Autonomous Bicycle Roll Angle Control System
Blair Williams

Bicycle Roll Angle Control System Final Prototype Design

Bicycle Roll Angle Control System Fabricated Prototype Device
Summary

The goal of this project was to design an autonomous bicycle roll angle control system. By controlling the roll angle of a moving bicycle, stability can be obtained for autonomous operation. Such a device can be used as the basis for developing more advanced types of automatically-driven two-wheeled robotic vehicles which are important for military reconnaissance or space exploration applications. A functional bicycle stability control system may also aid in the design of stability-assistive mechanisms in future human operated twowheeled vehicles for safer operation. Additionally, such a device can be used to explore research-related questions as pertaining to inverted-pendulum-like control or made use of pedagogically for engineering control system classes at Hope College.

Several design requirements were evaluated to develop this bicycle roll angle control system. For the control system to function autonomously, all system components were required to be mounted onboard the bicycle, including power sources. An accurate means of measuring roll angular states was required, as well as an easily reprogrammable interface for implementing various control methods. The design also called for a low cost design, as the project budget was limited to $800. Safety was also a vitally important factor in determining the product’s design. Additionally, little modifications to the original bicycle and low-maintenance system components were also desired of the developed device.

To formulate a feasible design for a bicycle roll angle control system, several concepts were considered. For programming control methods and acquiring system data, a laptop-LabVIEW setup, FIRST Robotics controller, and I/O microprocessor board were all considered. To measure the bicycle’s system states, the various conceptual designs included use of a rearwheel cart with an attached potentiometer, an accelerometer and rate gyro combination, ultrasonic sensors, a hanging mass with attached optical counter, and a motion-tracking camera. As the proposed control system required actuating both the bicycle’s rear wheel and handle bar steering angle, various configurations of stepper, DC, and servo motors were considered for driving these control system features. The concepts also evaluated several means of transmitting torque from these motors. Other unique features considered with the conceptual designs included use of an existing electric-powered bike or running the device stationary on a powered treadmill.

The final roll angle control system design makes use of an onboard laptop equipped with LabVIEW for data acquisition and control implementation. A weighted average of sensor readings from an accelerometer configured as an inclinometer and the discrete integration of a rate gyro is used to obtain roll angle measurements. The developed prototype utilizes a stepper motor to actuate the required steering angle and a DC window motor to drive the bicycle. Batteries are mounted onboard the bicycle to power all the devices. Circuits were developed to configure all the electrical components, and both digital and physical filtering methods were applied across the measurement sensors’ output signals. A least-mean-squares fitting algorithm was used to identify physical parameters of the bicycle system for control implementation. The control system components are all interfaced with a LabVIEW program, and a control method is implemented. Thus far, the control system has succeeded in stabilizing the bicycle for brief runs. As improved control methods are developed and implemented from root locus analysis and model simulations, the finished prototype device is fully equipped with all of the necessary
hardware specifications for realizing effective roll angle control.