Design self-balancing bicycle

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Keywords: Self-balancing; gyroscope; control system

ABSTRACT – Recently, many investigations have been done regarding to the problems of controlling two-wheeled self-balancing robot. This paper reviewed based on five previous journal in order to find out which method is suitable to design a self-balancing bicycle and it will focus on the control system of the structure. There are several ways in order to design an efficient self-balancing bicycle which are by using control moment gyroscope (CMG), mass balancing, steering control and reaction wheel. Based on previous research, the usage of CMG is the suitable choice since it can produce large amount of torque, it has no ground reaction forces, and the system can be stable even when the bicycle is stationary.

1. BACKGROUND STUDY

Bicycle is a common form of transportation, recreation, and also can be a medium in exercising which have been used for years of many people. Bicycle also can serve to provide physical therapy, as they are a low impact form of exercise that can train balance, strength, stamina and coordination. Though one may consider riding a bicycle to be a fairly simple task, this is not the case for many people especially for young children, and adults who have never learned to ride a bicycle, injured people, or people suffering from developmental or cognitive disabilities. A system that could provide balancing assistance to a bicycle rider without otherwise affecting the experience of riding a bicycle could provide great benefit to these groups of individuals. Such a system could be used both as a teaching tool, and as a physically therapeutic device.

Recently, many investigations have been done regarding to the problems of controlling two-wheeled self-balancing robot, which are widely taken into applications in the field of autonomous robotics and intelligent vehicles. First and the foremost problem is bicycle keep falling when it is not in controlled especially at low forward velocity [1-2]. Besides, the lack of controlling flywheels in the horizontal position also become a problem in this cases. Without controlling the flywheels in the horizontal position, the bicycle will lose its balance after a particular limited flywheel's angle [3]. So that, many inventors have been made research and development to encounter this problem such as introducing the self-balancing bicycle. Self-balancing bicycle use sensors to detect the roll angle of the bicycle and actuators to bring it into balance as needed, similar to an inverted pendulum where it is an unstable nonlinear system and can be implemented in several ways. This paper reviewed based on five previous journal in order to find out which method is suitable to design a self-balancing bicycle and it will focus on the control system of the structure.

2. METHODOLOGY

The methods to achieve a self-balanced bicycle are mainly classified into four types. The first type is using a control moment gyroscope (CMG) [1-4]. This method can provide a large torque, but energy consumption of CMG is very high because the flywheel is spinning all the time. The CMG consists of a spinning rotor with a large, constant angular momentum, whose angular momentum vector direction can be changed for a bicycle by rotating the spinning rotor. The spinning rotor, which is on a gimbal, applies a torque to the gimbal to produce a precession, gyroscopic reaction torque orthogonal to both the rotor spin and gimbal axes. A CMG amplifies torque because a small gimbal torque input produces a large control torque to the bicycle

The second type is mass balancing where mechanical structure of mass balancing is simple, but the torque this method could provide is small.

The third type is steering control where a controller controls the amount of torque applied to the steering handlebar to balance the bicycle. Advantages of this system are low mass and low energy consumption, while its disadvantages are it requires ground reaction forces and it cannot withstand large tilt angle disturbance. The energy consumption of steering control is low, but it cannot balance the bicycle at low forward velocity.

The forth type is using a reaction wheel where speed of a reaction wheel is increased or decreased to generate a reactionary torque about the spin axis which is parallel to the bicycle's frame [5]. As the bicycle begins to fall to one side, a motor mounted to the reaction wheel applies a torque on the reaction wheel, generating a reactionary torque on the bicycle, which brings back the bicycle's balance. Advantages of this system are it is low cost, simple and no ground reaction, while disadvantages are it consumes more energy and it cannot produce large amount of torque.

A very well-known self-balancing bicycle robot using a reaction wheel is the Murata Boy which was developed by Murata Manufacturing Co., Ltd in 2005.

3. RESULTS AND ANALYSIS

Among these methods, the CMG, a gyroscopic stabilizer is a good choice because its response time is short and the system is stable when the bicycle is stationary. Gyroscopic stabilization, where one or more motorized gimbals tilt the angular momentum of a spinning rotor. As the rotor tilts, the changing angular momentum causes a gyroscopic precession torque that balances the bicycle.

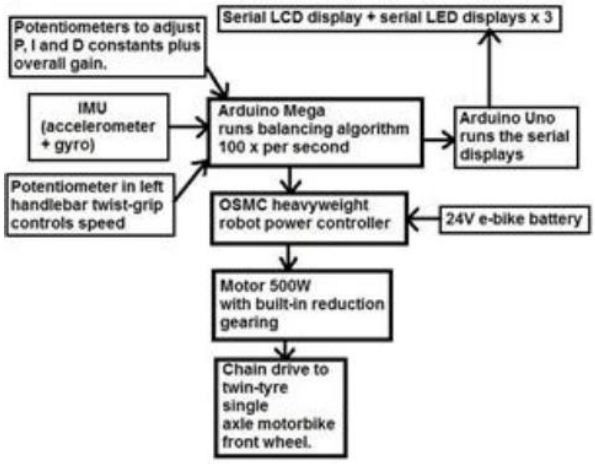

Figure 1 An example of main components of self-balancing control system.

Advantages of this system are it can produce large amount of torque, it has no ground reaction forces, and the system can be stable even when the bicycle is stationary. Disadvantages are it consumes more energy and it is physically complex. Research studies using this concept include Narong et al. [1,5], Jiarui et al. [2], and Sandeep et al. [4].

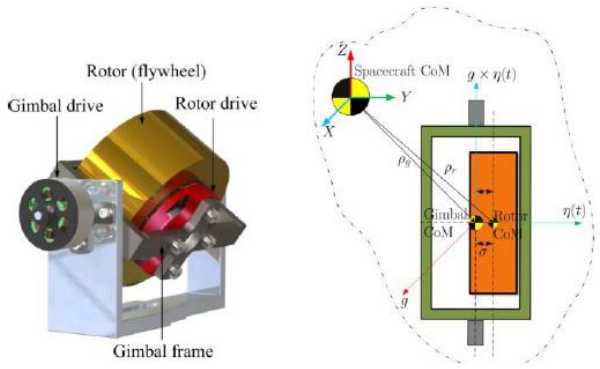

Figure 2 Control moment gyroscope (CMG).

4. CONCLUSIONS

In the nutshell, there are several ways in order to design an efficient self-balancing bicycle which are by using control moment gyroscope (CMG), mass balancing, steering control and reaction wheel. Based on previous research, the usage of CMG is the suitable choice since it can produce large amount of torque, it has no ground reaction forces, and the system can be stable even when the bicycle is stationary. Unfortunately, CMG consumes more energy and it is physically complex but this disadvantage will be contained with further research and development in the future.

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