Distributed Bike Locking System

Praneeth Mekapati, Cameron Obrecht, & Rohan Sreerama

Design Document

Introduction

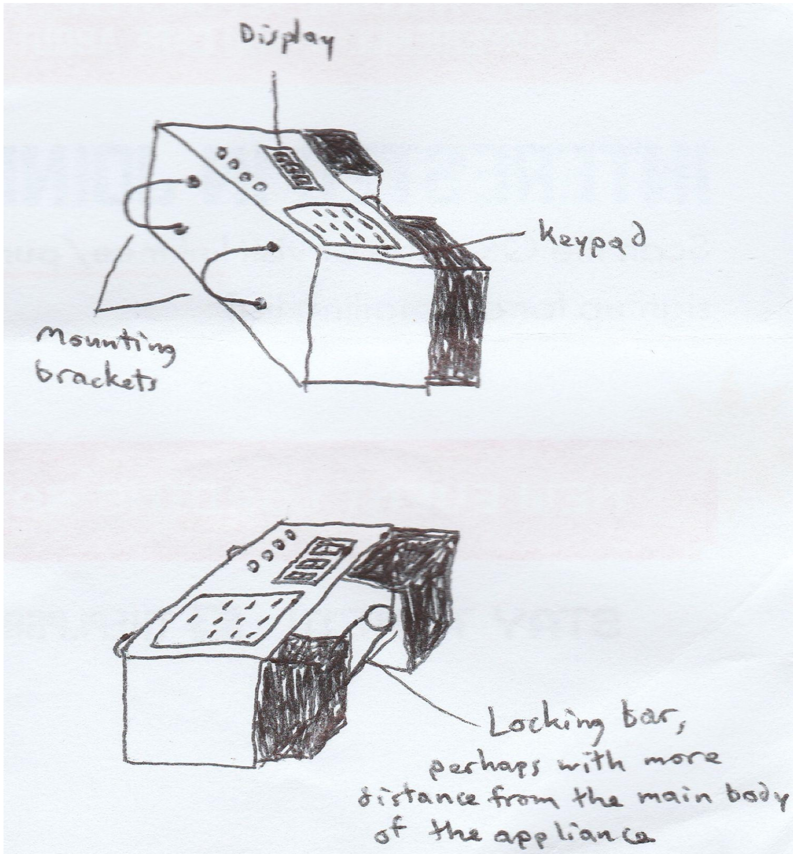
- **Problem:**

  Bike theft has always been a big issue in this world. They are always stolen every 30 seconds. Almost two million bikes are stolen every year resulting in a loss of over $350,000,000 as mentioned in the Ultimate Guide to Bicycle Theft Statistics article. Although there are individual bike locks, thieves are able to cut these locks with tools such as the bolt cutters. This shows that bikes are able to be stolen even when the bikes are locked by the stands. Also, there are times when people forget to bring their locks with some sense of urgency. This also can be a problem where they need a way to keep their bikes safe after coming back from their events which can include school, work, play, etc.

- **Solution:**

  In order to solve the problem of bike theft, we are proposing a distributed bike lock system. This is going to be a group of independent, public, automated, passcode-driven locks permanently attached to existing bike racks that will significantly reduce bike theft. They will be placed on the bike racks in order for an easier process of locking the bike. The system will sound a high pitched alarm when any sign of physical theft activity is happening and this will be detected through the use of sensors and buttons. This will take a user input of the number of hours to lock their bike as well as the amount of money from the user for that input amount of time. This keeps their bike firmly locked for that amount of time.

- **Visual Aid:**



Bike lock unit

High Level Requirements

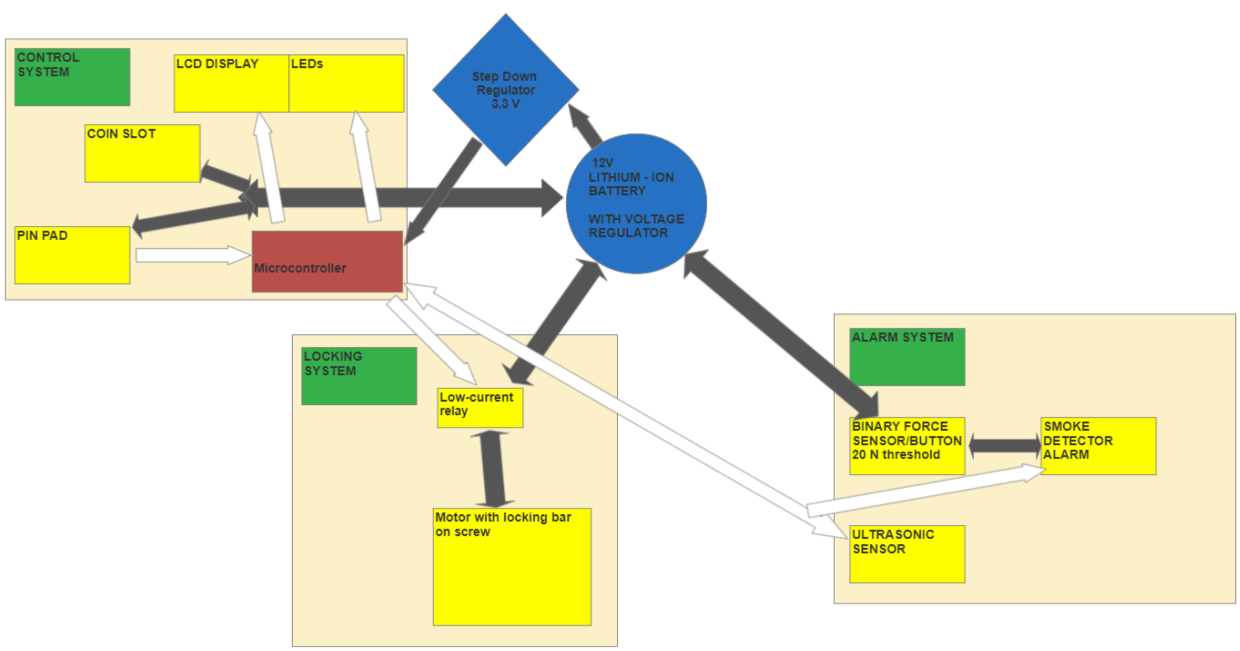
The finished appliance will have to:

- Be secure. The appliance will have to be difficult for a malicious actor to destroy, whether by preventing the attempt or by continuing to hold the bicycle securely even if severely damaged.
- Accept payment honestly, without failing to accept a coin. Makes sure to read the dollar amount based on coin input and create the time based on it.
- Locks the bike for the specified input time and later charges the user if they don't unlock the bike at the right time
- Locks and unlocks the bike based on the user input in key-pad and makes sure the key-pad input is accurate to what the user typed in before in order to unlock the bike

- Sounds the alarm if there is a man trying to steal the bike through the use of wire cutters or other tools with the use of a binary motion sensor

Design

- Block Diagram:



- Subsystem Overview:

- Control Subsystem: Responsible for locking and unlocking the gear motor based lock. Takes user input for the number of hours they want to lock the bike for through the use of the pin pad. Makes the user deposit coins in the coin slot to start the locking of their bike and the required amount is $0.50 per hour. This transfers the signals to the LEDs to keep track of the lock process and the LCDs to display the status of the system eg. four digit pin with *'s, money needed to deposit, the status of the lock

- Alarm Subsystem: Sounds the alarm when there is a thief attempting to steal the bike, with a high pitched continuous beep. It is operated directly by a battery, in an analog circuit with no need for intelligent alarm activation as long as a force signals the sensors. This in turn will send the signal to the alarm which will sound a beeping noise with a high enough frequency to be unpleasant to the ears. This includes the force/motion sensor to detect any movement of the thief along with the ultrasonic sensor to detect the movement from a particular distance. If both the sensors are able to detect unusual or suspicious activity with strong force or object or hand movement close to the alarm system, then this would trigger the alarm.
- Lock Subsystem: Rotates the long screw to shift the bar left or right based on the signal from the microcontroller. This makes sure the bike is firmly locked in a way that no thief can try to force the lock to open with any tools or break it. The Alarm Subsystem is also near the lock and this is the best way to ensure no tool or force comes near the lock to steal the bicycle. This is operated with the use of the control subsystem. The lock is activated when the control system successfully receives and processes the input signals from the keypad and the coin slot. Overall, the lock subsystem is reliant on the control subsystem.

- Subsystem Requirements:

- Control Subsystem: Requires a microcontroller to take user input from the keypad and coin slot, and send output to the status LEDs, numerical display, and motor controller (embedded in the motor). The microcontroller is embedded on a PCB, and it interprets the data from the coin slot and adds the values of the coins to determine when the proper amount due has been paid. It then sends a signal to the motor controller when the right amount of money has been paid, according to the number of parking hours specified by the user. The microcontroller board is connected to a voltage-regulated power source via a plug. The microcontroller is responsible for starting and stopping the lock motor based on the number of revolutions traveled, which is sent as data by the motor controller. The keypad sends a signal to the microcontroller after the 4 digit PIN is typed. Then the microcontroller waits for the input signal from the coin slot. The input will be successfully processed when the user pushes the correct amount of money into the slot. The microcontroller after having the correct amount of money from the user with a 4 digit pin will send a signal to the motor. The microcontroller will require a 5 V input from a power source which will be the step down regulator. The keypad will have the same from the step down regulator. The LCD and the LEDs will be powered and programmed by the microcontroller. The coin slot will have power provided by the lithium battery consisting of 12 V and later connected to the microcontroller. The microcontroller will first display the message on the LCD to let the user type the number of hours they would want to lock their bike for with the use of the key pad. If the number of hours is greater than 0, the microcontroller then sends a signal to the LCD and the LCD will prompt the user to type in their 4 digit pin for verification. After the user enters it, the controller makes sure the user typed a 4 digit pin and it will later display the message in the LCD to prompt the user to insert coins for the inputted number of hours. If it successfully reads the inputted amount of money and correctly matches with the money required for the specified number of hours, the microcontroller will send the signal to the locking subsystem to start the process. If the user crosses the inputted time limit, the microcontroller will require the user to pay extra money to unlock their bike. In order for the user to unlock the bike, the microcontroller will utilize the LCD to prompt them to type their four digit pin. If correct, the microcontroller will send a signal to the lock to unlock it.

- Alarm Subsystem:
    - Requirements: Sound the beeping noise when the force from the binary force sensor goes above the given threshold. In this process we also have to make sure that the force is from a stranger and not an environmental action like wind.
    - Verification: In order to verify the sounding of the alarm, we have put a force threshold at 20 N. This would be a good threshold because we understand that the bike is locked with a motor that has a tight locking bar and a thief would have to try really hard to break the motor. The whole circuit will be enclosed in a physically hard shell and it would be hard to penetrate that shell or to try and unlock it. If it goes above the threshold the current will travel to the alarm which will then sound the beeping noise for suspicious activity.
- Lock Subsystem:
    - Requirements: The motor will move the bar to either lock or unlock based on the signal from the microcontroller. This will be based on the requirements being satisfied successfully in the control subsystem. This will help with the microcontroller sending a signal to the alarm subsystem if any suspicious activity is detected such as penetration of the lock or strong force being applied to break the lock.
    - Verification: The motor based lock will have power from the lithium battery of 12 V and is connected to the microcontroller. The microcontroller will provide a signal to the motor to unlock based on successful verification of the user based on the passcode. If successful the

motor will rotate the bar to unlock the bike. Otherwise the bike will stay locked. The bike will start to be locked when the user goes through the process inputting the number of hours greater than 0, inputting a 4 digit number code, and inputting the correct amount of money specified for the number of hours with the coin slot. Afterwards the motor will get a signal to rotate the bar to lock the bike.

- **Tolerance Analysis:**

  The possible risks of the system that can interfere with the completion are with the signals from the microcontroller to the motor-driven locking bar. This can be a problem with the time the motor takes to get the signal from the microcontroller, and also the time it takes for the motor to lock the bike. Another problem is with how well the motor locks the bike and the way it is unlocked. This is because the motor needs to stay firm in one place for the bike to be locked. We also need to make sure we have the clipped terminals (secured wiring) especially for the coin slot. The coin slot will not process the money properly and it can drop the coins in random places which can also increase the chances of money theft. The signal relays are important in that they have to be programmed properly with the Programmable Interrupt Controller. This includes taking signals from both the keypad and the coin slot and then outputting them to the LEDs and the LCD screen. Both the successful keypad 4-digit input, and the right amount of coins in the coin slot to start locking the bike with the motor, need to be taken into consideration.

Ethics & Safety

The appliance of our design is not a particularly hazardous device. It uses 12 volts, which, across the natural electrical resistance of the human body (at least 2300 ohms according to the National Library of Medicine), does not allow a dangerous amount of current to flow (about 5 milliamps), seeing as the smallest current that can cause uncontrollable muscle movement is 10 milliamps according to OSHA. Our appliance only contains one moving part that is visible from the outside. With the ACM Code of

Ethics and Professional Conduct in mind, discrimination, fairness, respect, and privacy are in no way called into question by our design, simply because of the nature of the device. Anyone can use it, information is not shared, and the procedure for using it is made clear by the status lights and the writing next to them on the exterior of the device.

The only issues that might arise during use of the device are honesty and physical safety. The device must accept coins without error or failure, especially since there is no coin return mechanism as there is on many vending machines. If there is a lapse in the functionality or communicative ability of the coin slot, however brief, it could have the effect of stealing from the user, with a coin or several coins not counted. In the design, we will have to ensure that all connections to the coin slot are secure, shock-resistant, and not prone to corrosion. Clips for connection plugs, or directly soldered wires, will ensure that connections will not come apart without deliberate human intention, and small amounts of conductive grease on electrical contacts will keep them free of rust (if clips are used). If there is any other problem, however, the device will need to have on the exterior the contact information of the managing or owning party, so that the dissatisfied user can have maintenance staff sent out from the (presumably nearby) building. This will be laser-engraved or somehow printed or inscribed on the exterior by the dealer when ordered by a client, and provision of appropriate contact information (such as a phone number) by the client will be a condition for the sale of the unit or units, if the dealer has an incentive to enact a policy like that. The owner of the bicycle racks and lock appliances must be familiar or employ a custodian familiar with the device, to remedy any potential problems when necessary.

As far as physical safety, there are two risks. The first is that the device will be both loose and bulky, and so can slide down the two-foot-tall bicycle rack tube and potentially land on the user's foot if the user accidentally lets go of the device while using it. It will need to be held up by hand during user interaction, although depending on the shape of the rack, the installer of the appliance may be able to mount it tightly, if possible without compromising its ability to be used with any bicycle. Rubber stops may also be necessary to prevent significant shock due to dropping, or from careless release after the user takes their bicycle and leaves at the end of the parking period. A decal can be attached to the outside of the device saying "dropping may cause personal injury" or something to that effect.

The second physical risk, and likely the more dangerous one, is accidental insertion of the user's finger into the locking bar receptacle, opposite the place where the bar comes out. The motor with its gearing has a great amount of torque, so any object that gets in the way of the locking bar when in motion will probably not stop the motor, even if it means that the object successfully obstructs the moving bar and the motor breaks out of its mounts inside the appliance. Some sensor could be employed to stop the motor if something got in the way of the locking bar, but we decided that it would be simpler to apply a decal to the exterior saying "keep fingers away" or something similar, and flash an LED continuously until the bar finishes its movement. A binary force sensor (or some button that requires a large force to press) could be placed behind the motor, so that anything that gets in the way of the bar will cause the force generated by the motor to be transferred into the button, which will tell the microcontroller to stop the motor and avoid damage to anything or anyone. The device is not exactly poor-judgment-proof, but there arises the need for safety decals, and the durable construction of the device may help to differentiate it favorably from any possible alternatives that the user may find. Generic "Warning" and "Danger" stickers are available commercially. The motor is not nearly powerful enough to need to meet National Electrical Manufacturers Association standards, as their minimum is 200 horsepower.

During development of the appliance, the only hazards are overloading circuitry by incorrect wiring, battery volatility, and injury from the strong motor. We will use a 12-volt arrangement of lithium-ion rechargeable batteries, which have energy density, cycle life, and ubiquity in their favor, but which deliver a spontaneous show of fireworks if impaled, deformed, overcharged, or heated too much. To avoid these hazards, care must be taken in wiring, and nothing overlooked, and the battery will have to be handled and stored with its potential volatility in mind, including the way in which it is charged. Battery management circuitry will have to be present, if it is not already built into the battery when we get it. Understanding the hazards is perhaps the most crucial element of this, and it is important not to underestimate the general dangers that will become apparent as we work on it.

Sources

https://simplebikeinsurance.com/guide-bicycle-theft-insurance/

https://www.ncbi.nlm.nih.gov/pmc/articles/PMC2763825/#:~:text=The%20%E2%80%9Ctotal%20body%20resistance%E2%80%9D%20of,the%20skin%2C%20and%20other%20factors.

https://www.osha.gov/sites/default/files/2019-04/Basic_Electricity_Materials.pdf