2013 13th International Conference on Control, Automation and Systems
Oct. 20-23, 2013 in Kimdaejung Convention Center, Gwangju, Korea

A Time-Delayed Control Method for Robust Balancing Performance of a Two-Wheel Mobile Robot

Sung Teak Cho[1] and Seul Jung[2*]

[1] Department of Mechatronics Engineering, Chungnam National University, Daejeon, 305-764, Korea
(Tel : +82-42-821-7232; E-mail: savagegard_n@nate.com)

[2] Department of Mechatronics Engineering, Chungnam National University, Daejeon, 305-764, Korea
(Tel : +82-42-821-6876; E-mail: jungs@cnu.ac.kr) * Corresponding author

Abstract: This paper presents a design of a time-delayed controller for the robust balancing performance of a two-wheel mobile robot (TWMR). The PD control method can balance the TWMR, but it lacks for the robustness due to the disturbance. To reject the disturbance effectively, the time-delayed control method is utilized. For the comparison of the robust balancing performance, the performances of the PD control method and the time-delayed control method are compared. Experimental studies are conducted to demonstrate the performance of the time-delayed controller.

Keywords: Two-wheel balancing robot, PD control, time-delayed control, robust balancing.

1. INTRODUCTION

Mobile robots are one of major robot types for achieving mobility. Recent research on robotics is shifting from industry-oriented robots to service-oriented robots. Mobile robots play important roles in various areas, especially in service, exploration, and transportation.

Different from wheel-driven mobile robots (WDMR) control of two-wheel mobile robots (TWMR) is quite challenging since they have to maintain balance with two wheels. Major research topics of mobile robots are simultaneous localization and mapping (SLAM), trajectory planning, and control. Among them, SLAM is the most active research subject in the areas of mobile robots.

Two-wheel mobile robots are now getting popular after the appearance of SEGWAY that can be used as a transportation vehicle for a human driver to commute in short distances [1]. Control of TWMR is quite challenging since TWMR is a combined system of an inverted pendulum system and a mobile robot. Two wheel torques have to control the balancing angle and position. TWMRs have advantages over other vehicles in their usages in the narrow and crowded areas.

The most important performance of TWMR is the balancing task. TWMR has to maintain balance under outer disturbances such as intentional hits or unwanted disturbance inputs from the uneven grounds.

In the previous research of balancing control tasks, a linear control method has been used for balancing and navigation [2]. The body of TWMR is designed to be symmetrical so that the center of gravity is located on the center of the wheel axis. This helps linear controllers to make balance with ease.

However, if TWMR is not symmetrical, then linear control methods may not have effective control performance. Therefore, a fuzzy control scheme as an intelligent control method is used for a two-wheel mobile robot system [3]. Performance by the fuzzy control method is compared with that of a linear control method. Although linear control methods work well for the balancing control, TWMR is notably oscillating back and forth. However, the fuzzy controller makes TWMR more stable and still.

In this paper, as an extension of the previous research, a time-delayed control method as a robust controller is applied to TWMR. The time-delayed control method is known as a robust controller for the disturbance rejection in robot manipulator control applications [4-9]. We can expect the same effect of the time-delayed control method to reject outer disturbances in TWMR.

The time-delayed control method uses the previous information to cancel out uncertainties. Since the TWMR is the nonholonomic system that two wheel torques control x-y position and a balancing angle, how to apply the time-delayed control algorithm to the system has to be considered. Here we apply the time-delayed method to each wheel.

Experimental studies of TWMR are demonstrated. The balancing performance under the disturbance of intentional hits is conducted to compare performances of the PD control and the time-delayed control method.

2. TIME-DELAYED CONTROL

The time-delayed control has been known as a robust controller for long time. The idea of the time-delayed control method is to use the previous dynamic information to cancel out uncertainties. Therefore, the sampling time should be fast enough so that the delayed information is as effective as the current information.

Let the nonlinear dynamic system be

$$D\ddot{x}(t) + g(t) = f(t) \tag{1}$$

where D is the inertia matrix, $g(t)$ is nonlinear