ECE 445

Umbrella Rental System

Design Document

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Group 72

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Index

1. Introduction **3**

1.1 Objective 3

1.2 Background 3

1.3 High-level Requirement 4

2. Design **5**

2.1 Block Diagram 5

2.2 Physical Design Plot 6

2.3 Functional Overview 6

2.4 Operation Flowchart 10

2.5 Risk Analysis 10

3. Requirements and Verification **11**

3.1 Verification and Confidence Level 11

3.2 Requirements and Verification Chart 11

4. Tolerance Analysis **13**

5. Cost Analysis **14**

6. Schedule **15**

7. Ethics and Safety **16**

Reference: **18**

1. Introduction

1.1 Objective

Umbrella is something we don't want to carry but really wish we did when it starts to rain. Unfortunately, sudden rains often occur in our campus area, rendering many students unprepared. Walking in the rain is uncomfortable and will lead to many negative consequences like wet clothes and possible illnesses. One solution is to find the a near convenience store and buy a new umbrella, but it is definitely not economical if we are to buy an umbrella every time we forget to bring one with us.

Our answer to this problem is an umbrella rental system. The system will scan student IDs (campus solution) or other kinds of ID card with RFID to keep track of students' accounts in the database and determine if a user is eligible to rent. Accounts with unreturned rentals or damage records will be denied of service until those issues are resolved. If an account is eligible to rent, the system will decide if an umbrella is available; if there is one, it will unlock an available umbrella for the user, and record the time, slot number and ID. When a user return an umbrella to the rack, the system will record the time again to see whether a payment is required (for paid systems). In order to prevent fake umbrellas (e.g. a stick) from being returned to the system, the basic redundancies include equipping each umbrella with a RFID which need to be scanned during checkout and return. For more secure solutions we can also add sensors that detect size and weight of the "umbrella" being returned, or substitute barcode with an embedded RFID chip in the umbrella.

1.2 Background

In the United States, there is hardly any place that offers umbrella rental service besides luxurious places and hotels. If rain starts pouring down and one person need to commute on foot, the only choice without wasting time or getting wet would be to buy a new umbrella. In the long term it is costly and inconvenient, for not bringing an umbrella again in the future means the person needs to buy another umbrella when raining.
Outside the US, however, there are many umbrella rentals operated by chain convenience stores. The rental requires a deposit in advance and a receipt upon return. The whole process is slow and requires an employee to operate. There is plenty of room to improve here too.

Our project will be able to provide a fast and convenient way to rent and return an umbrella without the need of a human employee. By scanning the membership card or an ID, the system can respond in an instant validating account eligibility and release an umbrella to the user. The card can be reused without paying extra deposit as long as there is no damage reported against the account.

Since every user account on file is linked to their valid ID along with a deposit (or cash balance), these will be used to protect against damages to the system or umbrellas. Renters will be prompted to check and report damage after an umbrella is released from the rack. If damage is reported during this period, master PC will track the last user who rented this particular umbrella, a damage case will be generated against that user and sent to system administrator, once approved the user will be charged full price of the umbrella. For added security, other redundancies like a security camera could be installed to monitor rental and return process to protect against intentional damage during this time or as evidence for future needs.

The return process is simple too, just walk up to the the system and scan the barcode on your umbrella, report any damage, and everything else will be taken care of by the system.

1.3 High-level Requirement

- Our system must have high reliability with excellent MTBF (Mean Time Before Failure) time as it is designed to be unmanned 24/7 service system.
- System must be as low cost as possible, ideally under $100
- System design and UI need to be easy to use
- System must have low operation cost, minimize non-conventional costs like umbrella damage charged to operator through optimized designs.

2. Design

2.1 Block Diagram

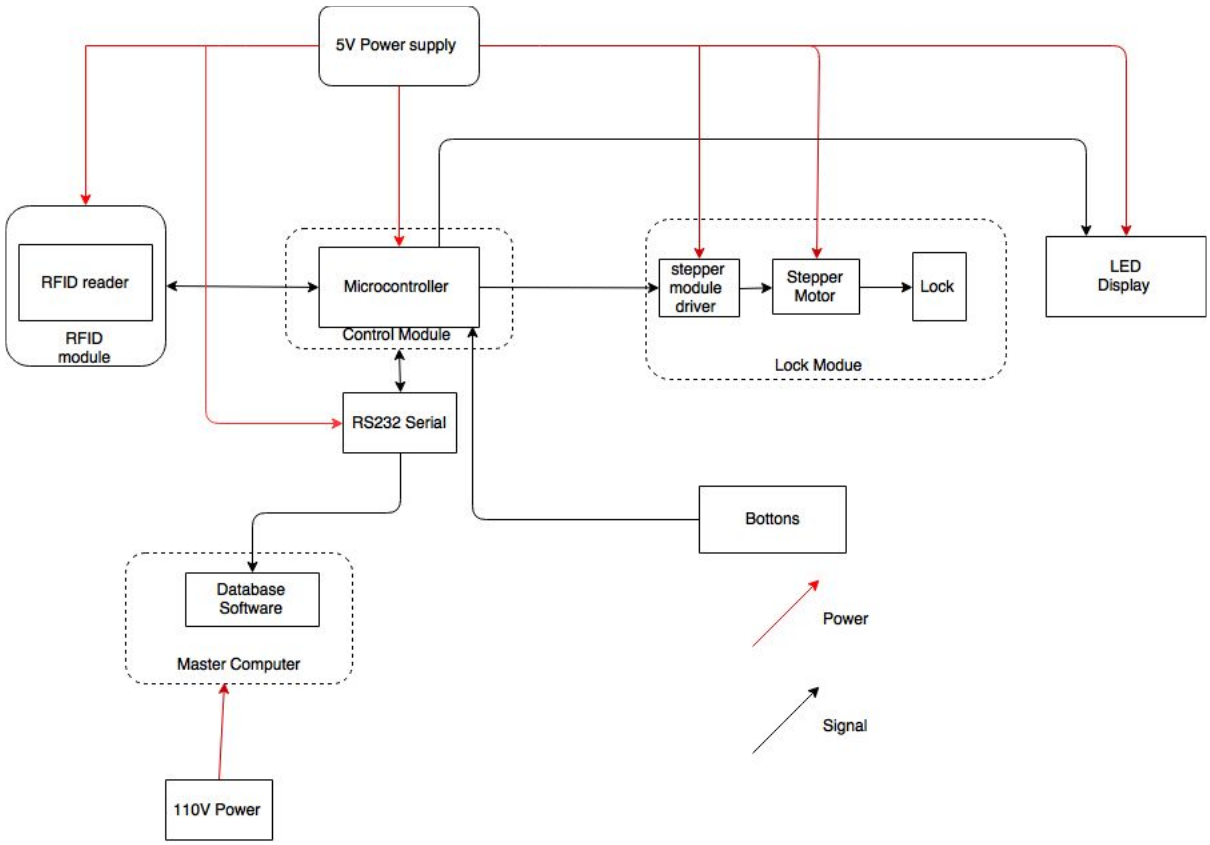

Figure1: Block Diagram

2.2 Physical Design Plot

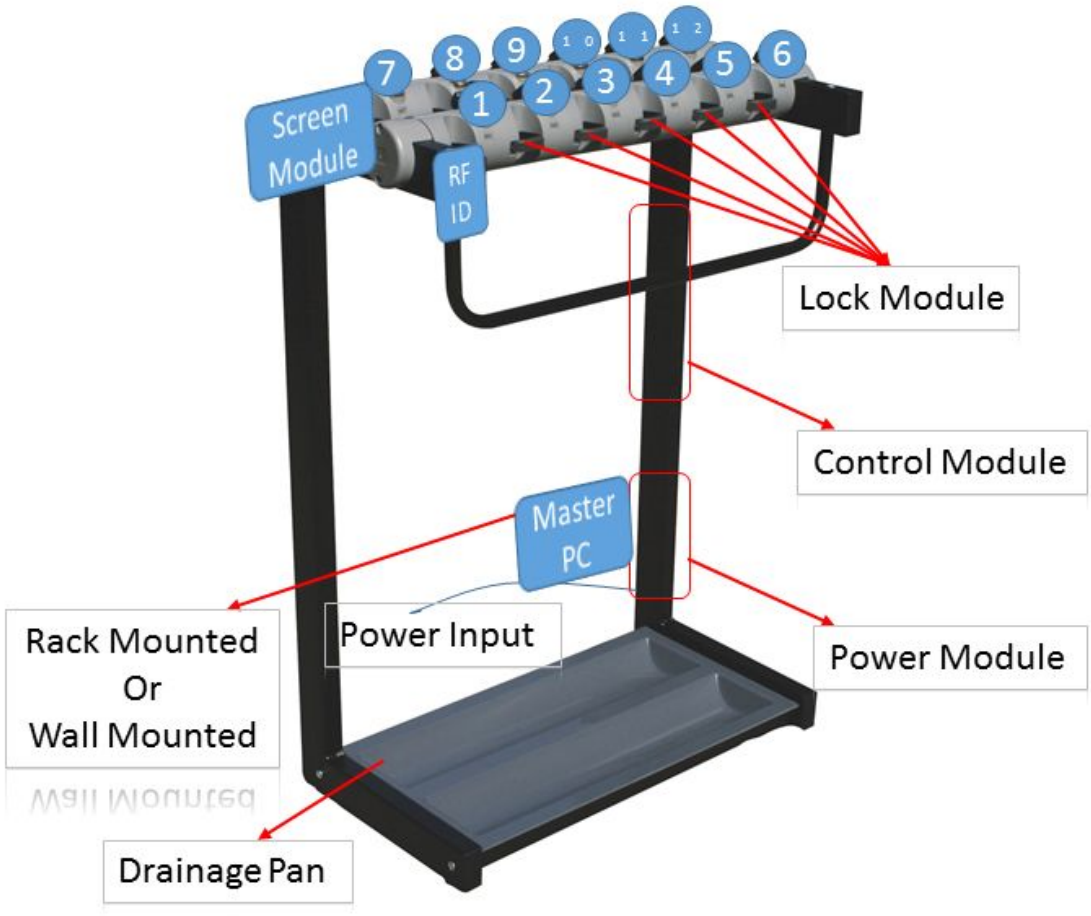

Figure2: Physical Design Plot

The draft above shows a rough schematic of the system, with the physical rack and various modules inside. The rack/system will be approximately 1.2m wide and 0.7m deep, height will be determined by the type of umbrella used but estimated around 1m tall.

2.3 Functional Overview

Power Module:

- Powers the Control Module, the RFID Module and the Lock Module with 5V DC voltage through Wall to USB 5V 1A adapter.
- This module provides Vcc power for the circut and modules.

RFID Module:

- Consist of a NXP PN532 RFID reader. This chip provides 13.56MHz communication ability with SPI mode support [1].
- This module reads the RFID card and output them as digital signal to Control Module

over SPI interface.

- Powered by the power module through 5V DC voltage.
- Data used to authenticate users and umbrellas.

Control Module:

- Consist of an AT89S52 microcontroller. Compatible with MCS-51 instruction set containing a in system programmable flash memory besides the CPU (8bit).
- Powered by the power module through 5V DC.
- Takes input from RFID module for user ID (and possibly umbrella RFID) over UART (Universal Asynchronous Receiver/Transmitter), relay the data to master PC. Once authorized by master PC, it will output digital signal to Screen Module to update display content, as well as control signal to Lock Module for umbrella release.
- During normal operation microcontroller also reports umbrella lock positions to master PC (in Lock Module, for Stepper Motor implementation lock can be controlled to turn by desired degree through number of pulse signals sent to the motor driver. For Servo Motor implementation lock angle is controlled through the width of electric pulse signal sent from the control module)
- This module verifies if the user is authorized, coordinates which lock should be open/closed, provide info to users by controlling Screen content and sends data to master PC for logging

  Control Module Schematics:

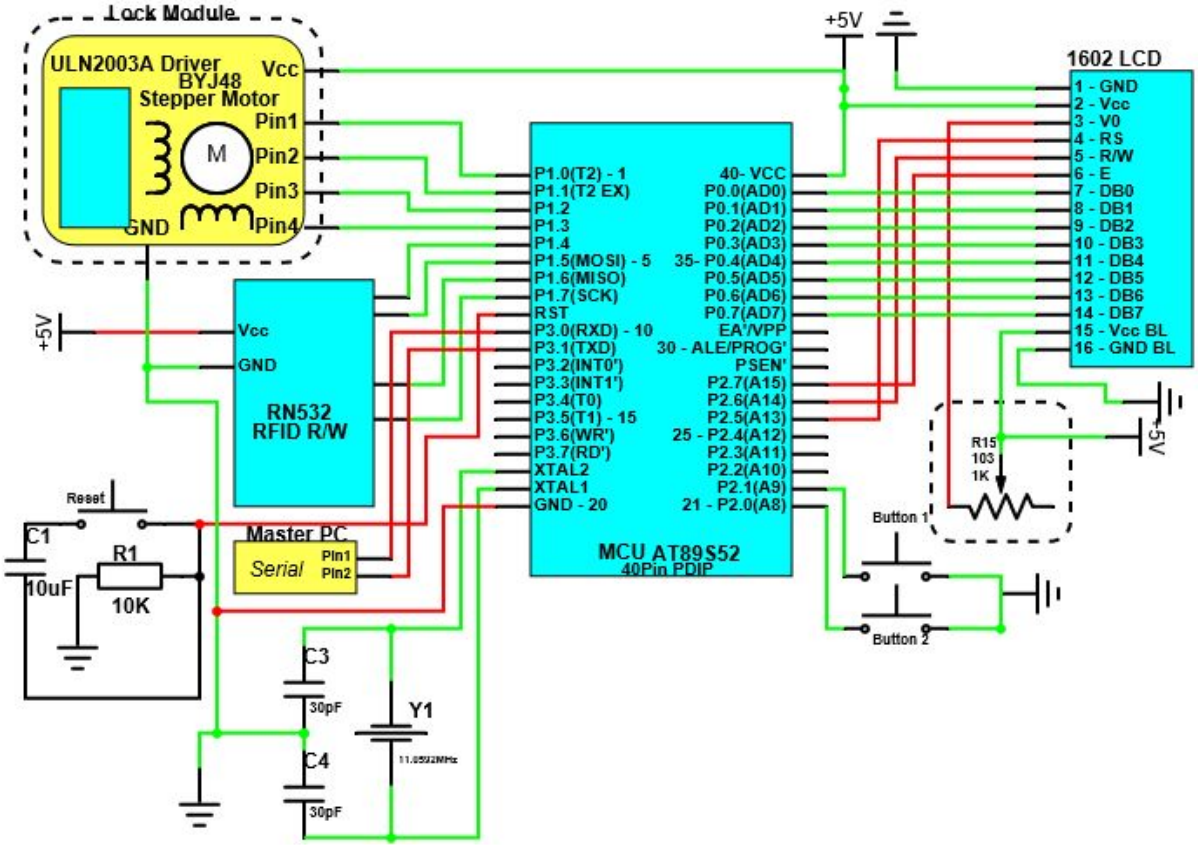

Figure3: Control Module Schematics

* Red wire for Vias. Green wire for regular connection.

Lock Module:

- This module receives the signal from the microcontroller and execute unlock process, which allows the renter to get umbrella from the rack.
- Consist of stepper motors, interface ICs, and physical locks. 28BYJ-48 5V stepper motor will be used. Stepper motor will be interfaced with an array of Darlington Transistors (ULN2003 7 NPN Darlington Transistor chip) as driver. This driver IC amplifies the current from the power module and microprocessor, providing adequate power to drive the stepper motor.
- Powered by power module at 5V DC.

  Lock Module Schematics:

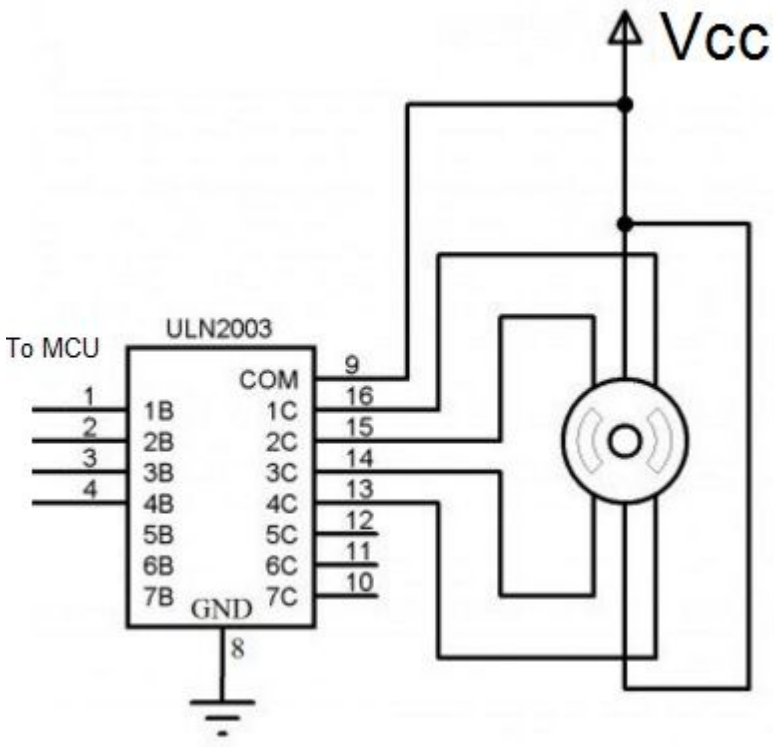

Figure 4: Lock Module Schematics

Screen Module:

- Consist of a LCD 1602 screen.
- Powered by power module through 5V DC voltage.
- Takes digital signal input from Control Module with ASCII support.
- LCD mono color display, 2 lines, 16 characters with LED backlight.
- This module displays rental information and the options when renting umbrella i.e. inspect for damage

Master Computer:

- Consist of a physical PC and database software.
- The physical PC is not within the scope of our design.
- Takes digital signal input from Control Module that includes user ID data and umbrella lock position on rack.
- Software database recording all user data and rental information (time stamp, umbrella ID)
- Make queries within the database to decide if a user can be permitted new rental.
- Send signal to microprocessor to allow or deny access.

Buttons:

- Allows renter to report damage when prompted on screen, during both umbrella rent out and umbrella returns.

2.4 Operation Flowchart

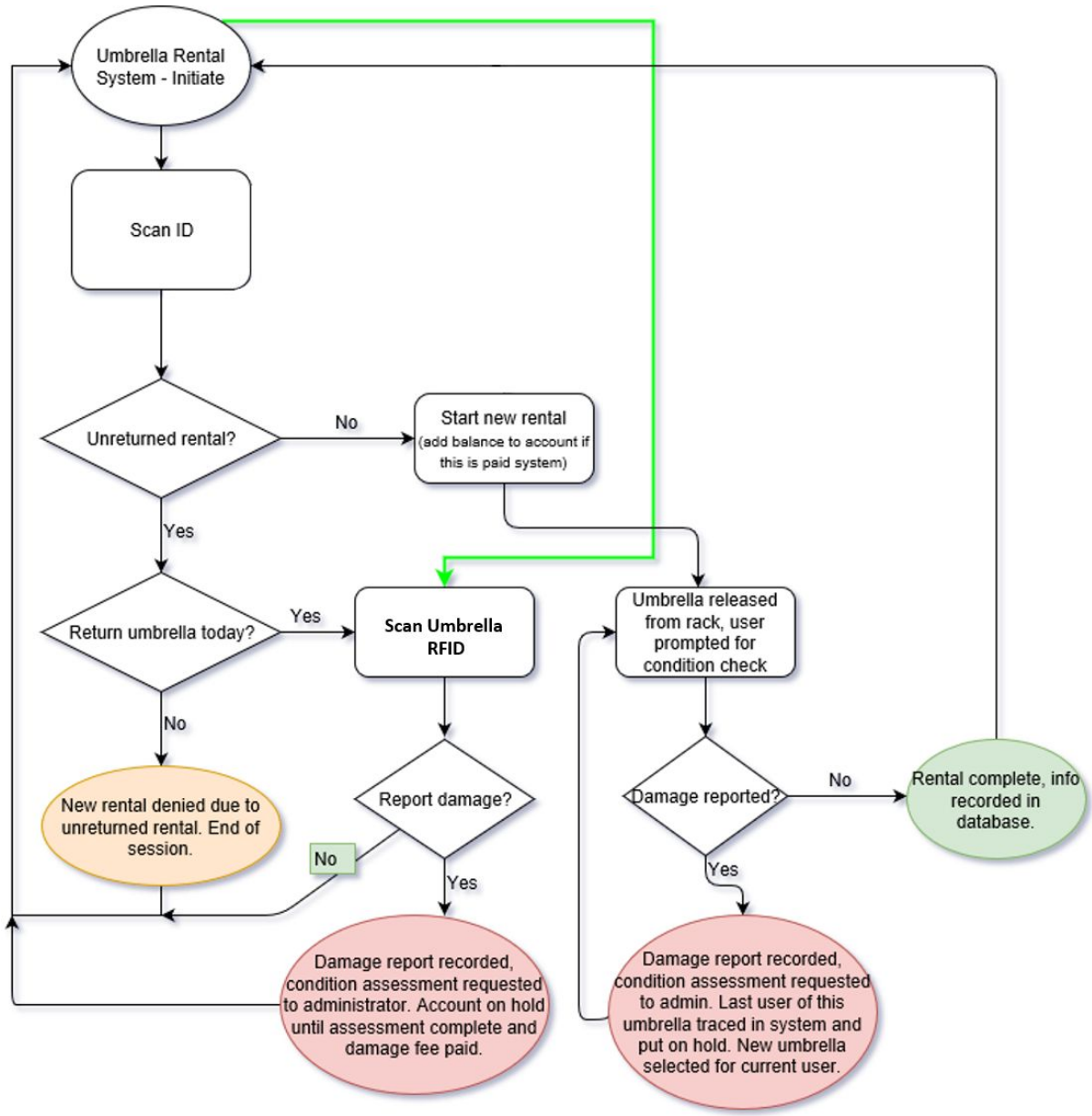

Figure 5: Flow Chart

* Element with green background represent successful rental or return. Element with Orange background represent denial of service due to unreturned record. Element with Red background represent damage report and require case be reviewed by system admin/maintenance.
** Green arrow line stands for Express Return Process, where no ID scan or identification is needed, only umbrella ID/barcode.

2.5 Risk Analysis

The block that poses the greatest risk to successful completion of the project is the control module. It has to communicate between RFID module, master PC, Screen module and Lock Module and be programmed to process all data correctly at low latency. We have to carefully

select our chip to meet all I/O requirement and as well as capability of onboard Flash memory for temporary data storage. The communication protocols between the microcontroller and master computer may be complicated and have more of an impact on the performance of the microcontroller than that of I/O with other modules.

The physical design of the rack and locking mechanism must be solid enough to not only hold all umbrellas but also lock them in place when programmed to do so.

3. Requirements and Verification

3.1 Verification and Confidence Level

One of our requirements include accuracy rate within a certain range at 95% confidence level; to verify those requirements, we have to calculate the number of repeating experiments we have to conduct.

RFID Module Accuracy Verification: expected accuracy is 90%. For 95% confidence level and confidence interval of 80% to 100%, there are:

$$p = 0.9,$$

$$1.96*\sqrt{p(1-p)/n} = 10\%$$

$$n = 35.$$

3.2 Requirements and Verification Chart

Requirement	Verification	Score
Power Module 1.Provide stable voltage at 5V +/- 5%. 2.Provide at least 1A of sustained current at 5V voltage.	1. a.) Connect multimeter to power module Vcc and GND to measure voltage. b.) Verify this voltage is within 4.75V to 5.25V range. 2. a.) Connect a 5 Ohm resistor that can withstand 1A current between power module's Vcc and GND b.) Use a multimeter to verify that stable current of 1 A can be reached.	5
RFID Module 1. Must support interface other than	1. Our choice of PN532 as our RFID reader satisfy this requirement because it has SPI	10

UART because microcontroller has only one set of UART I/O 2. Scan and send correct 13.56Mhz RFID card data to microcontroller in two seconds after a user scanned his RFID tag, with 80% - 100% message accuracy at 95% confidence level.	interface support 2. a.) First verify our AT89S52 microcontroller and LCD screen. b.) Program the microcontroller to take inputs from RFID module and display received data on LCD screen. c.) Connect RFID module to microcontroller and scan an RFID tag. d.) Compare the RFID tag's stored data with that displayed on the LCD screen. e.) Repeat step 3 and 4 35 times, verify that at least 32 tests have the correct RFID readout.	
Control Module 1. Microcontroller should operate at around 5V DC with adequate Vin tolerance for reliability in case of unstable power supply. 2. Microcontroller of choice (AT89S52) should have one full 8 bit I/O port for RFID Module, one full 8 bit I/O port for Screen Module, another 8 bit I/O port for Lock Module control signal (likely use only part of 8 bit), and one more 8 bit I/O as backup for additional functionality. Microcontroller should also have on board programmable flash of at least 8KB for temporary storage. 3. Microcontroller should be able to communicate with master PC using serial ports with each message of 100 bits correctly transferred and acknowledged in 1 second.	1. a.) Connect multimeter to microcontroller Vcc and GND to measure voltage b.) Upload code to set all pins to OUTPUT HIGH c.) Probe each output to ensure voltage is in 4.0V to 5.5V range. d.) Repeat testing at different power levels around from 4.0V to 5.5V with increments of 0.1V. 2. An AT89S52 chip has three 8 bit bidirectional I/O port with internal pullups, and another 8 bit open drain bidirectional I/O port. [2] This chip is therefore sufficient for the requirement.The chip also have an 8K Bytes Flash. Verified through manufacture datasheet for chip of choice.[2] 3. a.) Write two test programs for master PC and microcontroller. b.) Run them to verify they can achieve bi-direnctional communication in 1 second for each direction.	15 (5,5,5)
Lock Module 1. Mechanical part of our lock can be drived with our stepper motor, which has a torque of >34.3mN.m.[3] 2. The lock must successfully open or close in a maximum of 5 seconds.	1&2. a.) Connect the stepper motor to the mechanical lock. b.) Program the stepper motor to open/close the lock. c.) Make sure the lock opens and closes correctly each within 5 seconds.	5
Screen Module 1. Display shall have at least 2 lines, each with 16 characters. 2. Takes digital input from microcontroller, full ASCII support. 3. Screen shows printable ASCII	1&2. Our choice of LCD 1602 module satisfy the first two requirements. It has 16x2 characters and full ASCII support. 3. After implementing our LCD screen driver on the microprocessor, write a test program to display all printable ASCII characters on the	0+5

characters correctly.	screen.	
Software on Master Computer and Microcontroller 1. The database software runs on windows operating system. 2. We aim for adequate reliability for 24/7 database system online usecase. The software on PC, if crashed, will not cause persistent data in the database to be lost. 3. In the case of microprocessor power loss and reboot, states of umbrella availability should not be lost.	1. a.) Force terminate the database software on PC. b.) Examine the data in the database. Data that was already stored in the database prior to the termination should not be lost. 2. a.) Unplug the rack from power. b.) Examine the rack information on master PC and ensure the data is not lost.	10 (5+5)
	Total	50

Figure 6: Requirements and Verification

4. Tolerance Analysis

The module with most electrical complexity in our design is the power module. It powers the microprocessor, stepper motor, ULN2003 driver IC, RFID module and LCD screen. It is essential for our power module to meet the requirements of all its loads. To simplify our power module, we choose use one single source voltage in our design. This voltage is chosen to be 5V. In the following analysis we will examine whether this design is appropriate.

1. 28BYJ-48 5V stepper motor has DC resistance rated at 50 Ohm+/-7% at 25 C. [3]
   Only one of them will be active at any time.
   i. Power Supply Voltage: Vcc = 5V, tolerance not explicitly stated
   ii. Rated Power = 5V*5V/50Ohm = 0.5W.
2. NXP PN532 RFID reader/writer:
   Power Supply Voltage: Vcc = 2.7-5.5V
   Power dissipation = 500mW when active.[1]
3. AT89S52 microprocessor:
   Power supply Voltage: Vcc = 4.0-5.5V
   Maximum Input Current Icc = 25mA when active.[2]
4. LCD 1602 Screen:
   i. Power supply Voltage: Vcc = 4.7V - 5.5V

ii. Typical Power Supply Current = 1.1mA[4]

5. ULN2003 driver IC:
    i. Output Voltage: 5V adopted by design
    ii. Maximum Power dissipation: 1.47W[5]

Considering the voltage ranges above, the power source must meet a voltage within 4.7V - 5.5V. Therefore, a source voltage of 5V will satisfy the voltage requirements of all the connected modules.

At 5V voltage, power for AT89S52 will be 125mW, power for LCD 1602 will be 5.5mW. Therefore, total power required will be 2.601W at 5V. The 5V 1A supply will allow a current overshoot by the factor of 1.92. Therefore, we can safely adopt the 5V 1A standard power supply here.

5. Cost Analysis

Labor Cost

Name	Hours Invested	Hourly rate	Total
Shuodong Zhang	220	$30	$6600
Yiheng Xu	220	$30	$6600
Xinyi Wu	220	$30	$6600
Total Labor Cost	$19800		

Figure 7: Labor Cost

Parts

Item	Quantity	Unit Price	Total
Microcontroller (AT89S52)	1	$3	$3
Microcontroller Programmer	1	$15	$15
PCB Board	1	$15	$15
Stepper motor and driver	2	$2	$4
RFID Reader and cards(PN532)	1	$40	$40

Serial RS232	1	$5	$5
LCD Screen1602	1	$3	$3
Umbrella Rack	1	$15	$15
Total Parts	$130		

Figure 8: Parts Cost

Total Cost

Item	Total
Parts	$130
Labor	$13200
Grand Total	$13330

Figure 9: Total Cost

6. Schedule

Week	Work Duty	Delegation
2/20	Finalize our design details and prepare for design review	Shuodong, Xinyi, Yiheng
	Make sure all parts are ready	Shuodong
2/27	Finalize the pin assignment and start working on the unlock process	Yiheng
	Implement RFID & Stepper Motor and test power supply	Xinyi
	Setting up Master PC database with required function	Shuodong
3/6	Finalize the functions communicate with RFID and Stepper Motor	Yiheng
	Test the motor and RFID	Xinyi
	Coutinue working on the database software with debugging	Shuodong
3/13	Work on the interface communicate between Microcontroller and Database	Shuodong, Yiheng

	Assemble the circuit and work on the firtst draft of PCB	Xinyi
3/20	Spring Break	Shuodong, Yiheng, Xinyi
3/27	Finalize the Microcontroller programme	Yiheng
	Testing the the full circuit, submit the revised PCB	Shuodong, Xinyi
4/3	Testing the full circuit and debugging	Yiheng, Xinyi, Shuodong
4/10	Debugging the corner cases and implement with the umbrella rack	Yiheng, Xinyi, Shuodong
4/17	Prepare for the final demo Get ready for presentation	Yiheng, Xinyi, Shuodong
4/24	Work on the Final Paper	Yiheng, Xinyi, Shuodong

Figure 10: Schedule

7. Ethics and Safety

The IEEE and ACM codes of ethics both states that we should avoid harm to others, especially our users. By design, our product is only a verification and logging system for access of shared resource (umbrellas), and is not likely to make direct contact with our users. Therefore, throughout operations and usage of our product it is quite impossible to physically harm people.

Under rare circumstances our system may fail if its circuit comes into contact with water (from the umbrellas), but with all modules (except mast PC) powered by 5V DC maximum it is safe from causing any serious harm to human. And before that, safety precautions like water drainage pan and high mount location of circuitries are reliable enough to prevent any electrical part of the system being shorted.

The ACM Code of Ethics also states that we should respect privacy [6]. We log user activities by recording their IDs, leasing and return time (and possibly video recordings of them if we decide to utilize a security camera). We plan to limit our data collection by automatically deleting archived files when a certain time period has passed.

Our project takes responsebility of IEEE code of ethics #1 “To accept responsibility in making decisions consistent with the safety, health, and welfare of the public, and to disclose promptly factors that might endanger the public or the environment.” [7] This system will benefit the community by providing great convenience and will not cause harm to public safety or the environment.

We will also try to do our best to follow IEEE code of ethics #3 “to be honest and realistic in stating claims or estimates based on available data.” [7] We will make sure that our function works based on the data we collect. To follow IEEE code of ethics #7, we will also be open to accept any critic or comment on our design and the technical implementation. All suggestions are helpful towards a successful project.

Reference:

[1] nxp.com “PN532/C1 NFC Controller Product Short Data sheet”, 2017, [online]. available: http://www.nxp.com/documents/short_data_sheet/PN532_C1_SDS.pdf. [accessed 20-Feb-2017]

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[7] ieee.org “IEEE IEEE Code of Ethics”, 2017 [online]. available: http://www.ieee.org/about/corporate/governance/p7-8.html. [accessed 07-Feb-2017]