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Novel Air Blowing Control for Balancing a Unicycle Robot

Jong Hyun Lee, Hye Jung Shin, Seung Jun Lee, and Seul Jung, *Member, IEEE*

Abstract—**This paper presents the implementation of a novel control method of using air for balancing the roll angle of a unicycle robot. The unicycle robot is designed and built. The roll angle of the unicycle robot is controlled by blowing air while the pitch angle is also controlled by DC motors. Successful balancing performances are demonstrated.**

I. Introduction

THE unicycle robot has quite an interesting characteristic in a robot control aspect and appeals to many researchers as well as educators to tackle challenging problems of balancing tasks. The robot looks like an inverted pendulum system, but it also navigates on the plane like mobile robots. Thus, the unicycle robot has a combined structure of two systems, an inverted pendulum system and a mobile robot system. The corresponding control of the unicycle robot becomes quite challenging since the robot has only one wheel to balance itself and also to move to different location as well.

There are several challenging attempts to balance the unicycle robot. The Murata girl is the one that balances itself with a mass controlled balancing mechanism which is a popular mechanism of balancing systems[1]. The Gyrover has a more challenging structure that uses the gyro effect which is similar to the Murata girl. Since the Gyrover has a wheel structure, all the actuators are placed inside the wheel[2]. Design aspect becomes the most important issue than control of the Gyrover.

In the framework of balancing robots, we have developed a series of balancing robots called BalBot. From mobile inverted pendulum systems to single wheeled robots, all of robots are required to balance themselves[3,4]. After successful demonstration of two wheeled mobile robots, a single wheeled robot is implemented and controlled.

As an extension of BalBot series, a unicycle robot is implemented and controlled. Two angles, a roll angle and a pitch angle of the robot are controlled. Controlling the pitch angle and the position is same as controlling the inverted pendulum system. Simple PID controllers can control both angle and position through suitable gain selection procedure. One big challenging difference between one and two wheeled robot is necessity of controlling roll direction angle. There is no need to control the roll angle of two wheeled robots since two wheels are constrained in roll motion. Therefore, the roll angle control of single wheeled robot is quite a challenging task.

In this video, control of a unicycle robot is demonstrated. Our proposal is to use air blower to control the angle to refrain the robot from falling in the roll angle direction. This is quite a novel idea of using air power for balancing. The schematic design of the unicycle robot is shown in Fig. 1. The robot has two arms and one wheel. On the head, there are two blowers located in a slanted angle. To minimize the mutual effects, two angles are decoupled and controlled separately by linear controllers.

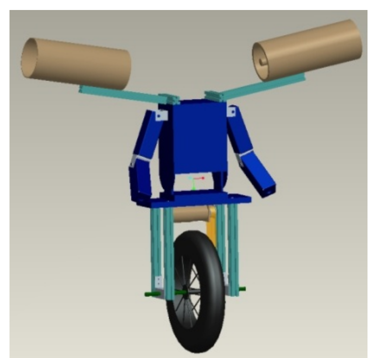

Fig.1 Schematic design of a unicycle robot with air blowers

II. Control Schemes

A. Pitch Direction Control

Pitch direction control is same as the mobile inverted pendulum control[3,4]. PD and PID controllers are designed for pitch angle and position, respectively. And they summed together to generate an input torque to a DC motor. Fig. 2 shows the control block diagram for pitch direction.

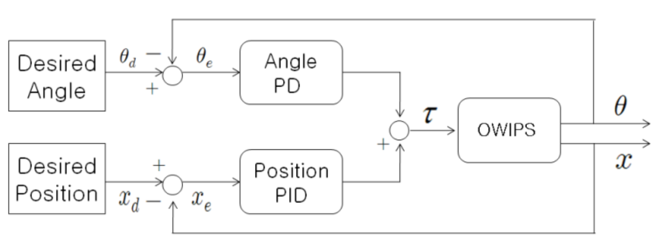

Fig. 2 Pitch angle control structure

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J. H. Lee was with the Mechatronics Engineering Department, Chungnam National University, Daejeon, Korea 305-764. He is now in military service(e-mail: ljh1000je@hanmir.com)
H. J. Shin was with Chungnam National University, Daejeon, Korea 305-764. She is now with the Korean Tire Company, Daejeon, Korea. (e-mail: loyem@naver.com)
S. J. Lee is with the Mechatronics Engineering Department, Chungnam National University, Daejeon, Korea 305-764, (e-mail: sgjb123@hotmail.com)
S. Jung is with the Mechatronics Engineering Department, Chungnam National University, Daejeon, Korea 305-764 (phone: 82-42-821-6876; fax: 82-42-823-4919; e-mail: jungs@ cnu.ac.kr)

B. *Roll Direction Control*

Control of roll directional angle is quite different from that of pitch direction. Fig. 3 shows the control block diagram for roll direction. Two separate duct pans are

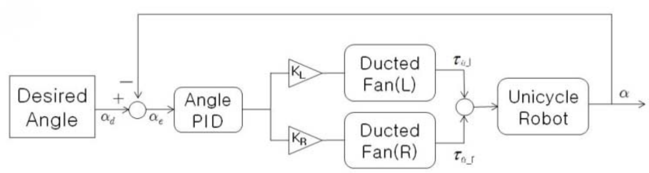


Fig. 3 Roll angle control structure

III. UNICYCLE ROBOT

A. *Real Robot*

The real unicycle robot is shown in Fig. 4. It consists of a wheel, two blowers, two arms, a DC motor, and control hardware. The robot is controlled remotely by a joystick.

Fig. 4 Real unicycle robot

B. *Control Structure*

The robot is controlled by AVR processor. The AVR processor handles sensor fusion, controllers, communication, and actuations. A DC motor is controlled to balance pitch directional control and two motors for ducted fans.

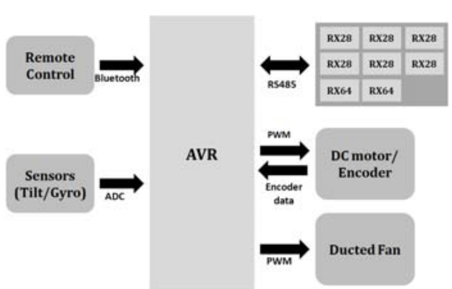


Fig. 5 Overall system structure

C. *Sensor Fusion*

Detecting accurate lean angles is one of the most important tasks for successful balancing control. Here low cost sensors, a gyro and a tilt sensor are used with a complementary filter shown in Fig. 6[4]. Angles sensed by a gyro and a tilt sensor are fused together as shown in Fig. 7. Fig. 7 (c) shows the compensated signal for (a) tilt angle and (b) gyro angle.

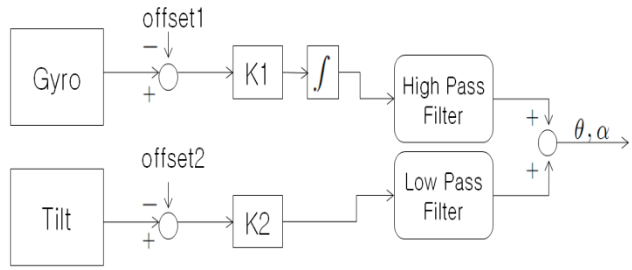
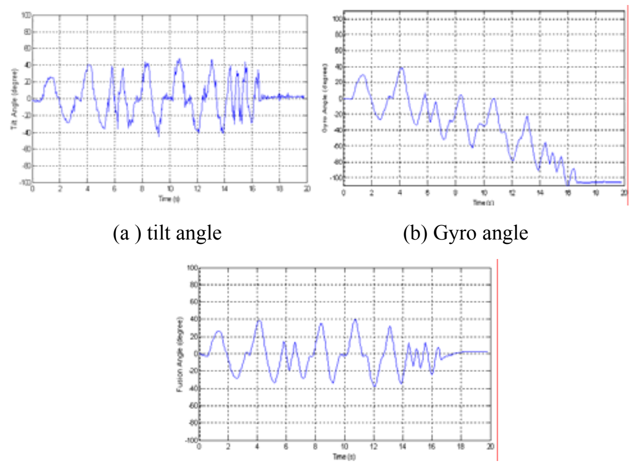


Fig. 6 pitch angle control structure



(a) tilt angle (b) Gyro angle

(c) Fused angle

Fig. 7 Sensor data and fused angle data

IV. CONCLUSION

A unicycle robot is implemented and controlled. Roll and pitch angles are sensed and fused by the filter for the linear controllers to balance. The roll angle is controlled by air blowers while the pitch angle is controlled by a DC motor. Successful balancing and moving tasks have been demonstrated by remote joystick control. The robot is controlled remotely to move forward and backward. This video proves the feasibility of using air power to control the balancing robots. For the next research topic, to complete balancing tasks of the unicycle robot, the yaw angle is also required to be controlled.

REFERENCES

[1] "Murata Girl", http://www.murataboy.com/

[2] Y. S. Xu, K. W. Au, G. C. Nandy and H. B. Brown "Analysis of Actuation and Dynamic Balancing For a Single Wheel Robot", *Proc. IEEE Int. Conf. on Intelligent Robots and Systems*, pp. 1789-1794, 1998

[3] S. S. Kim and S. Jung, "Control experiment of a wheel-driven mobile inverted pendulum using neural network", *IEEE Trans. on Control Systems Technology*, vol. 16, no. 2, pp. 297-303, 2008.

[4] H. J. Lee and S. Jung, "Gyro sensor drift compensation by Kalman filter to control a mobile inverted pendulum robot system", *IEEE International Conference on Industrial Technology*, pp. 1026-1031, 2009.