Enkidu Bike Locker

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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 Requirements

- 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

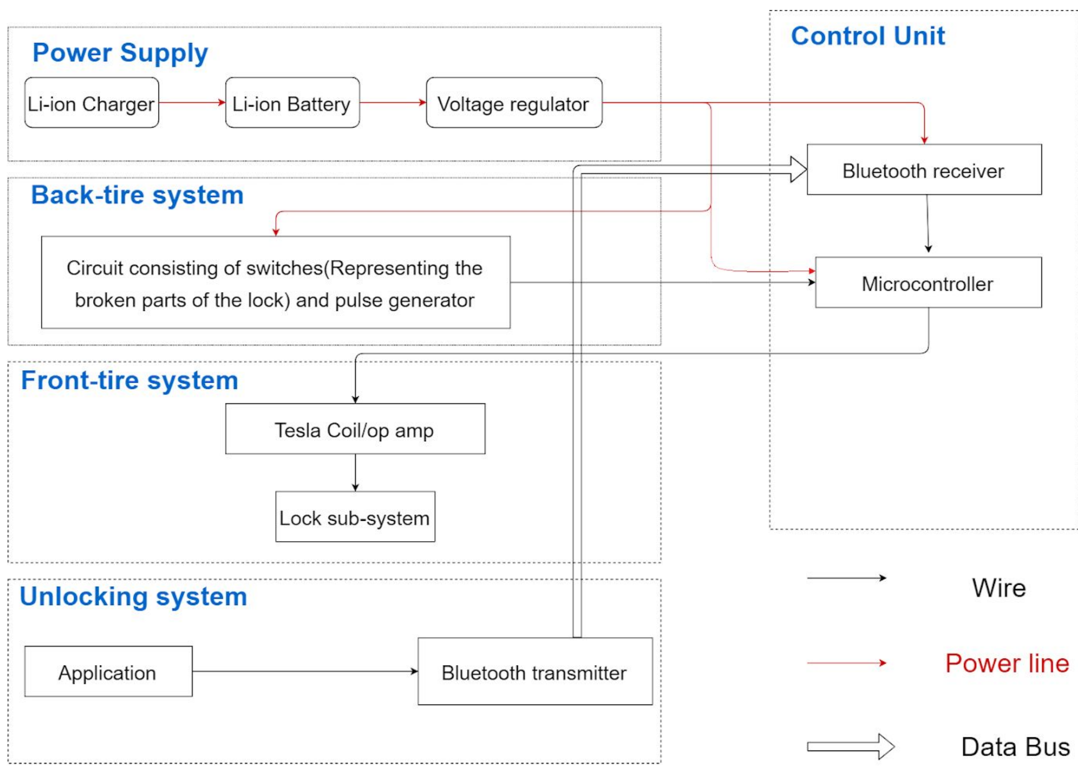

Figure 1 Block Diagram

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

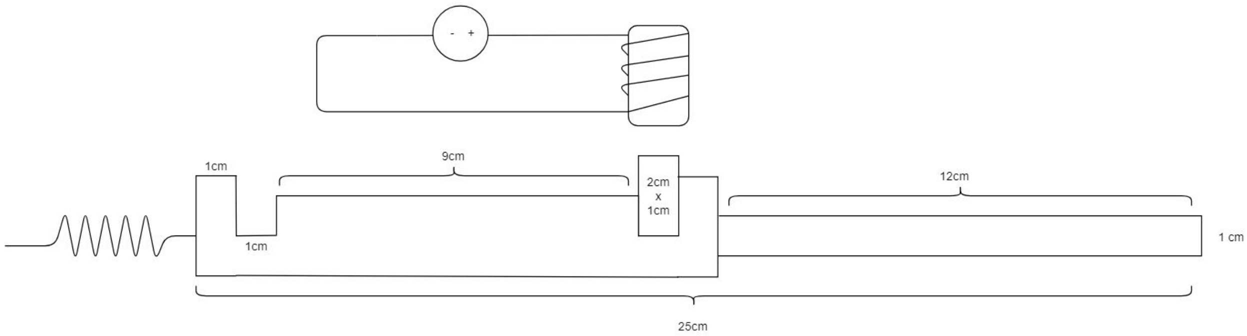

Figure 2.1 Not locked

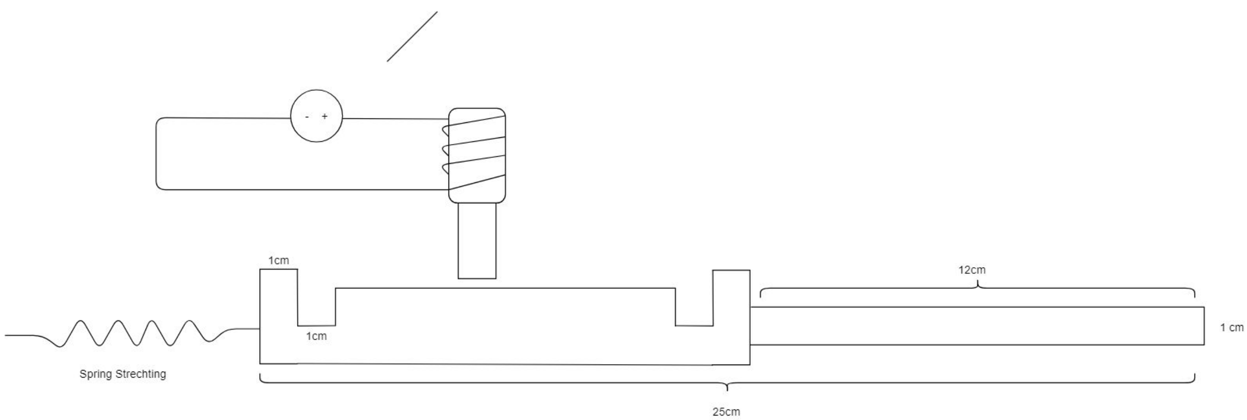

Figure 2.2 locking

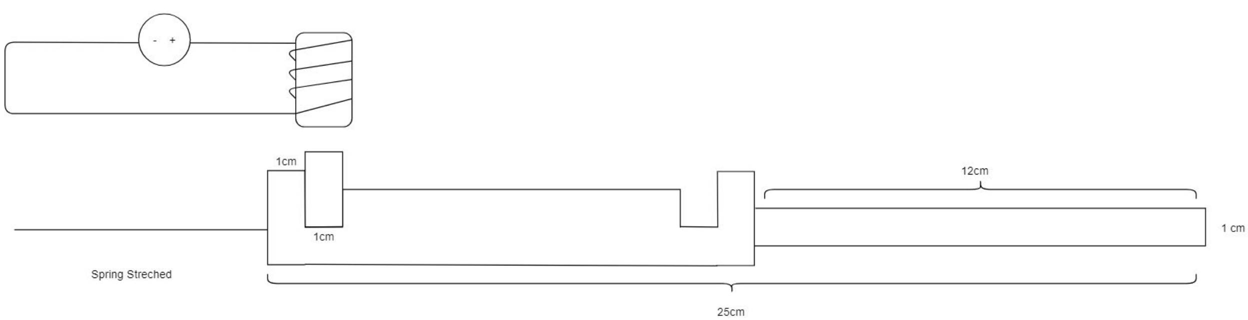

Figure 2.3 locked

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

The charger must charge the li-ion battery when it is connected to a wall power outlet. The battery should be fully charged in about 3 hours. The charger has an income voltage of 110V, which is the common voltage used in USA, and has a constant outcome voltage of 4.2V.

Requirement: Must charge the Li-ion battery to 4.16-4.23V with a continuous >300mA charge current, from a 110V source, and stay below 125°C (the maximum operating temperature).

2.1.2 Li-ion battery

The lithium-ion battery must be able to provide enough power to lock the front-tire system at least a month after it is fully charged. When fully charged, it should provide enough power to operate the whole system (lock the front lock and unlock it using bluetooth) at least twice.

Requirement: The battery must be able to store enough charge to lock the front-tire lock a month after it is fully charged and at least lock and unlock the lock twice when fully charged.

2.1.3 Voltage regulator

This integrated circuit supplies the required 3.3V to the rest of the system. This chip must be able to handle the peak input from the battery (4.2V) at the peak current draw (300mA).

Requirement 1: The voltage regulator must provide 3.3V +/- 5% from a 3.7-4.2V source.
Requirement 2: Must maintain thermal stability below 125°C at a peak current draw of 250mA.

2.2 Back-tire System

Back-tire system represents the lock for everyday usage if we implement this device on a bicycle.

2.2.1 Circuit

The circuit consists of mainly two manipulatable switches.
Switch 1 represents the locking part of the lock. When the switch 1 is open, 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.
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 signal to the control unit and therefore lock the front-tire lock.

Requirement 1: The circuit should output a current signal when switch 2 is opened.
Requirement 2: Nothing should happen when switch 1 is open and the whole circuit should output nothing and function properly.

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.

2.3.1 Tesla Coil/op amp

Device using to amplify the current so it will be sufficient for the usage of the lock sub-system described below.

Requirement: It should be able to amplify the current provided from the microcontroller in the control unit. Not needed for feasibility of the device if the current is sufficient for the usage.

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 prefered 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 prefered 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]:

$$F = \frac{B^2 A}{2\mu_0} \quad (1)$$

$$B = \frac{NI\mu}{L} \quad (2)$$

Where A is the cross section area of plug 1 vertical to the direction of the magnetic flux. μ_0 is the magnetic constant ($\mu_0 = 4\pi \times 10^{-7}$ H·m^{-1}). N is the number of turns of the coil around the electromagnet. μ is the permeability of the material (permeability of aluminum is around $4\pi \times 10^{-7}$ to 1.256665×10^{-6} H·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. $A = 2 * 10^{-4}\ m^2$. By calculating using the above data, we have B = 0.03T.

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:

$$mg\mu = -kx \qquad (3)$$

Where k stands for the spring constant, m the mass of plug 2 and μ the friction coefficient.

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

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

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 -4.5N/m. It is a reasonable number for us to implement the system.

Requirement 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.
Requirement 2: When a signal is sent from the unlocking system described below, the current will stay for a longer period of time (around 10 sec) to allow the user to compress the spring and manually unlock the system.

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 Application

The application is on the phone that has an installed facial or fingerprint recognition. Once it is authorized, it should be able to send the signal using bluetooth transmitter.

Requirement: The facial or fingerprint recognition must have an accuracy of at least 80%.

2.4.2 Bluetooth Transmitter

The bluetooth transmitter should send a signal to the designated receiver once the authorization is passed.

Requirement 1: The bluetooth transmitter should be able to find the correct receiver.
Requirement 2: The bluetooth transmitter should keep connected to the receiver within 5 meters.

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

The bluetooth receiver receives signals from bluetooth of the owner's phone. Once it receives the signal, it sends to the microcontroller.

Requirement: The bluetooth receiver must successfully receive the signal once it is sent by the transmitter.

2.5.2 Microcontroller

The microcontroller collects signals from back-tire system and bluetooth receiver, and send signals to the front-tire system.

Requirement: The microcontroller must be able to send the correct signal to the front-tire system.

2.6 Risk Analysis

When computing the needed current and spring constants in the front-tire system, there are several uncontrollable factors that may affect the results of our computations.

First, the friction coefficient between the surface of our shell and plug 2 might be higher than predicted. Although the friction coefficient are usually below 1 between metal surfaces, it is still highly possible that the surfaces are not in a proper contact. Corrosion after long time usage of the device will also increase the friction coefficient and thus affect the utility of the spring. We will need to measure the relatively exact friction coefficient between surfaces to compute the accurate spring constant. Also, we desire our system to be waterproof as much as possible in order to slow down the corrosion process.

Second, the unknown internal resistance of our device may require us to provide a higher current than we expected to the lock sub-system. It is also highly possible that the needed current will be too high for us to supply. We will need a tesla-coil or op amp to magnify the current sent towards the lock sub-system. Also we can increase the number of turns on the electromagnet to increase the force created by the magnetic field.

Third, the unknown potential effect of the electromagnet to the whole system. It may have undesired attracting or repelling effects on other parts of the system, even stop the whole system from functioning if the magnetic field is too large. We want our I*N value to be as exact as possible(the current computed value is 1180). Even though the electromagnetic effect is controllable, it may still have other minimal effects on the device, like decreasing the friction coefficient if it attracts plug 2. We will need to design those parts to be plastic in order to avoid those undesired effects from the electromagnet.

The facial recognition is a significant risk for our project. Designing a mobile app on the phone with facial recognition might be the biggest challenge we are facing. We need a large dataset for training and for now, we don’t have a reliable source of data yet. Accuracy is another thing that might cause us the most troubles. Picture of the owner could be taken in different angles with different hair style and background. Thus, we have an alternative method of fingerprint recognition if the facial recognition cannot be realized successfully.

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.

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