Electronic Replacement for COVID-19 Building Monitors at UIUC

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1 Introduction

1.1 Objective

COVID-19 has put everyone across the world in dire straits. Every system or service that is a part of life has been put through one of the most extreme stress tests we have seen in over a hundred years. However, places like the University of Illinois have been trend setters for solutions to the many problems that COVID has placed upon these systems. They have developed new forms of testing, state of the art tracking applications, and many other procedures and systems. However, even with these huge strides in innovation, some approaches are archaic in comparison. Human building monitors and one such problem. These monitors are in place to make sure that the right people are being let into the right places, using the Safer Illinois App developed by the university. This app provides access to testing results for the students, and faculty, and creates a randomized, unique building access pass, so it cannot be replicated. Even with this amazing software, we still put these human monitors at risk.

Our goal is to create an automated replacement system for these building monitors that still adequately protects the residents of the building. We will do this by creating a physical two-factor authentication network, that uses a central microcontroller to monitor the door for suspicious activity. As we do not have access to the backend of the Safer Illinois application, or the ability to use campus buildings as a workspace for our project, we will be designing a proof of concept 2FA system for UIUC building access. Our solution would be composed of two main subsystems, one that allows initial entry into the "airlock" portion of the building using a scannable QR code, and the other that detects the number of people that entered the space, or a form of people counter, to determine whether or not the user will be granted access to the interior of the building.

1.2 Background

Studies show that appropriate social distancing and mask wearing results in an approximately 3% transmission rate of SARS-CoV-2 [1]. While this seems positive in the grand scheme of things, these monitors are still at risk, and taking away the human element could potentially save these people from infection. On average, humans make about 4-6 errors per hour [2]. Let's say in the case of a building monitor, this error includes misuse of masks or improper social distancing, this creates great risk for all involved, and is not isolated to the monitor either. Since the students/staff being checked are interacting with those monitors, they make errors as well, further complicating the issue. People are not perfect, and human error will always find a way to create problems. With a fully automated system, we can remove that human element, and create a system that can monitor all buildings on campus around the clock.

1.3 Physical Design

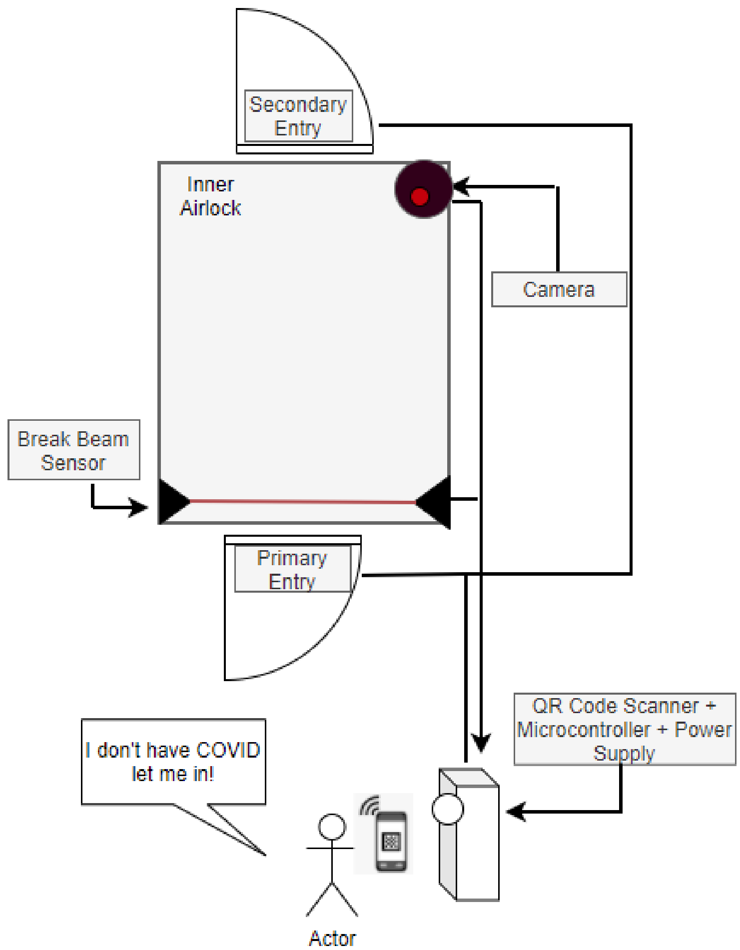

Figure 1: Pictorial Diagram of Design

1.3 High-Level Requirements

- Must be able to decode the encoded QR code automatically, and determine the initial positive/negative testing requirement for entry. ("QR Code Scanner should be able to determine if the user is allowed primary entry using the encoded information from the generated QR code”)

- Break-beam sensor and pressure mat within the airlock must work synchronously to determine the presence of a single student/faculty member, as well as accurately keep track of entries with a <5% error rate. (Will use an extensive list of outlier situations for testing).
- The system must be able to process each person within a 30 second time frame, to prevent congestion at the entryways of buildings across campus.

2 Design

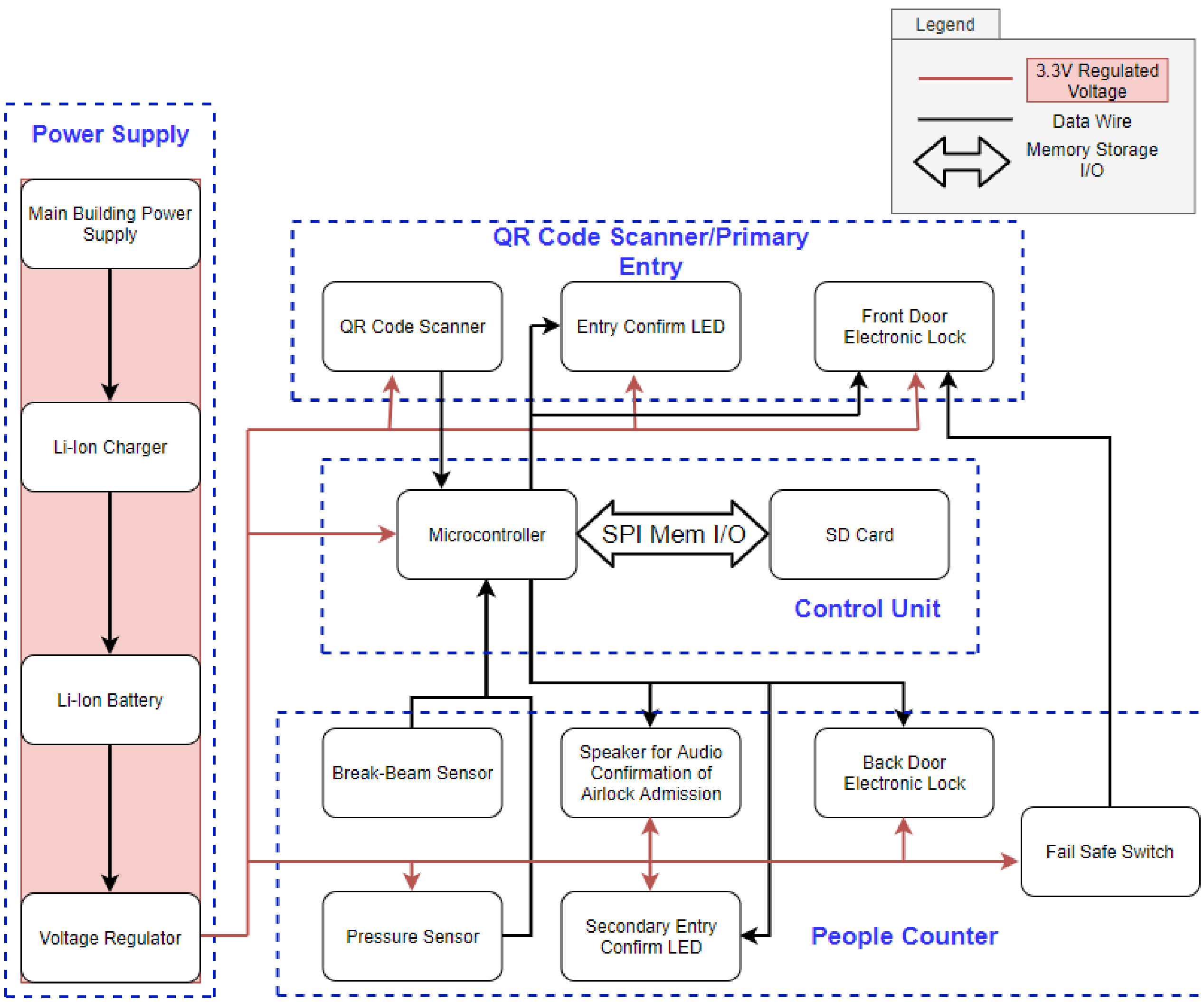

Figure 2: Block Diagram

2.1 Power Supply

A power supply is required to keep the communication network up continually. Power from the main building supply will charge a battery, which is then regulated to 3.3V for the rest of the system. We have a seperate battery supply in the instance the power from the building is cut, and the system needs to continue operating.

2.1.1 Main Building Power Supply

The system needs the power to work properly. Since the system was installed at the door, it can get power directly from the building. Also, it needs to provide enough power for the Li-ion charger, in case the main power supply has any problem.

Requirement: Must provide stable power of 110V, which can power the system directly and charge the Li-ion charger.

2.1.2 Li-ion Charger

Will charge the Li-ion battery in the instance of a power outage, allowing the system to continue operating.

Requirement: Must charge the Li-ion battery to 3.7V with a continuous current, from a 110V AC source.

2.1.3 Li-ion Battery

The Li-ion battery should be able to keep the system powered and working under the circumstance of the main power source of the building being cut off.

Requirement: The battery must be able to store enough charge to provide at 3.3V/5V for 1 hour with no main building power supply..

2.1.4 Voltage Regulator

This part of the power supply can provide the required 3.3V to the whole system.

Requirement: Must be able to convert 110V AC to 3.3V/5V DC.

2.2 QR Code Scanner/Primary Entry

This part of the system will be installed on the first/outside door. It is used to make sure everyone entering the area between the outside and the inside door is safe and authorized.

2.2.1 QR Code Scanner

The QR Code Scanner is able to scan the QR code on every student's phone. Only when the correct QR code was scanned, the outside door will be opened and the information will be sent to the Control Unit. The scanner needs the reliable power of 5V to work properly, and uses UART RS232 to connect to the microcontroller.

Requirement 1: Since the system must be able to process each person within a 30 second time frame, it's important to have the scanner have a high accuracy (> 95%) to detect the QR code.

Requirement 2: The scanner will be put outside, so it must be able to work properly under the sunlight.

2.2.2 Entry Confirm LED

When the QR Code Scanner scans the correct QR code, it will send the information to the Control Unit. After that, the Control Unit will switch the LED light on to tell the person to come in.

Requirement: The Entry Confirm LED must be clearly visible from 1 meters away.

2.2.3 Front Door Electronic Lock

At the same time of the LED on, the Control Unit will also unlock the outside door lock to let the person enter the People Counter area.

Requirement: The lock will work under 12V, and when receiving the signal from the microcontroller, it must unlock/lock the door in a short period of time to avoid the congestion of the crowd.

2.3 Control Unit

The Control Unit is able to control the whole system as well as the computation of the logic. It will control and decide the status of the inside door based on the data collected from the sensor as well as the information scanned from the QR code.

2.3.1 Microcontroller

The Microcontroller is the core of the Control Unit. It will be in charge of the control of the whole system and make the decision of the lock status of the inside door.

Requirement: The microcontroller must be able to communicate over CAN, UART and SPI simultaneously. It needs to process the data sent by both sensors at the same time, and send the control signal to the LED, speaker and electronic lock.

2.3.2 SD Card

The microSD card will hold the information needed for the system to operate, ranging from the data required to decode the provided QR code data, and sort through the information provided by the different sensors.

Requirement: The SD card must provide both read and write function.

2.4 People Counter

This module can count the people entering the first/outside door. When more than one person enters the area between two doors (which means unauthorized people enter), the second door will not open and people will be notified to leave the area.

2.4.1 Break-Beam Sensor

The sensor will count the number of times that the line connecting them is broken by some external object. This information will then be sent to the microcontroller to be processed, and determine the number of people who crossed the passageway.

Requirement: The Break-Beam Sensor can work under 3.3V/5V DC, and it must have enough accuracy to avoid the false alarm.

2.4.2 Pressure Detection Sensor

This sensor will detect the number of unique pressure points present across the mat, and send that information to the microcontroller, to add more information required to determine the number of people present.

Requirement: The Pressure Detection Sensor needs to be installed at a place where people who enter the building must pass. It also needs to be water-proof, since if it's raining outside, there may be water on people's shoes.

2.4.3 Speaker

The speaker will be used to tell the person whether he is authorized to enter the next door, or there's more than one person in the area so they are required to leave and enter the area one by one.

Requirement 1: The speaker must be clearly heard when people stand in the counter area.

Requirement 2: The speaker needs to work under the voltage of 3.3V.

2.4.4 Secondary Entry Confirm LED

The LED will be switched on when the person is allowed to enter the second door.

Requirement: The Entry Confirm LED must be clearly visible from 1 meters away.

2.4.5 Back Door Electronic Lock

The control unit will decide whether the person is allowed to enter the second door, and send the signal to the Electronic Lock.

Requirement: The lock will work under 12V, and when receiving the signal from the microcontroller, it must unlock/lock the door in a short period of time to avoid the congestion of the crowd.

2.4.6 Emergency Button

When unexpected system failure occurs, like both the inside and outside doors are locked, people in the People Counter area can use this button to manually unlock the outside door to leave.

Requirement 1: The emergency button must be easily-pressible.

Requirement 2: The emergency button must be large enough for people to find.

2.6 Risk Analysis

The QR Code Scanner/Primary Entry part of the system was set outside of the building, so the rain/snow weather may break the device.

The Break-Beam sensor needs to detect the numbers of people coming across it, so it needs to be set at a proper threshold. Sometimes the sensor may detect two times for the same person, and it will cause the false alarm, and slow down the whole system which may lead to the failure of the project.

The other risk is how to successfully and correctly detect the people entering the first door. The false alarm will slow down the efficiency of people entering the building. When a person with luggage enters the building, we have to detect "one person with a luggage" and "two people". Also, the miss is a more critical risk. If two people enter the building together and the system fails to detect that, it will increase the risk of spreading the COVID-19.

3 Safety and Ethics

According to ACM's ethical guidelines [4], we should use personal data legally and collect only the necessary personal information. Given that this project cannot use data from safer Illinois, this project will simulate a two-factor authentication system. Therefore, this project will not collect data from users and will not use biometric information. If this project does go into realization, the system will not collect biometric information from students and will only use publicly available identifying information, such as students' name, and their NetId. And they will not be made public by this system.

Potential security issues for this project may include the use of electricity. This project may use 120v and convert it to low voltage for use. Therefore, the risk of electrical shock to humans is extremely low.

This system will use lithium batteries as a backup power source. According to Occupational Safety and Health Administration, lithium batteries can be damaged by physical impacts including shocks, punctures and crushes, posing a risk of explosion. In addition, high environmental temperatures can shorten battery life. Therefore, this project will protect the lithium battery from physical shocks and ensure that the lithium battery works in a suitable environment. The batteries will be checked regularly and replaced with new batteries when needed. There will be routinely checks to ensure that there are no short circuits in the system and that circuits will only be operated and modified when they are not charged.

Considering that there is a risk of both doors in this system locking at the same time, there will be a button to disable the lock and be able to allow people to leave the building.

Some of the devices in this project will work outdoors, such as the QR code scanner. Given that it is difficult to guarantee a dry environment outdoors all the time, all devices outdoors must meet the IP76 standard to guarantee safety.

References

[1] The Lancet, 'Physical distancing, face masks, and eye protection to prevent person-to-person transmission of SARS-CoV-2 and COVID-19: a systematic review and meta-analysis', 2020. [Online]. Available: https://www.thelancet.com/journals/lancet/article/PIIS0140-6736(20)31142-9/fulltext. [Accessed: 15-Feb-2021]

[2] The Pulse, 'Human Factors, Human Error and the role of bad luck in Incident Investigations', 2016. [Online]. Available: https://www.linkedin.com/pulse/human-factors-error-role-bad-luck-incident-graham-edkins/ [Accessed: 18-Feb-2021]

[3] Association for Computing Machinery, "ACM Code of Ethics and Professional Conduct," *Association for Computing Machinery*, 2018[Online]. Available: https://www.acm.org/code-of-ethics [Accessed: Fed. 16, 2021]

[4]United States Department of Labor, “Preventing Fire and/or Explosion Injury from Small and Wearable Lithium Battery Powered Devices” *Occupational Safety and Health Administration*, 2019[Online]. https://www.osha.gov/dts/shib/shib011819.html [Accessed: Feb. 17, 2021]