Enkidu Bike Locker

ECE 445 Design Document
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2/18/19
1 Introduction

1.1 Objective

The bicycle was invented in motion due to a volcanic eruption two hundred years ago. It becomes a new way of individual transportation to represent the quality of lives, which means being healthier and environmentally friendly, in cities. As transportation technology developed better and better today in cities, the bicycle still takes an important role in urban areas [1]. From 1992 to 2006, bicycle sales increased from 15.3 million to 18.2 million per year in the United States. According to National Crime Victim Survey (NCVS), approximately 1.3 million bicycles stolen report to the police, perhaps the actual bicycles stolen four or more times greater than the number of stolen report, which means there is at least total of 6.5 million bicycles stolen at 2006 in the United States [2].

Our goal is to reduce the bicycle stolen rate. Instead of using traditional locks to lock the bicycle, we will use the Enkidu Bike Locker, which is an anti-theft device that will automatically lock the front tire when the back tire is not properly unlocked. The lock on the front tire can only be unlocked using the facial recognition of the owner.

1.2 Background

Intelligent Fingerprint padlock, designed by Tinkux, can unlock the lock by fingerprints, which costs $149.99 on Amazon. Smart Bike Lock, designed by LINKA, can lock and unlock the lock when smartphone approaches, which costs $194.99 on Amazon. The costs for locks are not affordable for most bicycle users.

Our lock must be as affordable as possible to ensure bicycle to users experience the best reliable locks with the lowest price.

1.3 High-level Requirement

- Locks must be able to work at least monthly without being charged and during the hazardous weather conditions.
- The unlocking system should have decent reliability under various circumstances. (i.e The facial or fingerprint recognition must have an accuracy of at least 80%).
- Locks must be as low-cost as possible, ideally under $30.
2 Design

Provided below is our physical design for the “lock sub-system” in the Front-tire system shown above in the Block Diagram.

Figure 1. Block Diagram

Figure 2.1. Physical Design -1
There will be shells and constraints surrounding the device in order to protect it and restrain the movements of the plugs (they will not be able to move along the directions into or out of the screen). Those are not drawn above for the neatness of the diagram. Also in the real world, the spring will not be completely straight after stretched by itself, but it is not drawn like that for the clear demonstration in the diagram.

When there is no current passing through the electromagnet, the system will stay as demonstrated in Figure 2.1 as the spring remain compressed. Once current passes through the electromagnet, the metal plug will be attracted so the lock will move to the right due to the compressing spring. Again when the current is gone, the metal plug will drop and fall into the second plug down below. The metal stick will be pushed out for around 10 cm after such a process indicated above.

To unlock the front tire lock, a steady current will be sent to the electromagnet from the unlocking system. There will be indication for the user to know when the lock is ready to be
unlocked. The user will need to pull the plug back in and store the potential energy back onto the spring to unlock the system manually.

### 2.1 Power Supply

A power supply is required to make the whole system work when needed. Power is delivered from a Li battery which is rechargeable. The regulator keeps the voltage to be 3.3V for the rest of the system.

#### 2.1.1 Li-ion charger

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verifications</th>
</tr>
</thead>
</table>
| 1. Transform 110V voltage from wall power supply to 7V. | 1. a. Plug the transformer to the wall power supply.  
| 2. Charge the Li-ion battery to 4.16-4.23V with a continuous >300mA charge current, from the output of the transformer of 7V | b. Use a voltmeter to test the output voltage to be 7V±0.5%.  
| 3. Stay below 125°C when maximum current and voltage is applied. | 2. a. Discharge a li-ion battery to 3.7V cell voltage.  
| | b. Charge the battery at the output of the AAT3693 from an input of 7V.  
| | c. At the termination of the charge cycle, signified when the “charge status” pin of the AAT3693 goes high, we will ensure that the battery is charged between 4.16-4.23V  
| | 3. a. Throughout the charging cycle outlined in verification 2.b-c, observe the temperature. Use an IR thermometer to ensure that the IC does not reach temperatures greater than 125°C.  

2.1.2 Li-ion battery

<table>
<thead>
<tr>
<th>Requirements</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. The battery must be able to store enough charge to lock the front-tire lock a month after it is fully charged.</td>
<td>1. Put the fully-charged Li-ion battery still for a week.</td>
</tr>
<tr>
<td>2. At least lock and unlock the lock 10 times when fully charged.</td>
<td>a. Use a voltmeter to test the voltage after then</td>
</tr>
<tr>
<td></td>
<td>b. Calculate the remaining voltage if the battery is put still for a month and ensure the remaining vol</td>
</tr>
</tbody>
</table>

Note: We have not calculated the whole current used to operate the system.

2.1.3 Voltage regulator

<table>
<thead>
<tr>
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</tr>
</thead>
<tbody>
<tr>
<td>1. The voltage regulator must provide 3.3V +/- 5% from a 3.7-4.2V source.</td>
<td>1. Connect the output of the voltage regulator to VDD, and draw 300mA</td>
</tr>
<tr>
<td>2. Must maintain thermal stability below 125°C at a peak current draw of 250mA.</td>
<td>a. Measure the output voltage using an oscilloscope, ensuring that the output voltage stays within 5% of 3.3V</td>
</tr>
<tr>
<td></td>
<td>b. During verifications a and b, use an IR thermometer to ensure the IC stays below 125°C</td>
</tr>
</tbody>
</table>

2.2 Back-tire System

Back-tire system represents the lock for everyday usage if we implement this device on a bicycle.
It will set off the alarm when the lock is not properly unlocked. No alarm will be sent when it's properly unlocked.
2.2.1 Circuit Description

The circuit consists of mainly two manipulatable switches and a pulse generator. Switch 1 represents the locking part of the lock. When switch 1 is opened, it means that the Back-tire lock is unlocked properly. Under this circumstance, no false alarm should be sent to the whole device and it should still be able to function properly afterwards.

Switch 2 represents the rest parts of the lock besides the locking part. When we turn switch 2 open, it means that the Back-tire lock is unlocked improperly (i.e. broken violently by the thief). Under this circumstance, the system should output a current pulse signal to the front-tire system and therefore lock the front-tire lock.

<table>
<thead>
<tr>
<th>Requirements</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. The circuit should output a current pulse signal when switch 2 is opened.</td>
<td>1. a. Simulate the circuit on LTSPICE to make sure that the simulation gives us the correct result.</td>
</tr>
<tr>
<td>2. Nothing should happen when switch 1 is open and the whole circuit should output nothing and function properly.</td>
<td>b. Measure the output of the circuit after it is implemented.</td>
</tr>
<tr>
<td></td>
<td>2. a. Short the circuit consists of switch 1 so it will not affect the circuit. Measure the output after implementation to make sure it gives the correct result.</td>
</tr>
</tbody>
</table>

2.3 Front-tire System

Front-tire system is a back-up safety plan of the bicycle for security purpose. It will be automatically locked when the back-tire system is not unlocked through a proper and legal way (i.e. switch 2 is turned open rather than switch 1). The system will not be unlocked unless a signal is received from the unlocking system which can only be passed by the owner of the bicycle.

2.3.2 Lock sub-system

The physical design of this sub-system is provided in the previous section.
The system consists of mainly an electromagnet (with a current source), two plugs (material remains to be decided, the preferred choice is aluminum): plug 1 (a cuboid of 1cm*1cm*2cm), plug 2 (consists of two ruts to hold plug 1 and the stick used for physically locking the bicycle. Around 25 cm long), a spring (used to store the potential energy in order to lock the system when plug 1 is pulled out of the rut).

The preferred choice for the material of the plugs will be aluminum. From the perspective of feasibility, aluminum is lighter than copper or steel. Also it’s corrosion resistant compared to other competitive choices.

Functions used to compute the needed magnitude of current [4]:

\[ F = \frac{B^2 A}{2\mu_0} \]  \hspace{1cm} (1)

\[ B = \frac{NI\mu}{L} \]  \hspace{1cm} (2)

Where \( A \) is the cross section area of plug 1 vertical to the direction of the magnetic flux. \( \mu_0 \) is the magnetic constant \( (\mu_0 = 4\pi \times 10^{-7} \text{ H} \cdot \text{m}^{-1}) \). \( N \) is the number of turns of the coil around the electromagnet. \( \mu \) is the permeability of the material (permeability of aluminum is around \( 4\pi \times 10^{-7} \) to \( 1.256665 \times 10^{-6} \) \text{ H} \cdot \text{m}^{-1} \) [5]). \( L \) is the distance between plug 1 and the electromagnet.

From our design, assuming that we are using aluminum as the material for plug 1, then the mass of plug 1 will be 7g at maximum. \( F \) is needed to be at least 0.07N to be able to pull on plug 1.

\[ A = 2 \times 10^{-4} \text{ m}^2 \]. By calculating using the above data, we have \( B = 0.03\text{T} \).

From our design, we can see that the maximum distance a plug can be lifted by the electromagnet is 1.5cm. The distance should be around 5 cm in total. Plug in the numbers, we finally get our desired \( IN \) value:

\[ IN = 1180 \]

This is a reasonably small number. It should not be hard for our system to provide such a current source for our electromagnet.

Functions that will be used to decide the choice of spring:
\[ mg\mu = -kx \] \hspace{1cm} (3)

Where \( k \) stands for the spring constant, \( m \) the mass of plug 2 and \( \mu \) the friction coefficient.

From our design, our spring will be needed to stretch out for around 10 cm = 0.1 m. The mass of our entire plug 2 is around 45 g (assuming aluminum as the material).

Through our calculations, we get

\[-\frac{k}{\mu} = 4.5 N/m\]

at minimum.

The friction coefficient between metal surfaces are usually below 1.[6]

As we can find on the online shops, the spring constants of most of the spring we can find on the online shops are above the value of -4.5 N/m. It is a reasonable number for us to implement the system.

<table>
<thead>
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<tbody>
<tr>
<td>1. The system will lock itself using the lock sub-system once it receives the signal sent from the control unit caused by the inappropriate unlock of the back-tire system. When locking itself, the current will stay for around 1 sec so that plug 1 will drop into the rut and lock the system.</td>
<td>1. a. Input a pulse signal with a relatively short time constant (around 1s) to the device and observe the result. The spring should stretch and the metal stick should be pushed out for around 10 cm as indicated by the physical design.</td>
</tr>
<tr>
<td>2. When a signal is sent from the unlocking system described below, the current will stay for a longer period of time (around 5 sec) to allow the user to compress the spring and manually unlock the system.</td>
<td>2. a. Input a pulse signal with a relatively long time constant (around 5s) to the device and observe the result. The metal stick should be able to be manually moved and the spring should be able to be compressed.</td>
</tr>
</tbody>
</table>
2.4 Unlocking System

Unlocking system provides the only way to unlock the front-tire lock. As the owner of bike uses either facial recognition or fingerprint to authorize the access of the bike on an iPhone application, the bluetooth of the phone will send a unlocking signal.

2.4.1 Mobile Application

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verifications</th>
</tr>
</thead>
<tbody>
<tr>
<td>Facial recognition in the application should have at least 80% accuracy.</td>
<td>a. Take several pictures of the owner in different environments (i.e. sunny day, windy day and night)</td>
</tr>
<tr>
<td></td>
<td>b. Test the pictures to ensure the accuracy of above 80%</td>
</tr>
</tbody>
</table>

2.4.2 Bluetooth Transmitter

<table>
<thead>
<tr>
<th>Requirements</th>
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</tr>
</thead>
<tbody>
<tr>
<td>1. The bluetooth transmitter should be able to find the correct receiver.</td>
<td>1. a. Search for bluetooth receiver on the phone and make sure it can connect successfully.</td>
</tr>
<tr>
<td>2. The bluetooth transmitter should keep connected to the receiver within 5 meters.</td>
<td>2. a. Walk away from the receiver at least 5 meters.</td>
</tr>
<tr>
<td></td>
<td>b. Test if the bluetooth still works by sending a test signal.</td>
</tr>
</tbody>
</table>

2.5 Control Unit

The control unit manages when to lock or unlock the front-tire lock. The bluetooth receiver collects the signal from the owner’s phone and the microcontroller tells the front-tire lock what to do based on the signals from bluetooth receiver and back-tire system.

2.5.1 Bluetooth Receiver
## Requirements/Verifications

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verifications</th>
</tr>
</thead>
</table>
| 1. The bluetooth receiver must successfully receive the signal once it is sent by the transmitter.  
2. Latency should below 30ms                                               | 1. a. Connect the bluetooth receiver to a bluetooth transmitter.  
   b. Send a signal from the transmitter  
   c. Ensure that the receiver can receive the signal  
2. a. Measure the time between the signal is sent by the transmitter and the receiver receives the signal  
   b. Ensure that the time should be less than 30ms |

### 2.5.2 Microcontroller

<table>
<thead>
<tr>
<th>Requirements</th>
<th>Verifications</th>
</tr>
</thead>
</table>
| Can receive and transmit the signal from bluetooth to a pulse signal for the front-tire system. | a. Connect microcontroller to a bluetooth receiver  
   b. Send a signal to bluetooth receiver  
   c. Ensure that output signal is a pulse |

### 2.6 Schematics
3 Safety and Ethics

There are several potential safety issues with our projects.

Li-ion batteries will be extremely unstable if it is overcharged, charge with extremely high voltage or even exposed to the extreme temperature or conditions. We should consistently stay an eye on the condition of the Li-ion batteries to prevent it explodes. Make sure the Li-ion charge supply the 4.16-4.23 V and >300mA charge current and the temperature stays below 125°C.

We also need to design an outer case to prevent extreme weather. Due to the unknown outdoor weather conditions such as raining, snowing or fogging, the device might break or short, so we have to design the lock to be waterproof.

During designing Enkidu Bike Locker, we have to run huge amounts of facial recognition or fingerprint tests when we training the unlocking system. These data may be an invasion of other’s privacy, so we need to be careful about ethical issues when picking those samples.

Also, when a company publicizes their product, the level of credential is the problem. These results are not honest and realistic during product publicity, which violates the #8 of the IEEE Code of Ethics, “to be honest and realistic in stating claims or estimates based on available data” [3]. We plan to encrypt every face data we used to prevent the data divulge. We will open our data sources to the public as the proof of our honesty.