GE401
Product Requirements Documentation

Team 7

İlkhan Yalçın Kökdemir 22003447

Devran Dorak - 21803728

Baran Okay - 21901933

İda İnal - 22002614

İlke Bilge Yevgi 22002794

Emre Tanrıöver - 21902772

Tuna Özgür 22003244

Bilkent University

06800 Ankara

Abstract

This report contains information about QR based locking system to change the old type lockers like keys, access cards and wristbands in gyms locker rooms by improving user experience and lowering costs. As a result of the feedback we received from gym members (can seen in Figure 3), issues such as the risk of losing keys, lockers being left open with a combination, and forgetting the code can cause inconvenience, making it more challenging to access the lockers. QR code solution eliminates these problems. Simply put, this product allows the locker to be locked and unlocked by scanning the QR code on the lockers with their phones. This project not only brings innovation to lock systems but also meets the demands of users.

Table of Contents

1. INTRODUCTION

Many gyms and organizations nowadays are looking to digitally change their locker room locking systems. In this sense, boosting user experience and comfort as part of digital transformation has become a top focus for gyms looking to fulfill their consumers' shifting demands. Feedback from gym management and members reveals a reoccurring issue: many fitness users find wristbands and access cards limiting and difficult, therefore they avoid using them while exercising. However, the current systems in use are important to fitness owners and cause difficulties. These include card damage and loss, as well as any additional expenditures paid as a result. As a consequence of this issue, our concept proposes a new locking mechanism based on the locking system that can be locked and opened using the QR code, with the goal of making it easier to use lockers in the gym locker room using the phones we always have with us. Fitness customers no longer need cards, wristbands, or keys, thanks to this phone-open QR lock system, and the management no longer needs to maintain and store constant supply of keycards in case of a lost or broken card. which allows them to lock and unlock their lockers using their cell phones, which they always have with them.

2. NECESSARY SECTIONS

2.1 BASIC PRODUCT FUNCTIONS

Gym Members (End-Users)

Gym members primarily benefit from a convenient, secure, and straightforward way to access their lockers. With this system, users can lock and unlock their lockers by simply scanning a QR code placed on the locker using a mobile app on their smartphones. This eliminates the hassle of carrying physical keys, cards, or wristbands, which can be uncomfortable or easy to lose during workouts. Once the QR code is scanned and verified, the locker opens, confirmed by a green LED indicator that lights up to signal the unlocked status. When the member is done using the locker, they scan the code again to securely lock it, signaled by a red LED. Additionally, users receive a notification on their phones confirming the lock or unlock action, enhancing their sense of security. This streamlined process, combined with the visual and mobile feedback, offers users a smooth and reassuring experience, making locker access almost effortless. The use of a phone—a device members almost always have with them—adds to the convenience, aligning well with modern, mobile-friendly user expectations.

Gym Management and Staff (Administrators)

Gym management and staff experience a streamlined locker management process with enhanced security and monitoring capabilities through this system. Staff can assign lockers to members, generating unique QR codes that authorize each member's access, eliminating the need to handle and manage physical keys or access cards. Real-time monitoring and logging allow gym administrators to track locker access, with each interaction logged on a central server, including timestamps and user details. This comprehensive tracking not only enhances security but also provides valuable insights into locker usage patterns, helping the management optimize locker allocation. In addition, staff receive alerts for suspicious activity, such as multiple failed access attempts, allowing them to respond promptly to potential security breaches. With the ability to monitor and control lockers remotely, staff can assist users experiencing access issues by manually unlocking lockers when necessary, ensuring seamless support without physical intervention. By reducing the reliance on physical items and offering a centralized, digital approach to locker management, this system significantly lightens the management workload and contributes to a more efficient, secure locker room environment.

Overall Customer Experience

This QR code-controlled locker system addresses key customer expectations by enhancing convenience for gym members and streamlining operations for management. For gym members, the system provides a hassle-free, modern solution to locker access, allowing them to focus on their workouts without worrying about keys or access cards. The immediate feedback through LED indicators and mobile notifications reassures members that their belongings are secure, contributing to a more enjoyable gym experience. On the other hand, gym staff benefit from a reduction in maintenance and administrative overhead associated with physical keys and cards. The centralized system not only improves security but also allows staff to manage lockers more effectively, respond quickly to user issues, and optimize locker usage based on real-time insights. This dual focus on user convenience and operational efficiency makes the product an ideal solution for gyms looking to modernize their facilities while meeting the evolving needs of both users and staff. By seamlessly integrating with mobile devices, the system offers a future-forward approach that resonates with both tech-savvy users and management seeking to enhance service quality.

2.2 PHYSICAL CHARACTERISTICS

Dimensions:

- Magnetic Lock: 10 cm x 4 cm x 3 cm (Approximately)
- Microcontroller Unit (Arduino UNO WiFi R3 ATmega328P ESP8266 [1]): 68.6 mm x 53.4 mm x 15.4 mm
- Relay Module [2] : 3 cm x 2 cm x 1.5 cm (Approximately)

Weight:

- Magnetic Lock: Approximately 200 grams
- Microcontroller Unit: Approximately 50 grams
- Relay Module: Approximately 10 grams

Material:

- Magnetic Lock: Stainless steel body with an electromagnet
- Microcontroller: A printed circuit board
- Relay Module: Plastic and copper components
- LED indicator: RGB LED
- Plastic Housing: To cover the integrity of the product and increase durability

2.3 INTERFACES OF THE PRODUCT

2.3.1 SYSTEM INTERFACE

The solution of the problem revolves around an interface which utilizes a web architecture to transfer, validate and securely handle the requests from the user to the electrical lockers. Unlike traditional electronic lock systems which require physical credentials and dedicated hardware to store the credentials and process the card locally, our solution implements server-based architecture that manages comprehensive tracking,

real-time monitoring and logging capabilities which enhances the security of the lockers further. Each logging interaction is logged with a timestamp and can be retrieved and checked out by the authorized staff. Users can interact with the system via a mobile app or web interface to scan QR codes, send unlock requests, and receive notifications about lock status. This enables the gym users to use their assigned lockers without the need of a physical product.

The connection between the system and the lock hardware is handled via 2.4Ghz Wi-Fi connection. Connectivity in this system is facilitated by a Wi-Fi module embedded in Arduino UNO WiFi R3 ATmega328P ESP8266, which enables remote communication for QR code verification and lock control. By connecting to the internet, the Wi-Fi module allows the system to access a central server, where QR code data is verified. This connectivity supports real-time control and enhances security by ensuring that only authorized users can unlock the system from a remote location.

The power supply is designed to meet the specific voltage requirements of each component. The magnetic lock is powered by a 12V DC adapter, providing the necessary power for the lock’s electromagnet to function effectively. Meanwhile, the microcontroller and relay module operate on a separate 5V DC power supply, typically supplied via USB or a dedicated adapter. This setup ensures that all components receive the appropriate power levels, supporting efficient and stable system performance.

2.3.2 USER INTERFACE

The QR code scanning process allows users to initiate the unlock sequence conveniently. Each locker has its unique QR code which stores the identifying coordinate of that locker. By scanning the QR code placed on the locker with their mobile device, users send a verification request including the coordinate of the corresponding locker to the system, which checks the code's validity and availability. If the locker is available and free to use,

the backend sends a signal to the microcontroller, which triggers the unlocking process. If the given coordinate is occupied, then the system controls which user had occupied that position. If the same user has not been validated, then the system denies the request and does not send a signal to the code, with a warning pop-up on the screen. This method provides a seamless and secure way for users to access the locker without needing a physical instrument. After activation of the lock, authorized staff can view the status of the lock from a dedicated dashboard and has the ability to control the lock. the As an illustration, you can see Figure 2.

Additionally, the system is equipped with an LED indicator as part of the microcontroller setup, offering real-time visual feedback on the lock's status. A green LED lights up to signify that the locker is in an unlocked state, while a red LED indicates that the locker is securely locked. This immediate visual feedback assures users of the lock's current state, enhancing user experience and system clarity.

2.3.3 PHYSICAL STRUCTURE

The microcontroller housing is designed to protect the microcontroller, relay, and wiring by enclosing them within a sturdy project box. This protective housing serves to shield the internal components from dust, accidental physical damage, and environmental factors, which could otherwise affect the system's performance and reliability.

In addition, cable management is carefully implemented to ensure all connections between the microcontroller, relay module, and magnetic lock are organized and secure. Properly routed and managed cables not only enhance safety by preventing accidental disconnections or short circuits but also ensure efficient power delivery and reliable signal transmission. This setup supports the system's longevity and consistent operation, allowing all components to function smoothly in a protected and orderly environment.

2.3.4 ELECTRICAL INTERFACE

The relay connection is crucial in this setup, as it allows the low-power microcontroller to securely control the high-power magnetic lock. The relay module acts as an intermediary, bridging the gap between the microcontroller and the lock. By isolating the high-power circuit of the magnetic lock from the low-power microcontroller, the relay ensures safe operation and prevents any potential electrical overload.

To control the relay, the microcontroller uses its GPIO pins, which are programmed to send signals to the relay module. When a signal is sent through these GPIO pins, the relay activates, allowing the 12V power to flow to the magnetic lock and engage or disengage the locking mechanism as needed.

The power interface for the system is designed to supply each component with the correct voltage. The 12V power supply is directly connected to the magnetic lock, ensuring that it has the power needed to maintain its electromagnet in a locked state. Meanwhile, the microcontroller and relay module operate on a separate 5V source, which can be supplied through USB or a dedicated adapter. This configuration guarantees that each component receives the correct voltage, ensuring stability and efficient operation throughout the system.

2.4 Power Requirements

2.4.1 Electronics

The magnetic lock requires a stable 12V DC power supply to function correctly, as this power maintains the lock's electromagnet in an active, locked state whenever engaged. Consistent 12V power is essential for ensuring the lock remains secure, as any interruption could compromise the lock's ability to stay engaged.

On the other hand, the microcontroller (such as an Arduino or Raspberry Pi) and

the relay module operate on a lower 5V DC power supply, which is typically provided via USB or a dedicated adapter. The relay module acts as an intermediary switch, allowing the low-power microcontroller to safely control the higher voltage needed by the magnetic lock. This setup ensures the microcontroller can effectively manage the lock without risking damage from direct high-voltage exposure, enabling seamless interaction between the control system and the high-power magnetic lock.

2.4.2 Computations

The power requirements for the QR code-controlled electronic magnetic lock system are essential to ensure smooth and reliable operation across both electronic and computational components.

Firstly, the electronic components of the system, including the magnetic lock, microcontroller, and relay module, demand distinct power sources to operate effectively. The magnetic lock itself requires a stable 12V DC power supply, which maintains the electromagnet's active state, ensuring it stays locked when engaged. On the other hand, the microcontroller, such as an Arduino or Raspberry Pi, along with the relay module, operates on a lower 5V DC power supply, typically provided via USB or a dedicated adapter. The relay module plays a critical role in enabling the microcontroller to control the higher voltage necessary for the magnetic lock, bridging the low-power control circuit with the high-power lock mechanism safely.

Beyond these basic electronics, the system’s computational components also impose specific power demands. The microcontroller not only manages QR code verification but also controls the relay module that ultimately interacts with the magnetic lock.

Although the microcontroller's power consumption is minimal—around 0.5W depending on the model—it is designed for efficient, continuous operation. Additionally, the Wi-Fi module, such as the ESP8266 or ESP32, used for remote QR code verification, introduces an extra layer of power usage, especially during data transmission. The Wi-Fi module’s consumption typically ranges from 0.2W to 1W, depending on its transmission frequency and network activity, which allows for a responsive, real-time connection to external devices.

In summary, the total power requirement for this system, considering all components—magnetic lock, microcontroller, relay, and Wi-Fi module—amounts to approximately 12W to 15W during full operation. This estimate accounts for power surges during Wi-Fi data transmission and relay activation. The careful allocation of power to both electronic and computational needs ensures that the system remains energy-efficient while providing a secure, dependable, and user-friendly locking mechanism.

3. CONCLUSION

The QR code-controlled electronic magnetic lock system provides a secure, user- friendly solution for keyless access to lockers and other secured areas. By integrating a lock module which consists of microcontroller, relay, and Wi-Fi module, and a backend logic, the system ensures that only authenticated users and authorized staff can unlock the magnetic lock via QR code verification. The user centric design, including LED indicators for visual feedback of status and a protective housing for sensitive components, contributes to the system's reliability and durability. This project demonstrates the effective use of low-power microcontrollers to control high-power devices safely through relay modules, highlighting the potential of smart access systems in enhancing security. While the prototype successfully meets the core objectives, future improvements could focus on enhancing security protocols for QR code verification, user features such as sharing locks and adding access controls for other users, minimizing power consumption.

Overall, strengths, weaknesses, opportunities, and threats aspects can sum up as Figure 2.

4. APPENDICES

Figure 1: Illustration of the QR Code Scanning

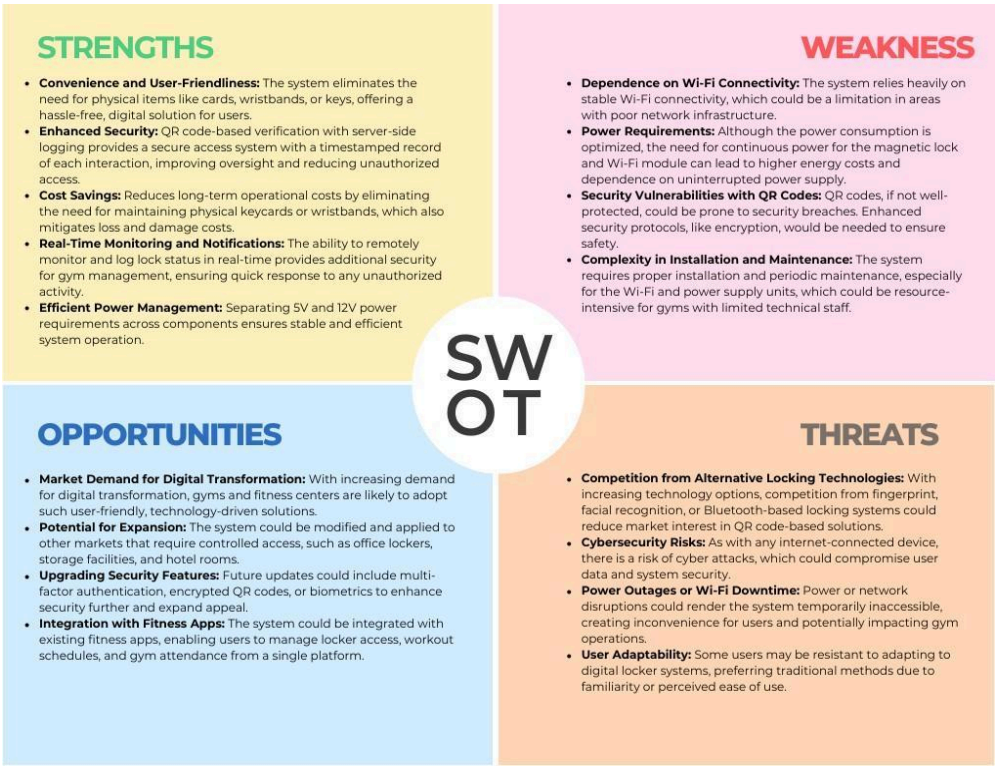

Figure 2: SWOT Analysis of the Product

Interviewee	Categories of the Demand	Description	Solutions	Risks
Gym Manager	Security, User-Friendly Systems	The Manager reported that users frequently complain about malfunctioning lockers, such as jammed locks, lost keys, or unauthorized access to other users belongings. These issues have caused frustration among gym members and increased administrative burden.	Our product supplies more modern, user-friendly system, such as one utilizing QR code technology for access.	For pool users, the requirement to bring a phone to use a potential QR code system could be a disadvantage. Many prefer not to carry their phone near water for safety reasons, and others simply do not want to bring their phone to the gym at all, making this a potential barrier to the adoption of a QR-based system.
Gym User	User-friendly system, Reliability	The User highlighted that the current locker system often causes frustration. Common issues include malfunctioning locks and the inconvenience of having to remember combinations. There have been instances where lockers were unavailable, or users had difficulty opening them leading to delays in starting workouts.	As indicated by user interviews, the current locker systems frequently malfunction, causing frustration. Our QR-based system must demonstrate reliability and minimal downtime, particularly through stable Wi-Fi connectivity and robust QR code recognition.	The User raised concerns that for pool users, bringing their phone near water might not be ideal
Dormitory Resident	Security, Ease of Access, Time	The Dormitory Resident highlighted that padlocked cabinets are unsustainable and lack user tracking, leading to multiple users occupying single cabinets and causing storage issues for others. This problem extends to dormitory storage rooms, where students often find their designated compartments used by others, creating confusion for both users and staff. She sees potential in transitioning to a QR system for better organization but believes an RF card option could also benefit students.	Our app offers a solution to this issue with a QR code-based locking system. Each locker can only be accessed by authorized users through unique QR codes, and usage records are maintained. This system ensures that users access the correct lockers, allowing management to monitor locker access and intervene if necessary. As a result, problems like locker confusion and unauthorized use in shared spaces are eliminated, creating a more organized and secure environment for both users and management.	The QR code-based locking system may not function properly in cases where the Wi-Fi connection is weak or lost entirely. This could hinder users' access to their lockers, disrupting their daily routines and potentially causing frustration.
Sales Employee at Gym	User-friendly system	The Employee did mention that some users intentionally kept the lockers locked to keep their belongings such as supplements and shoes overnight which is inappropriate and disallowed normally. She expressed that cards are easier to forget than locks and keys since physical locks have a presence in the homes and can be seen easier than the cards and not be forgotten while taking it to gym. Keeping the Inventory of keycards is needed in cases where a member, which creates a cost to the management in the long run. The QR solution will satisfy and result in a positive incrementation in their experience in gyms for most of the gym members, therefore for the gym management.	Our solution addresses these issues by implementing a QR code-based system that eliminates the need for physical keycards or locks, reducing the risk of forgotten or lost access items. Since the QR code is accessed directly through users' phones, there's no need for management to maintain an inventory of keycards, lowering long-term costs. Additionally, unauthorized overnight use can be tracked and restricted through the digital log, enhancing security and compliance with gym policies, thus improving the experience for both users and management.	While the system reduces the need for physical card inventory, it may require regular software updates, technical support, and cybersecurity measures, which could increase maintenance costs over time.

Figure 3: Summary of Interviews

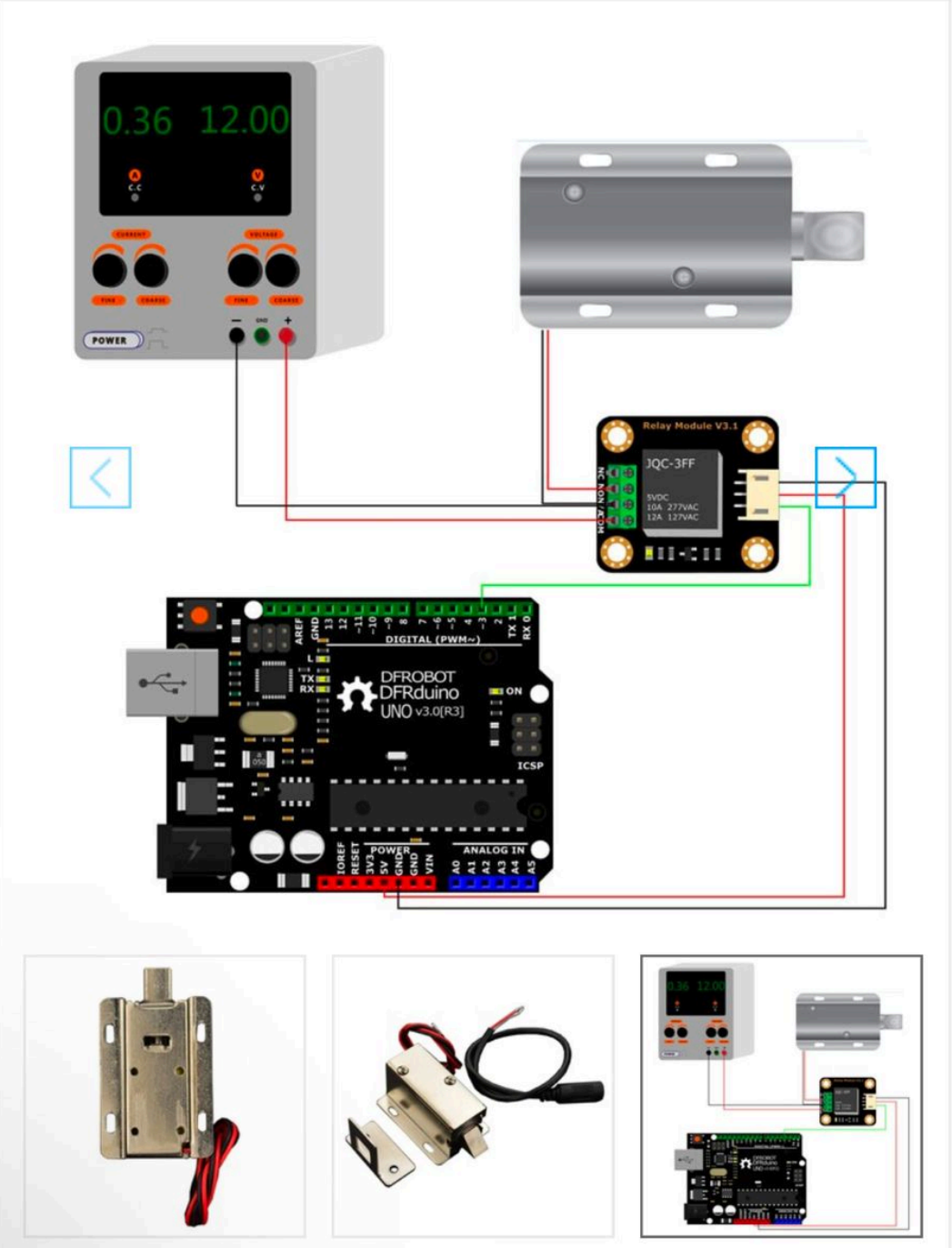

Figure 4: Electric Workflow and Physical Components

5. REFERENCES

[1]“Wifi Tabanlı Arduino Uno (Esp8266) ATmega328p 8Mb Flaş CH340G,” *https://www.direnc.net/*, 2024. https://www.direnc.net/wifi-tabanli-arduino-uno-esp8266-atmega328p-8mb-flas-ch340g (accessed Nov. 18, 2024).

[2]“1 Kanal 5 V Röle Kartı - Low Level Trigger,” *https://www.robotistan.com/*, 2024. https://www.robotistan.com/1-way-5v-relay-module-tekli-5v-role-karti (accessed Nov. 18, 2024).