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Dynamic Model of a Bicycle with a Balancer and Its Control

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Abstract

Research on the stabilization of bicycles has been gained momentum over the last decade in a number of robotic laboratories around the world. Modeling and control of bicycles became a popular topic for researchers in the latter half of the last century. The bicycle literatures are comprehensively reviewed from a control theory perspective in [1], which also describe interesting bicycle-related experiments. A. L. Schwab et al. [2] developed the linearized equations of motion for a bicycle as a benchmark and it is suitable for research or application. It is well known that the control of bicycle with steering at zero or slow linear velocity is very difficult. Thus, we are interested to stabilize the bicycle with the balancer that it can allow us to control the bicycle at zero or slow linear velocity. In this paper, we present the development of a bicycle with a balancer and the balancing control in our laboratory. The first generation of the bicycle with balancer was developed by M. Yamakita in 2005 [3] by using Lagrange dynamic equations and the balancing control used an output function which is defined by an angular momentum and the new state function is controlled to zero. We reported the experimental study of automatic control of bicycle with a balancer in 2006 [4] and in 2008 [5]. In order to control the bicycle in narrow place, we introduced acrobatic turn via wheelie motion that it can allow the bicycle turn on the back wheel at zero linear velocity [6]. This system is still in the development of experiment and we will report the results in the future.
In addition to extending those results to balancing the bicycle, we propose a new balancer configuration for stabilizing of an unmanned bicycle that it shows in Fig. 1 [7]. The balancer can be

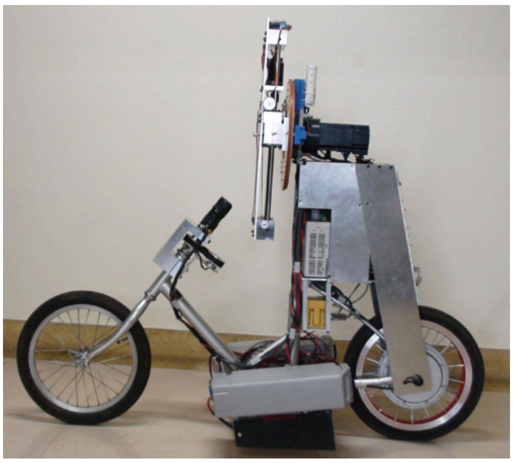
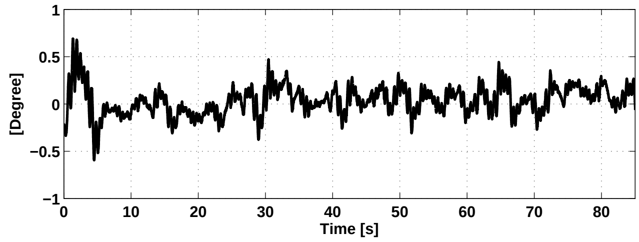


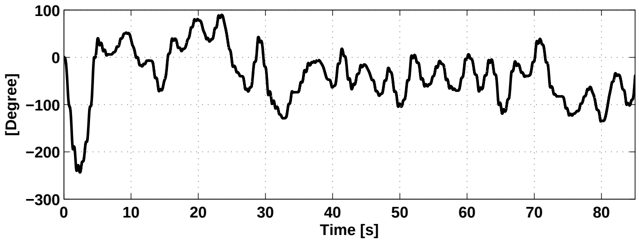
Figure 1. Bicycle with flywheel balancer hardware.

configured as a flywheel mode or a balancer mode by shifting the center of gravity of the balancer. This balancer configuration is changed according to the situation of the bicycle system, which corresponds to the change of the dimension of the system. The balancer is configured as a flywheel, when disturbances to the system are large, and it will switch to the balancer when the position of the center of the gravity should be shifted. Stabilizing bicycle with the flywheel has better performance than the balancer but it cannot control to shift the bicycle angle to track the desired value,

unlike the balancer which can do this motion. The simplify dynamic model of the bicycle with the flywheel balancer model is derived based on an inverted pendulum model. We consider the bicycle as a point mass with two wheels contacting with the ground, and we consider the bicycle and the balancer as a two link system where the first link is the bicycle body with steering and the second link is the balancer. The details of a bicycle with flywheel balancer was presented in [7]. We will report the experimental development in this paper. Figure 2 shows the experimental results of bicycle stabilization with the flywheel balancer.



(a) Roll angle α



(b) Balancer angleβ

Figure 2. Bicycle stabilization with the flywheel balancer

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