Boston University
Electrical & Computer Engineering
EC463 Capstone Senior Design Project

Problem Definition and Requirements Review

BikeGuard

Submitted to

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Project Summary

Whether it's gas prices, traffic, carbon emissions, or health and wellness reasons, many individuals choose to get around on a bike. With that being said, around 80% of bike owners in the United States have been a victim of bike theft.[1] Of these thefts only 5% of bikes are recovered and returned to their owners.[2] Standard mechanical bike locks offer only passive protection and are ineffective against heavy duty tools and lock picks. We propose a bike-attachable security device that will detect and alert users of potential bike theft attempts. The device will use its various sensors to monitor the bike and distinguish between theft and non-theft attempts. In the case of a theft attempt, the device will notify the owner via a mobile app device. The mobile app will display alerts, security options, a video stream, and a live tracking of the device.

[1] https://thebestbikelock.com/bike-theft-statistics-us/
[2] https://thebestbikelock.com/bike-theft-statistics-us/

1 Need for this Project

There are approximately one billion bicycles worldwide, which is about the same number as passenger cars[3]. Cycling culture is becoming widespread in many parts of the world, especially as urban planning continues to prioritize bike-friendly infrastructure. Even in the United States cycling is growing increasingly popular, with a 37% noted increase in cycling from 2019 to 2023.[4] However, with the growing popularity of cycling also comes the growing rate of bike theft. It is reported that over 2 million bikes are stolen in the United States each year—that's roughly one bike every 30 seconds, resulting in about 350 million dollars in stolen goods annually.[5] A recent survey found this problem was astonishingly common, with 80% of American cyclists having experienced one or more bike thefts.[6]

Why are so many bicycles stolen each year? The main reasons include high resale value, ease of theft, and the minimal risk of getting caught. Of the 2 million bikes stolen annually, fewer than 5% are investigated and returned to their owners.[7] Police often lack the time or resources to pursue bike theft-related crimes. A smaller case study of around 5000 bike thefts found that only around 54% of bike theft victims bothered to report the crime.[8] Due to the prevalence of bike theft, many individuals are reluctant to buy another bicycle, fearing the high likelihood of it being stolen again. This problem could significantly hinder the development of more bike-friendly and walkable cities.

The most common solution to deter bike theft today is using a cable lock or steel lock that secures around the bike frame. However, these locks offer only passive protection and are often ineffective, especially against organized bike theft, where groups of thieves work together in a coordinated effort, often targeting multiple bikes in a single operation. These groups are typically well-equipped with specialized tools like bolt cutters or lock-picking devices, allowing them to bypass traditional locks quickly and efficiently. Cable locks, even those made from strong materials like reinforced graphene, can be easily cut by these tools. Furthermore, organized thieves often have the skills and equipment to pick even high-quality locks, making traditional security methods ineffective. According to the same survey conducted by the best bike lock research group, about 33% of stolen bikes were secured with a cable lock, 15% with chain locks, and 14% with other types of locks, demonstrating the limitations of traditional locks in effectively preventing bike theft. [9]

With the growing popularity of cycling and the rise in bike theft, there is a need for a solution that actively deters theft before any attempt to cut or pick locks is made. An active monitoring and deterrent system for bicycles is essential to reduce theft attempts, safeguard property, and foster a thriving cycling culture worldwide.

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[3] https://www.europarl.europa.eu/RegData/etudes/ATAG/2022/729463/EPRS_ATA(2022)729463_EN.pdf
[4] https://www.bicycling.com/culture/a45325157/good-news-everyone-people-are-riding-more-than-ever/
[5] https://thebestbikelock.com/bike-theft-statistics-us/
[6] https://thebestbikelock.com/bike-theft-statistics-us/
[7] https://thebestbikelock.com/bike-theft-statistics-us/
[8] https://thebestbikelock.com/bike-theft-statistics-us/
[9] https://thebestbikelock.com/bike-theft-statistics-us/

2 Problem Statement and Deliverables

Bicycles are more likely than cars and motorcycles to be stolen. Most bike owners have experienced bike theft at least once. It's evident that the present bike theft prevention solutions are insufficient, lacking real-time monitoring and immediate alerts. The standard mechanical bike lock provides an insufficient solution – locks can easily be broken with brute force, tin snaps, bolt cutters, hacksaws, angle grinders, or lock picks. Additionally, bike seats and unchained wheels are vulnerable to theft even when a standard mechanical bike lock is used. Given the ongoing severity of this issue, there is an urgent need for a smarter and more effective bike security system, one that not only deters potential thieves but also actively monitors and alerts owners to theft attempts.

We propose a device that offers advanced theft detection and prevention by integrating sensors, processors, and communication technology. Users will be able to manage their bike's security through a mobile app. Below listed are our deliverables:

- Prototype design and manufacturing: A compact, weatherproof robust housing with a size that would not obstruct the normal functioning of the bike. The design will ensure durability against brute force and effective thermal management to avoid overheating of internal components.
- Hardware: Our design will include a microcontroller with internet capabilities as well as an accelerometer and an ultrasonic sensor to detect vibrations and movements, a small camera and a microphone to stream theft attempts, and a small siren to scare off thieves.
- Software: Our software will continuously gather data from the peripherals and utilize a theft detection algorithm to provide accurate bike theft classification. It will also handle communication with a mobile application to alert users of theft attempts, stream live camera footage during incidents, and allow remote control of theft detection mode. Moreover, real-time location tracking will be integrated for theft situations.
- Testing and validation: The system will be tested and validated to ensure real world use and its effectiveness. The battery life and functionality of our housing will be tested thoroughly. The software and secure communication will be ensured through field testing.
- Documentation: Documentation on how to use our device will be provided covering hardware details, software usage, and instructions for the mobile app.

3 Visualization

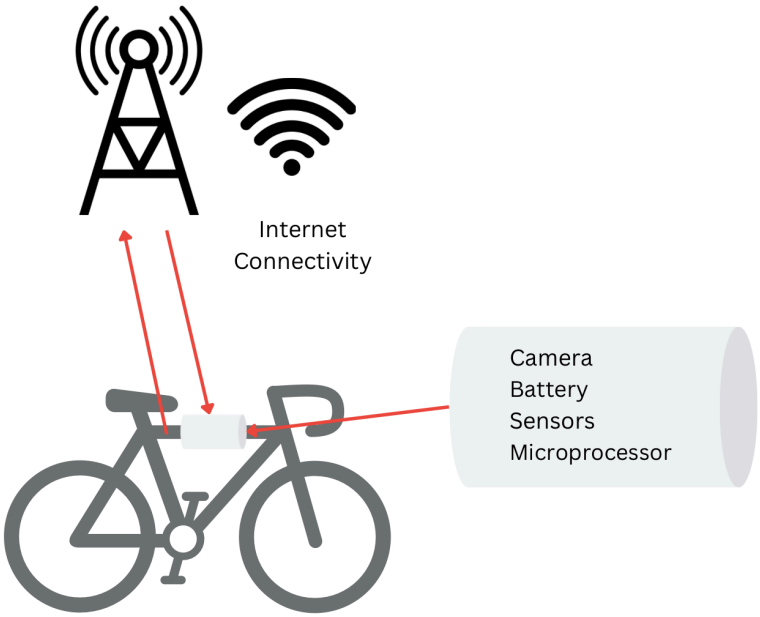

Fig 1. This image demonstrates the physical components of the BikeGuard including its sensors, microprocessor and battery. It also shows that our device will connect to the internet in order to communicate with our mobile application.

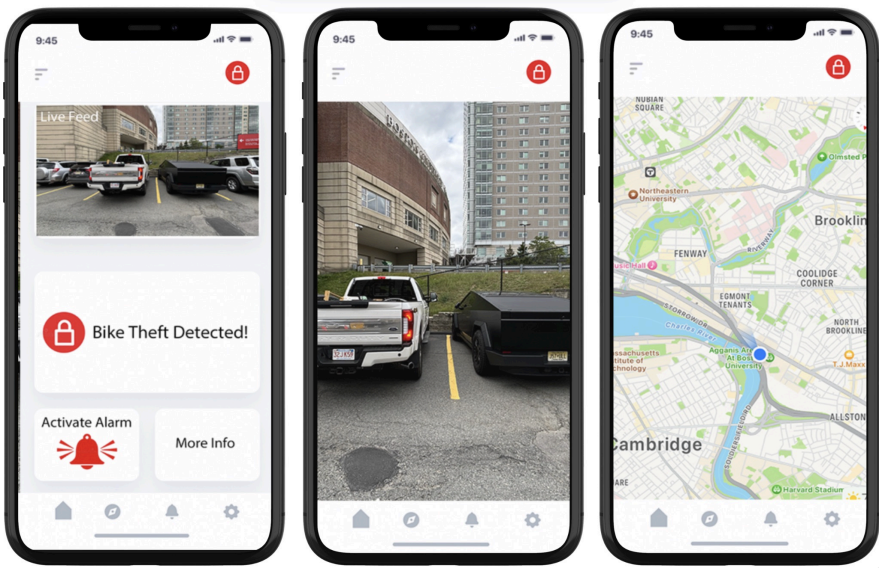

Fig 2. The figure above provides possible different views within the BikeGuard mobile application.

There are several components to the BikeGuard mobile application that are essential in providing theft protection. There will need to be several sections including a settings/profile page, map for bike tracking, live video feed, and a homepage for information/control.

4 Competing Technologies

Competing technologies include tracking devices such as Apple AirTag, Knog Scout, and Tile Sticker[10], as well as traditional bike locks such as Litelok X1, Hiplok D1000, and Onguard 8003 Pitbull STD U-Lock. GPS tracking devices are used to locate stolen bikes[11].

Apple AirTag

Litelok X1

Knog Scout

Their primary requirements include location tracking, connection to nearby devices, lightweight design, and battery longevity. However, they lack theft detection mechanisms such as vibration or proximity sensing, limiting their ability to detect theft attempts in real time. Similar to these devices, our technology prioritizes small size, portability, and ease of integration. Traditional bike locks offer a different solution to the problem of bike theft through mechanical and physical mechanisms. Their key requirements involve high resistance to physical force, weatherproofing, durability, portability, and security. These locks may still be vulnerable to tools like angle grinders, as they rely on passive defense mechanisms. The requirements revolving around weather resistance and portability align with our device. However, we will incorporate active theft detection through sensors and real-time alerts which will increase engineering requirements to being weatherproof, portable, and capable of integrating multiple peripherals like sensors and cameras.

[10] https://www.cyclingweekly.com/group-tests/find-your-stolen-bike-with-a-gps-tracker-165579
[11] https://www.cyclingnews.com/features/best-bike-locks/

5 Engineering Requirements

Mechanical Requirements

- Housing must attach securely to most bikes and scooters
- Housing must be resistant to 15 lbs of force
- Housing must not obstruct bike riding and scooter activities
- Housing must be weatherproof under normal to mildly severe weather
- Housing must be less than 35 x 35 x 35 cm in size and weigh less than 8 lbs
- Housing must be portable
- Housing must prevent microcontroller, peripherals, and battery from overheating

Power Requirements

- Battery must last for an active working time of around 24 hours, assuming a healthy battery
- Battery must be replaceable and rechargeable

Peripheral Requirements

- Device must have a small camera, an accelerometer, an ultrasonic sensor, a siren, an LCD or LED, and a microphone.

Software Requirements

- Onboard software must correctly classify between theft and non-theft attempts 90% of the time
- Onboard software must constantly scan for peripheral data when theft detection mode is on
- Onboard software must be able to communicate with remote device via cellular data
- Onboard software must convey device status via peripheral LEDs or LCD
- Remote software (i.e. mobile app) must alert the user of theft attempts
- Remote software must stream camera data in cases of a detected theft attempt
- Remote software must be able to turn off onboard theft detection when the user desires (i.e. while riding bike, while at secure location)

Microcontroller Requirements

- Microcontroller must have the potential to be battery powered
- Microcontroller must have network card and wifi capability

Networking Requirements

- Device must be able to connect to a common cellular provider (provider TBD)
- Device must be able to connect to wifi when possible
- Device must be able to use networking capabilities to convey location to remote user when theft detection mode is on

Security Requirements

- User data should remain private and inaccessible to other user

6 Appendix A References.

Ellis, Carl. “Bike Theft Statistics in the US (2024).” *The Best Bike Lock*, 25 Jan. 2024, thebestbikelock.com/bike-theft-statistics-us/.

“Find Your Stolen Bike with a GPS Tracker.” Cycling Weekly, 25 July 2022, www.cyclingweekly.com/group-tests/find-your-stolen-bike-with-a-gps-tracker-165579. Accessed 5 Oct. 2024.

Hurford, Molly. “People Are Riding More than Ever—and This Is Good News!” *Bicycling*, 26 Sept. 2023, www.bicycling.com/culture/a45325157/good-news-everyone-people-are-riding-more-than-ever/.

“The Best Bike Locks of 2024.” Cycling News, 1 July 2024, www.cyclingnews.com/features/best-bike-locks/. Accessed 5 Oct. 2024.

“World Bicycle Day - European Parliament.” *European Parliament*, 3 June 2018, www.europarl.europa.eu/RegData/etudes/ATAG/2022/729463/EPRS_ATA(2022)729463_EN.pdf.