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A self-stable remote control bicycle design and implementation as a teaching project

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Abstract:

The Polytechnic School of Engineering of Ferrol, from the University of A Coruña, has been increasing the amount of practical teaching for their engineering students. Within this framework, an optional course, called Interdisciplinary Project, started in the academic year 2019-2020. In this course, which lasts two semesters on the last year of the degree, the students have to address an engineering problem, starting from a theoretical study, and finishing with a solution to the problem.

During the 2021-2022 academic year, the topic consisted in the development of a remote control bicycle. From the teaching viewpoint, the project included several interesting topics, such as mechanical design, control theory, estimation theory, manufacturing, etc. In addition, the problem is interesting due to its possible applications, such as autonomous motorcycles, or steer-controlled narrow-track tilting vehicles, to name a few.

The main aim for this course was the development of a remote control bicycle, using exclusively the steering to keep the balance. The idea is that the bicycle could be controlled with two signals: one would provide the longitudinal control (i.e.: increasing or reducing the speed), and the other would provide the heading control. In order to fulfill this, the main challenge is to achieve the lateral stability of the vehicle.

The project started from a Littium Ibiza Dogma electric bicycle, which was lent for one year by Ciclos Roca, a local bicycle shop. This is a conventional pedal-assist e-bike, but it has a manual throttle, which enables for an easy way to control the longitudinal speed of the bicycle when it is transformed into a remote control vehicle. A Futaba 3-channel surface radio system was already available at the beginning of the project.

From the starting point, the students developed the control system, designed the mechanical modifications to be made to the bicycle, and implemented the whole prototype. Since the bicycle was initially lent for one year, no permanent modifications were allowed, and every modification should be reversible. Moreover, since this is "just" a teaching project, the budget should be kept as low as possible.

The design of the control algorithm was inspired in the one used in Maceira et al. (2021), where a linearized Whipple model (see Meijaard et al. (2007)) is combined with an LQR controller. However, in Maceira et al. (2021), the control input was the steering torque, while in this project, the steering angular rate was used instead. This design removed the need for a precisely characterized steering torque model or a steering torque measurement, but it required an additional PI controller instead, in order to achieve the

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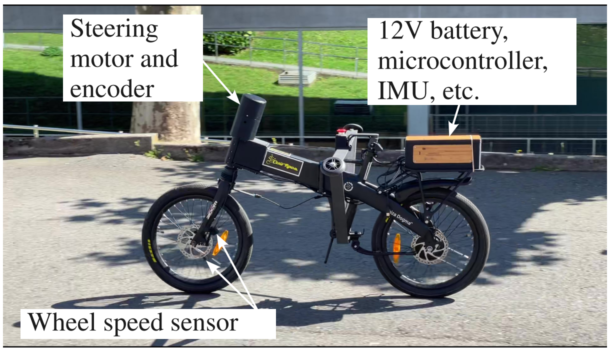

Figure 1. Left: the bicycle in its original state. Right: the remote control bicycle prototype.

proper input speed required by the LQR control. The output of the control system is the roll angle, and the roll angle reference is set by the user through the remote control.

In order to implement this controller, some measurements are required, namely, the longitudinal speed, the roll angle, the roll rate, the steering angle, and the steering rate.

The speed measurement was implemented using a Sharp GP1A57HRJ00F photointerrupter and a small 3d printed flap attached to the front disk brake, which interrupts the sensor beam once per wheel turn. The time between consecutive interruptions provides a good approximation of the longitudinal speed. In order to measure the steering angle and the steering rate, the motor employed to act the steering included an incremental encoder. In this case, a Pololu 37Dx73L 12V DC motor with a gear reduction of 150:1 was selected.

Finally, the main board of the system is an Arduino Uno Wifi rev. 2. This board was selected because, in addition to the microcontroller, it includes an IMU, which is used to measure the roll rate, and it is also employed by the roll angle estimator.

The original bicycle and the final result after the transformation can be seen in Figure 1. Without taking into account the original bicycle (lent for this first year of the project), and the remote control system, the cost of the whole project was kept below 500 euros.

In upcoming years, it is expected to improve steering system by means of a more powerful motor, and a drive with less backlash and capable of handling a greater torque. Also, a braking system will be added. After these improvements are made, it is also expected to add more autonomous capabilities to the vehicle, with automatic obstacle avoidance, or even autonomous driving.

References

Maceira, D., Luaces, A., Lugrís, U., Naya, M. A., and Sanjurjo, E. (2021). Roll angle estimation of a motorcycle through inertial measurements. *Sensors*, 21(19).

Meijaard, J., Papadopoulos, J. M., Ruina, A., and Schwab, A. L. (2007). Linearized dynamics equations for the balance and steer of a bicycle: a benchmark and review. *Proceedings of the Royal Society A: Mathematical, Physical and Engineering Sciences*, 463:1955–1982.

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