ERSAB
Electronic Response System for Assisted Braking

Team: Neil Stimpson, Prerak Sanghvi, and Vassily Petrov
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Introduction

Objective

When riding a bicycle, one of the risks is not being able to enable the brakes in time and crashing. While one can stop quickly by pulling hard on the brakes, some are worried that they will lock up the wheels if they brake too hard and are hesitant about slamming on the brakes as a result. Therefore, our proposed solution is to create an electronic braking system for a bicycle. Instead of a mechanical lever like on a normal bike, a pressure switch mounted to the handlebars. A motor for the front brake and a motor for the back brake, a wheel rotation sensor, and a microcontroller.

When the rider pushes the pressure switch, the motors would apply a force on the brake cable proportional to how they push the switch. While braking, the system records the speed of rotation of the wheels. If the deceleration of the wheels is such that they begin to lock up, the system will ease off the brakes. The current braking cable will be snipped and attached to a pull sensor. The pull sensor reveals how much pounds of force is applied by the rider which can be calibrated to the intensity of the braking level. The pull sensor will send data out to the microcontroller which can process the information. Furthermore, the microcontroller will be connected to a motor driver which will control our main braking mechanism. After the braking cable, the other end of it will be tied to a motor whose rotating action will apply or release the brakes. In this case, the tension of the string will be adjusted to brake electronically.

Subsequently, the plan to attach a 3D-printed wheel cap that will sit on the front or on the back axle which will rotate with the wheel. This wheel cap will have a specific number of holes through which a laser sensor would be pointed. This system will be connected to the microcontroller, thus giving us an accurate speed measurement. With this information, our brakes will be recalibrated, because at different speeds the braking needs a different intensity. Also, the plan is to install an accelerometer to our bike at the rear end. As it sees the bike has started to lift up while braking, it can release the brake and stabilize the bike. Testing will be needed in order to calibrate this correctly. Therefore, in order to install our microcontroller on the bicycle, a 3D-printed mount will be used to hold it.

The advantage of this system is that it can maximize braking performance without having the wheels lock. It removes the hesitation that riders face if they must brake suddenly -- it also makes it easier to apply the brakes for those that have weak hand strength and reduces wrist and hand strain from having to enable the brakes frequently. Ultimately, this design will be modular; additional features can be added if time permits. In this case, one extra feature may include adding a mount for an ultrasonic sensor to the front of the bike to sense obstacles. Ideally, the sensor would send a signal to apply the brakes automatically if an object is approaching too quickly. An accelerator on the rear wheel could detect fishtailing and apply the rear brake automatically to correct for this.

Background

This project came about as it primarily affected our team member Prerak, who flipped his bike when he slammed on his brakes and hurt his hand. Also, Vassily is an avid biker and considers this issue when he rides. In general, there exists a trade-off, as bikers may pass a threshold when they are riding, where they have to slam on their brakes if it's an emergency and risk injuring themselves despite depending on the safety functionality of the bike -- the brake.

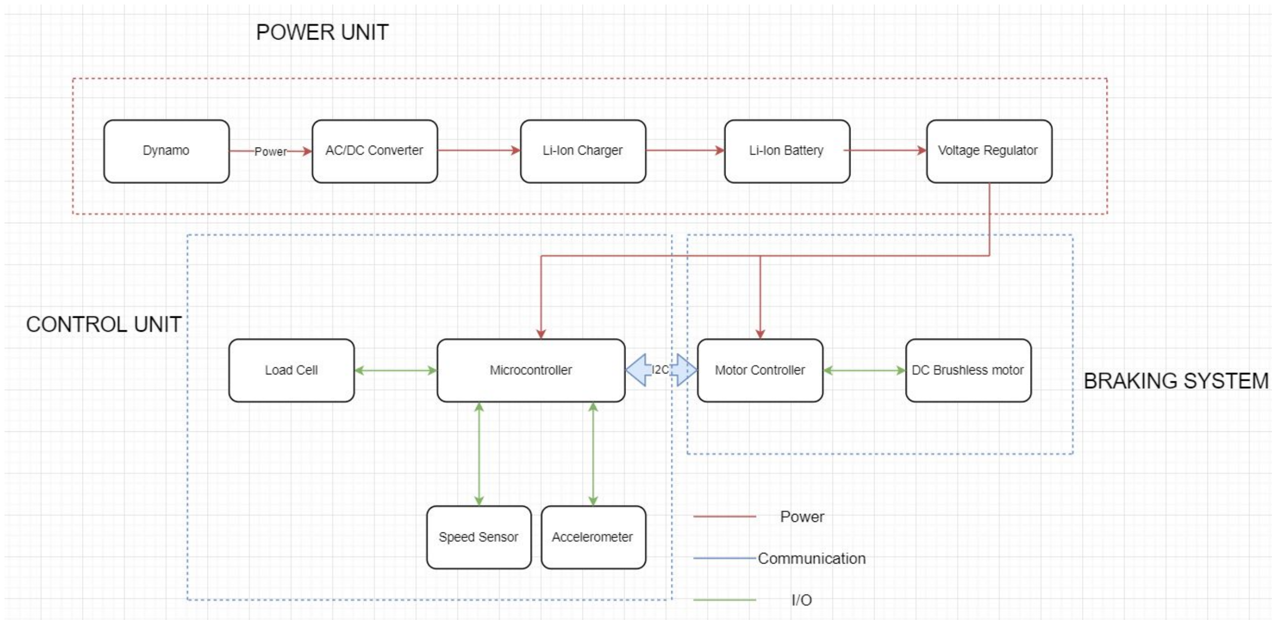
In 2015 there were 818 cycling fatalities according to the NHTSA[2] in the United States. 25.7% of these fatalities are due to no fault of the cyclist and 34.9% are due to failure to yield to right of way. In both cases, more cyclists may have survived if they were able to brake faster or take evasive action without locking up their brakes.

High-Level Requirements

- The speed sensor is able to send data to the microcontroller in order to enable the motor to activate the braking system for the bike.
- The brushless motor is able to provide sufficient torque to activate the brake.
- The PCB is designed compactly with the intention of integrating the power, control, and braking systems.

Design

Block Diagram



The electronic response system will require three categories of operation: power unit, control unit, and the braking system. The power unit will make sure the microcontroller operates at 3.3 V and motor controller operates at 12 V. The data processing will be handled by an ARM processor that will act as our microcontroller, the centerpiece of our control unit. The braking system involves a motor controller and its accompanying motor that will be chosen to provide high torque in our braking system that will be able to rotate the manually-attached brake effectively. Lastly, and I2C bus will enable the communication between the microcontroller and motor controller.

Physical Design

The bike's middle real estate will house the PCB for our electronic response system. This will include the motors and the connections necessary to send data to and from the sensors that will be attached to the front and rear wheels depicted above. Specifically, the attachments will be made via 3D-printed mounts for the electronics as well as 3D-printed rings with holes for detecting rotations per minute (rpm) of the wheels. Furthermore, one of the brakes will be cut and connected to the motor and pull the brake via rotations of the armature.

Power System

A lithium-ion battery will be used to run the electronics and the motors/actuators in a range of 9-12.6 V. It will need to be specced sufficiently large so that it could last for hours without needing to be recharged. The power system will incorporate a buck switching voltage regulator for generating the necessary stepped-down voltages for the controller and motor more efficiently than its linear regulator counterpart, since the difference between the input voltage and the regulated output voltage is dissipated as heat. In other words, the power saved from using a buck switching regulator is preferable as more current is drawn from the power supply during a bike ride.

Microcontroller

An ARM microprocessor be used to handle all of the data from the sensors and be able to react to input quickly, as it can operate at higher speeds than the alternatives like the ATmega328. It will need to be energy efficient enough to last for hours running from the battery. It will also need enough inputs to handle the connections from all of the sensors.

Motor Driver & Motor

The type of motor selected might be a servo or brushless motor depending on the winching pulling system, but at this time, a brushless motor is preferable. These motors were chosen based on their speed and torque so that it activates with sufficient strength to slow down the wheel. At this time, higher torque will be preferred over the rotation speed. The motor driver will need to be able to handle the maximum current of the motor. If possible the motor driver will be designed as well.

Table of assumptions:

Motor power rating	250W
Motor load	25%
Braking time	3 seconds
Braking frequency	30 /hour
Electronics consumption	2W
Target Battery life	12 hours

Based on the assumptions that were made about the system, The estimated battery capacity would have to be 61.5Wh. With a 3-cell Lithium-Ion battery, the nominal voltage would be 10.8v, the necessary battery would have a rating of at least 5.7Ah.

User Feedback

The user will need feedback as to the status of the battery and to alert when it needs to be recharged. This could be a series of light-emitting diodes (LEDs) that indicate battery percent, or a liquid crystal display (LCD) that shows a numerical representation of battery charge.

Tension/Force Sensor

The tension sensor would be attached to the brake lever and detect when the user wants to brake. The output will be an analog value so that brake force would be proportional to the reading from the sensor.

Wheel Rotation Sensor/Accelerometer

The wheel rotation sensor may be optical or magnetic and would be on both the front and rear wheels. Data from these sensors could be used to calculate wheel acceleration. An accelerometer mounted to the frame will be used to detect sudden jolts and shifts which would aid in determining when the bike loses control or begins to flip.

Risk Analysis

Our printed circuit board (PCB) will pose the greatest risk to completion, as it will require the most design effort to be completed.

Safety and Ethics

There are a few safety hazards that are associated with our project. Lithium-ion batteries for our power supply, which contains microscopic metal particles that may come into contact with other parts of the battery cell, leading to a short circuit within the cell. In unfortunate but likely situations, a thermal runaway can occur as a result of this short circuit -- a process where temperature rises uncontrollably until a violent chemical reaction erupts.

Another safety hazard could arise during the testing portion of our project, where riding the bike to analyze the functionality of the braking system may contain bugs, risk braking too hard, flipping over, and hurting ourselves in a variety of ways. Unfortunately, this particular safety hazard is the most prominent, because the objective is to prevent potential injury, so the threshold of safety will have to be towed very carefully to make sure accurate data is received as well as keep ourselves and others safe from physical harm.

With regards to the IEEE Code of Ethics[1], the first and ninth codes seek to preserve the safety of the public, and if testing our project risks crashing our bike, testing must be conducted in an area that is devoid of people in order to not endanger anyone. After scouring other ethical codes like the University of Illinois' campus safety policy, most ethical guidelines do not pertain to our project except for the aforementioned ones that discuss personal and public safety.

References

[1] Ieee.org. (2019). *IEEE Code of Ethics*. [online] Available at: https://www.ieee.org/about/corporate/governance/p7-8.html [Accessed 19 Sep. 2019].

[2] Nhtsa.gov. (2018). *Traffic Safety Facts*. [online] Available at: https://www.nhtsa.gov/sites/nhtsa.dot.gov/files/documents/812502_pedestrian-and-bicyclist-data-analysis-tsf-research-note.pdf?fbclid=IwAR2haj6i7xpE9nyCyEeqgjgRTxs1GmiGcvj2ojDA53sZ9f4XOfNWzsCEgZk [Accessed 19 Sep. 2019].