UNIVERSITY OF ILLINOIS AT
URBANA-CHAMPAIGN
ECE 445: SENIOR DESIGN

Covid-19 Convenience Locker

Project Proposal

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1.**Introduction**

1.1 Objective

COVID has affected students' lives for around a year and has caused tremendous inconvenience to us. It is likely that the COVID pandemic will continue for a long time. Here at U of I, we are required to take saliva tests day by day at specific locations. This will make our life inconvenient since we need to move to the Illini Union and somewhere else to take tests. Some students may live far away from these test locations and it is difficult for them to go to these test locations day by day. On the other hand, too many students presenting at the test locations at the same time may also cause potential infections. While we think it is feasible to arrange some lockers around student's apartments which will make it easier to access the testing tube and then store them.

We propose a locker with testing tubes inside locating at each large student apartment. The students are required to access the testing tube every other day and then store it inside the locker before a specific time. The testing staff should pick up the tubes each day. Our objective is to design a machine that can use mechanical structure to distribute and store the testing tubes. To identify the tester information, we would try qr-code verification to print identity labels. A mechanical component should be designed for each user to pick up and store exactly one testing tube, for example, mechanical FIFO or rotation distribution design. We also expect there is an energy saver module which could let the whole locker in sleep mode when there is no person accessing the locker. To avoid possible contamination by COVID virus, we also propose a liquid pump which will dispense alcohol spray after someone has used the locker. A temperature sensor and a cooling fan are also designed to avoid high temperature inside the locker when it is in summer. A thermal printer will be used to print labels while the students should stick it onto the testing tube.

1.2 Background

Since the spread of COVID-19, COVID testing has become a necessary part of everyone's life. In U of I, all students have to take saliva tests twice per week to gain access to buildings. According to the statistics of SHIELD, there are totally 1,387,056 tests taken on campus by now. Economically speaking, a large amount of testing will bring huge cost and utilize many resources. For example, every testing location has to be assigned a certain number of people to help distribute and collect testing tubes. In addition, for testers, it is probable that some of them have to spend much time going to the test location, which makes it inconvenient in daily life. For safety, although the distance between people is strictly controlled in the testing location, it is still possible to cause potential infection when many people take tests in the same place and same time. Because of these three reasons, we decided to design a convenience locker to help reduce the cost and trouble for testers. There is no need for human resources any more because the locker itself can distribute and collect tubes by internal rotator. For each community area, we can place several lockers there so there is no need for residents to go outside and take the test. Since people can get a tube and go back home to take the test and then return the tube, the situation of many people taking tests in the same place at same time will not happen any more, which decreases the potentiality of infection.

1.3 Physical Design

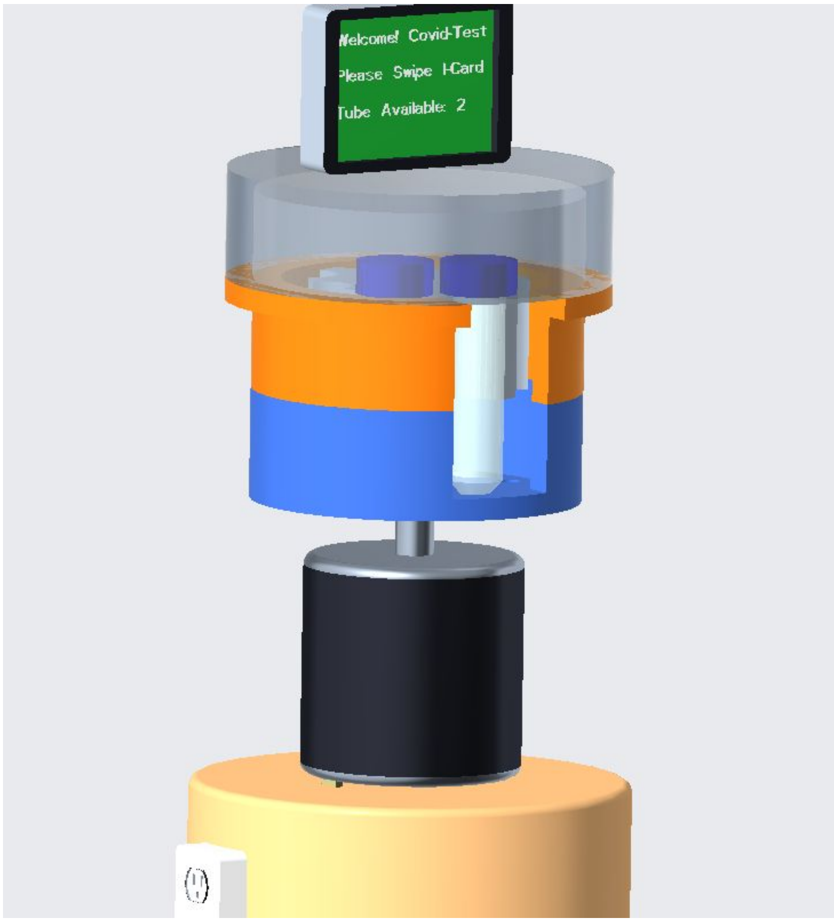

Fig 1. Physical Design of Covid Convenience Locker

1.4 High-level Requirements List

- The internal rotator must be able to rotate 45° each step to distribute and collect 8 testing tubes through servo motors.
- Barcode can be achieved by CCD/RFID with accuracy above 80% and the identity information will be printed
- LCD must be able to display temperature and humidity of the environment of testing tubes collected by temperature and humidity sensors.

2. Design

2.1 Block Diagram

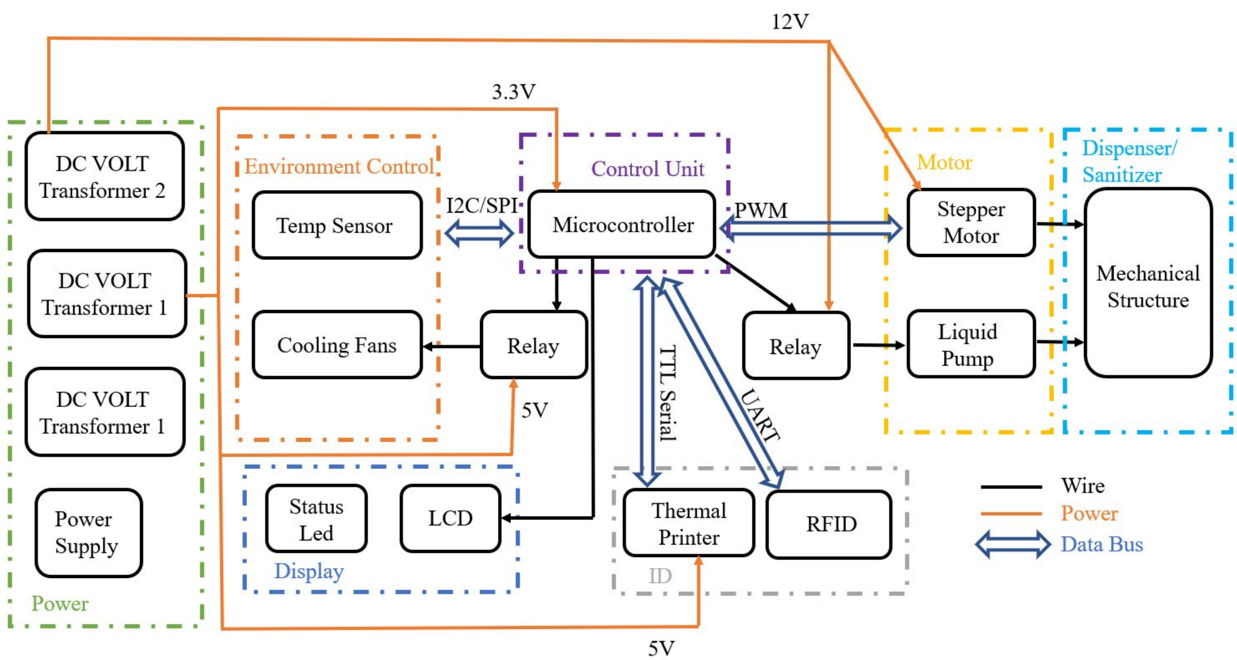

Figure 2. Block diagram of Covid Convenience Locker

2.2 Functional Overview

2.2.1 Control Unit

The control unit serves the key of the whole system. We would use atmega328p for the microcontroller. It should be able to control the temperature sensor and cooling fans while there is a relay on cooling fans. It will use an I2C panel to connect the environment system. It should be able to control the display system with LCD lights. We would use an RFID system and thermal printer for ID verification. The control unit should connect the RFID by USB which will identify the users. After identification, the thermal printer will print out the name or qr code tag. The central control system also serves to control the motor. It should control the motor to send and receive the testing tube. When there is no one using the locker, the sanitizer system will clean the inside of the locker. The control unit should send a delay signal to the sanitizer system when there is someone using the locker.

2.2.2 Power Unit

We consider using a 12V power supply which will be directly output the motor and sanitizer system. The 12V power supply will also be adjusted to 3-5V in order to fit the microcontroller and other systems' requirements.

2.2.3 Dispenser/Sanitizer System

We consider two ways of cleaning the inside of the locker. The first one is using a UV-light when there is no sample inside the locker. The UV-light can be open at night when all the samples have been collected by some people. This will be embedded if there is a lack of time. The other method is spraying alcohol. The microcontroller will send a delay to the pump when there is someone using the locker. The pump is connected directly to a mist nozzle, which could be achieved as sprayer. When he or she finishes using the locker, the pump will spray some alcohol to clean the inside of the system.

2.2.4 Environment Control

The environment control block enables the testing tubes to be stored in a safe environment. The sensors in this block can detect the environment variables like humidity and temperature and collect these data and then send to the microcontroller. The cooling fan can control internal temperature to keep samples fresh. The communication between sensors and microcontroller is achieved through I2C protocol. The microcontroller also controls the operation of the cooling fan based on the data sent by sensors.

2.2.5 Display Unit

This unit consists of Led and LCD to reflect the current situation of the locker. The microcontroller can send data collected by sensors in environment control to this unit and all required environment variables will be displayed on LCD. The status LED, controlled by the microcontroller, can be used as an alarm system to show any kind of emergency like spillage.

2.3 Block Requirements

2.3.1 Micro Controller (ATmega328P)

Due to the excellent compatibility with the arduino peripherals, ATmega328P is chosen as micro controller. ATmega328P communicates with temperature sensor BME280 using SPI, with thermal printer using TTL serial, with RFID via UART and stepper motor via PWM. Additionally, in this project, we would like to store up to 1000 students' information. From the memory calculation below, ATmega328P also meets the memory size requirement.

Memory Calculation:

Average Name Length [1] : 13 *char*

Gender Information: 6 char

Student Number: 1000

Memory Occupied: $(13 + 6) \cdot 1000 = 19$ kBytes

Requirement 1: The microcontroller needs to have on-chip memory larger than 19kB. (ATmega328 has 32kB)

2.3.2 Stepper Motor (Nema-17)

The core rotator, controlled by the servo motors, can achieve the functionality of distributing and collecting all testing tubes. According to the functionality of a rotating tube distribution system, the servo motor needs to be quick-responding and precise in positioning. A traditional servo motor will integrate an encoder to feedback the velocity and position information to the driver, which is MCU in this case. The MCU, on the other hand, will input pulse width modulation (PWM) as input signal to control the servo motor.

Requirement 1: The project has relative requirements on the angle accuracy (Ideally, $\Delta\theta \cdot integer = 45^\circ$) to make sure the testing tube is at the desired position (rotate exactly 45°) during each operation.

Requirement 2: To achieve the low operation cost, the servo motor should have low energy consumption. (Ideally, $V \leq 12\ volts,\ I \leq 1.5amp$)

2.3.3 Liquid Pump

To achieve an alcohol/IPA sanitizer system, a liquid pump is connected tightly with a mist nozzle. The liquid pump could be electrically powered and create the high fluid pressure within the inlet of the nozzle. Then the mist nozzle could spray the alcohol/IPA solution to the desired area. For automation purposes, the power of the liquid pump is controlled by the microcontroller via relay.

Requirement 1: To precisely control the timing to spray the sanitizer, the relay needs to have quick responding time. (Ideally, $\Delta t \leq 1s$)

Requirement 2: To achieve the low operation cost, the liquid pump should have low energy consumption. (Ideally, $P \leq 5W$)

2.3.4 Temperature Sensor (BME280)

To monitor the storage environment of testing tubes, the temperature information is important. The BME280 temperature sensor is chosen to sample environment temperature to the microcontroller. It communicates with microcontrollers using I2C or SPI protocol.

Requirement 1: To correctly measure the temperature in the illinois area, the measurement temperature should range from -30° to 40°.

Requirement 2: To make sure the cooling system will turn on at the correct timing, the temperature sampling rate should be high. (Ideally, $f \geq 1hz$).

2.3.5 Cooling Fans

The behavior of cooling fans is controlled by the microcontroller via relay. If the environment temperature provided by BME280 is above threshold temperature, the cooling system will automatically turn on and increase the airflow to decrease the temperature.

Requirement 1: To achieve the low operation cost, the fans are chosen with low operating voltage. (Ideally, $V \leq 5V$)

Requirement 2: To increase the durability, the fans with ball bearings are considered.

2.3.6 Radio-frequency Identification (RFID) Scanner (RDM6300)

UIUC new student I-card utilized RFID technology with low frequency (125kHz). To read the unique ID from the I-card, the low frequency RFID scanner is used here. The RFID communicates with the microcontroller via UART, and the unique ID will be presented on the LCD. [5]

Requirement 1: To increase the efficiency during the ID recognition, the RFID scanner needs to scan the card with low latency. (Ideally, $\Delta t \leq 1s$)

Requirement 2: For zero-contact purpose, the RFID scanner needs to detect the I-card with a certain distance. ($\Delta x \geq 3cm$)

2.3.7 Thermal Printer

After identification, the thermal printer will communicate with the microcontroller via TTL serial, and print out the corresponding identification information of the tester.

2.3.8 Power System

According to the selection of electronic components, the max voltage in our system should be 12V. A 12V ac to dc converter could be used as the power source (ALITOVE 12V/10A). Microchips such as LM117 could be integrated on the printed circuit board (PCB) to further separate the power into smaller voltages. Specifically, 3.3V for microcontroller, 5V for thermal printer, 5V for cooling fans and 5V for RFID.

Requirement 1: The power source could drain large enough current to satisfy the power consumption by stepper motor, liquid pump, and thermal printer.

($I \geq 1.5 + 2 + 0.4 = 3.9A$)

2.3.9 Mechanical System

The mechanical structure consists of two rotators each with 8 extruded spaces to hold the testing tubes. The top rotator is responsible for collecting used tubes, while the bottom is for distributing clean tubes. Two rotators are controlled by the servo motors. At each operation cycles, the two rotators will simultaneously rotate 45°. From the tester perspective, each operation will make one clean testing tube available. When finishing the saliva test, the tester could put the tube back to the empty spot on the top rotator.

Requirement 1: The rotator should be as light as possible to save power consumption by stepper motor.

2.4 Risk Analysis

This semester is a tough semester due to the covid pandemic. Two members of our team are working remotely which will make composing the structures difficult. Two online teammates will mainly do the design part of this project while the in-person team member will make real constructions.

The main risk we consider is the storage of testing samples. We are not sure about whether the sample is still valid if it is stored in the locker under different temperature circumstances. This problem is hard to solve since we are not experts in biology. We will put some temperature sensors in the locker to record the temperature and try to make it close to room temperature.

We should design the alcohol pump carefully to avoid contaminating the testing tube. If some amount of alcohol is dispensed to the testing tube, it would add inaccuracy to the testing results. There could also be some danger when operating the 3D-printer and applying motors to the system. We believe we can fix this with carefulness and proper lab safety training.

3 Safety and Ethics

3.1 Safety

There is obviously some concern since this locker is designed to store and dispense COVID testing tubes. It is quite possible that this machine will become a disease vector after some COVID-positive people use it. We need to minimize this risk and try to make the inside of the locker clean. The liquid pump filled with alcohol is designed to reach this task. The liquid pump will dispense alcohol after someone uses the locker in order to keep the inside clean. In addition, we should be aware of the danger caused by alcohol when the temperature is high. This is a locker which means it will have higher temperature than outside in the summer. We must take close attention to the temperature sensor in order to prevent fire.

3.2 Ethics

Both of the IEEE and AMS codes of ethics need us to hold paramount the safety, health, and welfare of the public. There is a possibility that COVID positive patients use the locker and then contaminate it unconsciously. This risk will be minimized by our design. The IEEE ethics code 6 requires us "to maintain and improve our technical competence and to undertake technological tasks for others only if qualified by training or experience." The IEEE ethics code 2 requires us to "improve the understanding by individuals and society of the capabilities and societal implications of conventional and emerging technologies, including intelligent systems." In other words, we want to make this project beneficial to the society and to improve the COVID testing system in UIUC. This is why we choose this project. We are eager to help the whole society by having more convenient ways to take COVID tests under such a hard circumstance. We want to make as few unnecessary contacts as possible to reduce the risk of infecting by COVID virus.

Reference:

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[5]M. Schoeffler, *Arduino-Tutorial: How to use the RDM630/RDM6300 RFID reader*, 06-Jan-2021. [Online]. Available: https://mschoeffler.com/2018/01/05/arduino-tutorial-how-to-use-the-rdm630-rdm6300-rfid-reader/. [Accessed: 19-Feb-2021].