opportune slope of the pavement or lurch the upper body backwards while the brakes are momentarily engaged.

2.4 Self-stability

Self stability for this section, present all the factors have effect to the control speed described above that contribute to balance there are a range of forward speeds for a given bicycle design at which these effects steer However, even without self-stability a bicycle may be ridden by steering it to keep that the effects mentioned above that would combine to produce self-stability may be overwhelmed by additional factors such as headset friction and stiff control cables (Assume no effect to balance condition)

2.5 Motor Controller and Driver

Motors and wheels were fastened to the structure; present by figure 2 and 3 the first system test was ready. There was no circuitry or microprocessor involved, only the motors, wheels, and a power supply. Each motor was connected in parallel and run at 24 volts, directly from the power supply.

Fig. 2 Actuator motor and Encoder

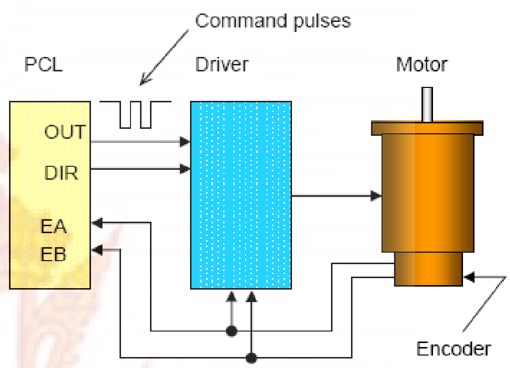

Fig. 3 Direction determinations for the incremental encoder

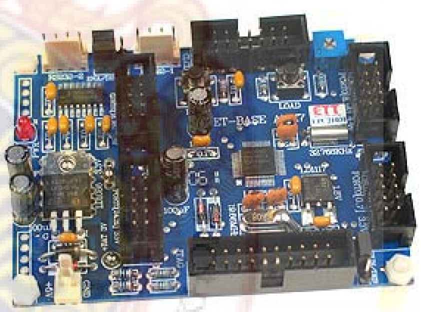

Fig. 4 ET-BASE ARM cortex controllers

Motors working correctly, it was time to add in the circuitry to the loop. The circuitry basically regulated power and direction to the motors, allowing the right amount of current and voltage to each motor.

Fig. 5 Driver motor board

Controller ARM cortex as show in Figure 4 and 5 are a programmable digital controller powerful microcontroller and driver. These controllers are based on the high performance 32-bit ARM7TDMI-S™ microprocessor, which features low-power consumption and 16-bit Thumb code for efficient and flexible designs. Other key features include a wide range of serial communications interfaces, on-chip 32 KB Figure 6 show Assembly Motor to bicycle

Fig. 6 Assembly motor to bicycle

3. Basic Speed Control

3.1 Forward speed

The rider applies torque to the front wheel and s control lean and maintain balance. At high speeds, small steering angles quickly move the ground contact points laterally; at low speeds, larger steering angles are required the same results in the same amount of time. Because of this, it is usually easier to maintain balance at high speeds.

3.2 ON-OFF Control

A means of altering the voltage applied to the motor to control A means of measuring the absolute speed of the motor ARM controller software running on a to keep the speed constant, Tacho generator or Encoder interrupt to measure the motor speed A periodic interrupt to works out the difference between the actual measured speed and target speed when target speed equal to zero Motor will be turn off Figure 7 show ON-OFF control duty cycle

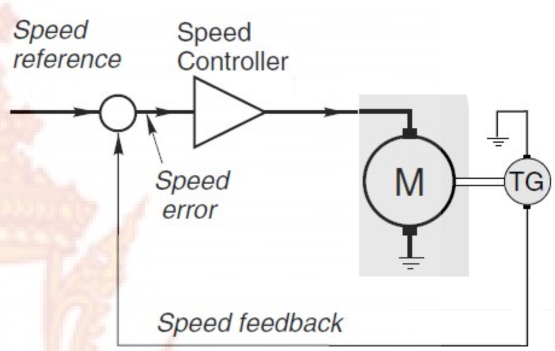

Fig. 7 ON-OFF control duty cycle

3.3 Designing the PID Controller

Relative closed-loop control can be integrated with a variety of other interfaces, speed from encoder or tacho generator. The term “closed-loop” stands for a continuous status feedback given to the microprocessor. The microcontroller communicates with input data, which allows it to figure 9 out the current speed of the bicycle, and in turn make changes

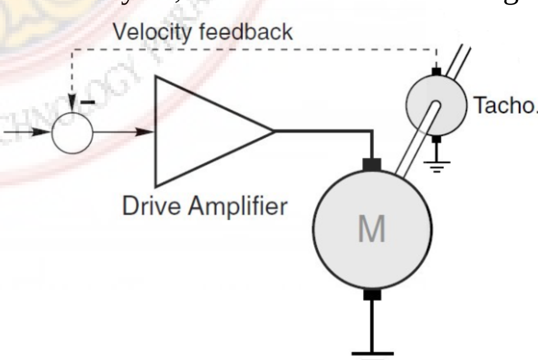

Fig. 8 Velocity feedback in motor

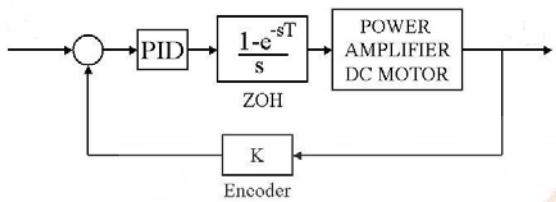

Fig. 9 Block diagram PID controller

The PID controller can thus be expressed as:

Output = Proportional Gain + Integral gain Derivative gain

Proportional Gain: Gives fast response to sudden load changes and can reduce instability caused by high

Integral gain. This gain is typically many times higher integral gain slowly moves the speed to the set point. Like integral gain,

Derivative Gain: Can be used to give a very fast response to sudden changes in motor speed.

Within simple PID controllers it can be difficult to generate a derivative term in the output that has any significant effect on motor speed. It can be deployed to reduce the rapid speed oscillation caused by high proportional gain. However, in many controllers, it is not used.

4. Simulation and experiment result

Simulation is performed to prove the validity of this controller. In the simulation, running velocity to set point this experiment show set velocity equal to zero when condition speed is 10 Km/hour

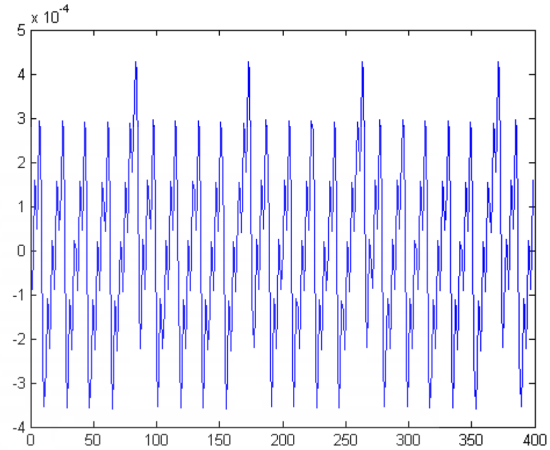

Fig. 10 PWM ON-OFF time controller

Figure 10 show speed control of bicycle robot by On-Off controller from PWM. The driving motor can keep velocity but signal is sing widely target set point

This result control by PD, PID and are shown in Fig.9, 10 the experiment with fixed and keep velocity target equal to zero at 10 km/hour Finally Fig.11 and 12 was done and the result is shown in Figure.13 and 14 the experiment with 15 km/hour

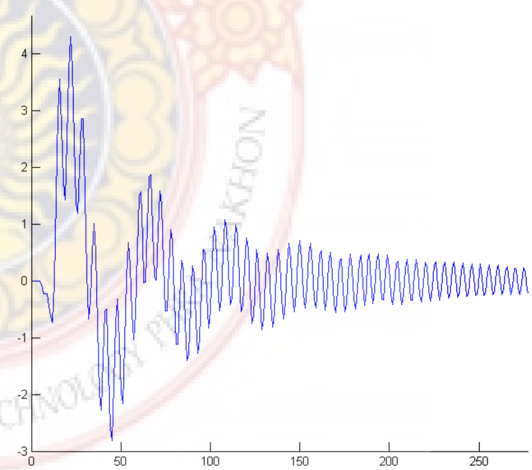

Fig. 11 characterization PD controller low speed control

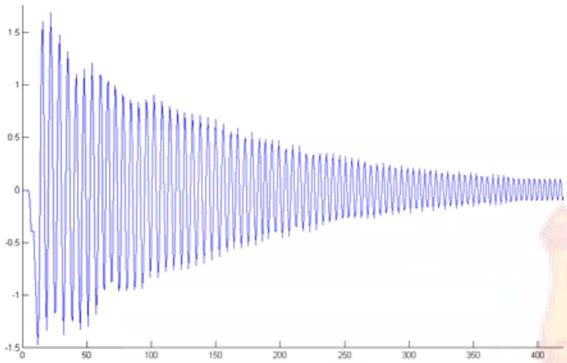

Fig. 12 characterization PID controller low speed control

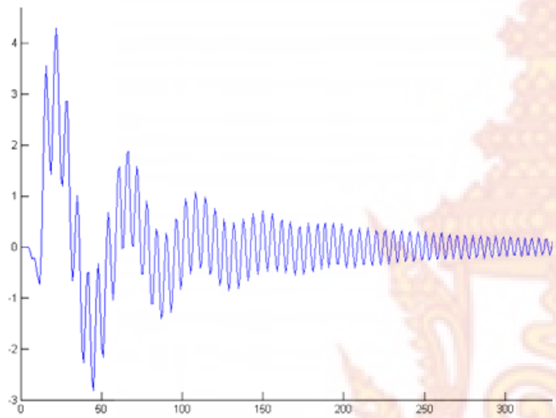

Fig. 13 characterization PD controller high speed control

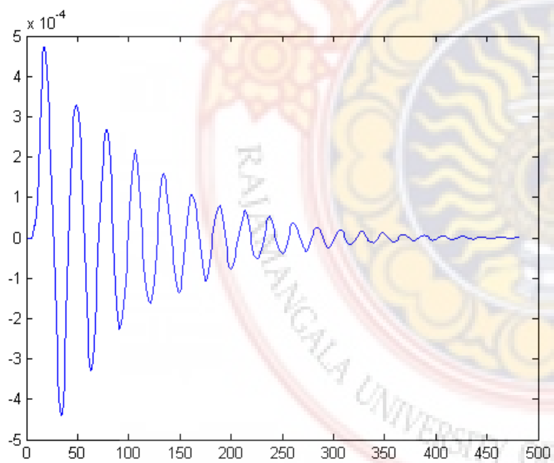

Fig. 14 characterization PID controller high speed control

4. Conclusions

This paper present speed control system design bicycle by low power (PID controller) compare with ON-OFF controller (vary duty cycle time control) the dynamic model of bicycles and speed control method were proposed. The validity of this control method is proved by simulations and experiments. In the experiment, PID controllers are good performance and save power supply better than ON-OFF Controller

5. Acknowledgements

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6. References

[1] Hand, R. S., *Comparisons and Stability Analysis of Linearized Equations of Motion for a Basic Bicycle Model*, MSc Thesis, Cornell University, May 1988.

[2] Meijaard, J. P., “Direct determination of periodic solutions of the dynamical equations of flexible mechanisms and manipulators,” *International Journal for Numerical Methods in Engineering* **32**, 1991, pp. 1691–1710.

[3] Sharp, R. S. , “The Stability and Control of Motorcycles,” *Journal of Mechanical Engineering Science*, 13(5), 1971, pp. 316–329.

[4] Whipple, F. J. W., “The Stability of the Motion of a Bicycle,” *The Quarterly Journal of Pure and Applied Mathematics* 30, 1899, pp. 312–348.

[5] A. Sharp, *Bicycles & Tricycles: A Classic Treatise on Their Design and Construction*. New York: Dover, 2003.

[6] D.G. Wilson, *Bicycling Science*, 3rd ed., with contributions by Jim Papadopoulos. Cambridge, MA: MIT Press, 2004.

[7] A.M. Letov, “Stability of an automatically controlled bicycle moving on an horizontal plane,’’ *Appl.*

Math. Mechanics, vol. 23, no. 4, pp. 650–655, 1959.

[8] D.E.H. Jones, “The stability of the bicycle,” *Phys. Today*, vol. 23, pp. 34–40, Apr. 1970.

[9] T.R. Kane, “Fundamental kinematical relationships for single-track vehicles,’’ *Int. J. Mech. Sci.*, vol. 17, no. 8, pp. 499–504, 1975.

[10] M. Kondo, “Experimental study on the stability and control of single-track vehicles,’’ *Proc. Japan Soc. Mech. Eng.*, vol. 58, pp. 827–833, 1955.

[11] D.V. Singh, “Advanced concepts of the stability of two-wheeled vehicles—application of mathematical analysis to actual vehicles,” Ph.D. dissertation, Univ. Wisconsin, Madison, WI, 1964.

[12] A.L. Schwab, J.P. Meijaard, and J.M. Papadopoulos, “Benchmark results on the linearized equations of motion of an uncontrolled bicycle,’’ in *Proc. 2nd Asian Conf. Multibody Dynamics*, Aug. 1–4, 2004, Seoul, Korea, 2004, pp. 143–151.

[13] R.S. Sharp and D.J.N. Limebeer, “A motorcycle model for stability and control analysis,’’ *Multibody Syst. Dynam.*, vol. 6, no. 2, pp. 123–142, 2001.

[14] www.wikipedia.org