Mug-Share Design Document

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Mug-Share Design Document

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Summary

The goal of the project is to create a mug-dispensing machine. This document outlines the design decisions made to best dispense mugs, verify users, along with other requirements, goals, and constraints (RCG) outlined in the Requirements document. The design involves a machine that records user and mug information, a web application which allows staff to monitor and edit this information, and a database which stores the information. Though many solutions exists for any given requirement, the chosen solution is the one that best satisfies all aspects of the project. The achieved RCGs for each design aspect are listed and explained, with supporting diagrams and figures to illustrate the connections between the various systems.

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1.0 SYSTEM ABSTRACTION

The Mug-Share system contains complex interconnectivity of various components that need to communicate with each other in order to function properly. These components can be separated into four interdependent families: a web application for handling device returns and for staff to view and alter user info, a database that stores all the data for the web application, a mug dispenser that is the physical device users interact with, and finally the Raspberry Pi that connects the physical device to the database. These connections are illustrated in a high-level system diagram in Figure 1. Further detail of these components will be explored in this document.
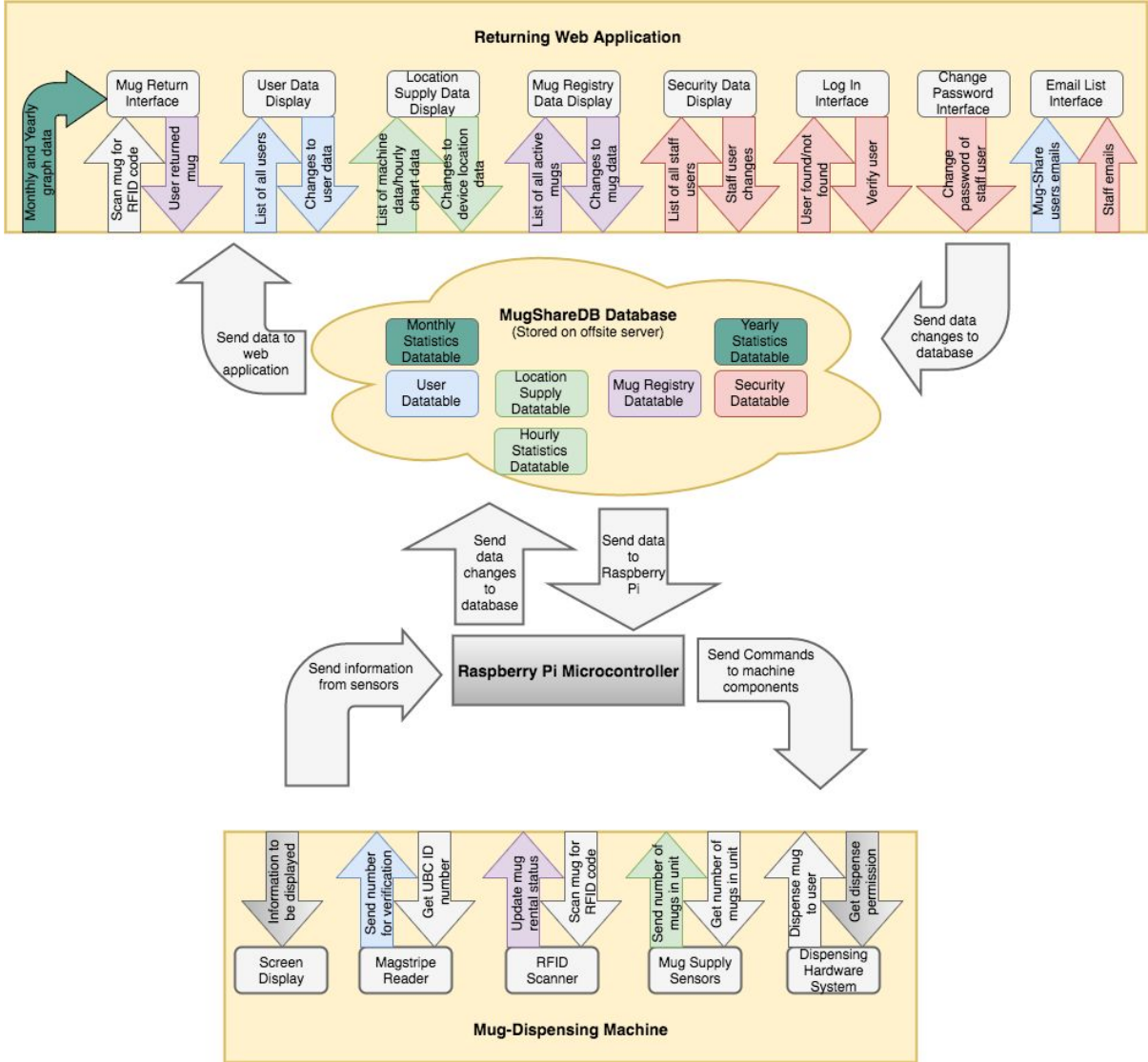
Returning Web Application

Monthly and Yearly graph data

Mug Return Interface — Scan mug for RFID code — User returned mug

User Data Display — List of all users — Changes to user data

Location Supply Data Display — List of machine data/hourly chart data — Changes to device location data

Mug Registry Data Display — List of all active mugs — Changes to mug data

Security Data Display — List of all staff users — Staff user changes

Log In Interface — User found/not found — Verify user

Change Password Interface — Change password of staff user

Email List Interface — Mug-Share users emails — Staff emails

Send data to web application

MugShareDB Database
(Stored on offsite server)

Monthly Statistics Datatable

Yearly Statistics Datatable

User Datatable

Location Supply Datatable

Mug Registry Datatable

Security Datatable

Hourly Statistics Datatable

Send data changes to database

Send data changes to database

Send data to Raspberry Pi

Send information from sensors

Raspberry Pi Microcontroller

Send Commands to machine components

Information to be displayed

Screen Display

Send number for verification — Get UBC ID number

Magstripe Reader

Update mug rental status — Scan mug for RFID code

RFID Scanner

Send number of mugs in unit — Get number of mugs in unit

Mug Supply Sensors

Dispense mug to user — Get dispense permission

Dispensing Hardware System

Mug-Dispensing Machine

Figure 1. Mug Share Component Connectivity Block Diagram

2.0 MECHANICAL & ELECTRICAL DESIGN

2.1 Mug Dispensing

The most critical mechanical design decision of the project is how to physically move one mug at a time out of the machine. Many designs were considered for their efficiency, reliability, and cost. Eventually a design that uses high quality, inexpensive hobby servos was chosen. This design allows gravity to move the mugs down a ramp, while the servos, shown in Figure A-2 in Appendix A, control the flow of mugs thus saving power as the machine does not need to actively push mugs to dispense them. One mug, mug A will be between both gates, with the remainder behind both servos. When a mug needs to be dispensed, the front gate will lower , allowing mug A to fall. The front gate will then raise up after a specific time interval. This movement is illustrated in Figure A-3 in Appendix A. This design is explored below along with the requirements, constraints, and goals (RCGs) it satisfies for the project.

I.   Dispensing method

RCG	FR3, NR1, C3
Description	The design of the dispensing system uses two gates that allow one mug to leave at a time.
Design	The loading zone can only hold a single mug. Hence lowering the front gate allows for only the mug between both gates to fall and the back gate holds the remaining mugs in place.
	The exiting process ensures a mug will be dispensed in less than 5 seconds. The gates can rotate down or up in less than a second and together dispense in under 5 seconds *.
	The dispensing ramp of the device contains two alternate positions for the top servo. This is to allow for a variety of mug diameters. The slits are

	positioned to allow for mug sizes from 70 to 90 mm in diameter, covering the majority of mug designs.
Reference	* Validation V1.2

II. Electromechanical components

RCG	NR4
Description	The motors and gates chosen are mechanically reliable.
Design	Metal geared servos are chosen in order to achieve a high reliability in the motors to prevent gear degradation. Metal gates are also chosen to be resistant to bending or breaking *.
Reference	* Validation V1.3

RCG	G3
Description	The motors used in this design meet the performance requirements while drawing less power.
Design	Although the servo chosen is a high-torque to ensure the performance, it is a small 15g hobby servo that only needs 5V and draws 1A at most. These motors are also drawing no (or less than 50mA) current when the machine is not in use.* This is comparable to a single LED being on. While a stronger 12V motor servo would have had excelled, this motor meets the requirements while consuming roughly 1.5 times less power.
Reference	* Validation V1.4

2.2 Sensing & Identification

This project requires the identification of the user as well as sensing and tracking of the mugs as they leave the machine. Some of the RCGs are achieved with the following solutions:

I.   Identifying users

RCG	FR1, NR5
Description	A magnetic stripe reader is chosen to scan the user's compatible UBC card upon arriving at the machine
Design	The magnetic stripe in UBC cards contain a set of characters, with the ID number included. The reader takes a scanned card and outputs the set of characters to the mug-dispensing machine which can extract the ID number consistently as long as the card is not damaged. This reader is inexpensive at less than $20 and reliable as they are rated for a lifetime of at least 1,000,000 swipes.*
Reference	* https://osayde.com/product/osayde-msr90-credit-card-reader-usb-3-tracks-hi-co-magnetic-swipe-reader-magstripe-scanner

II.   Mug tracking

RCG	FR7, NR5
Description	A low frequency Radio-Frequency Identification (RFID) reader is chosen to track the mugs as they leave the machine
Design	This requires the addition of waterproof 125kHz RFID tags beneath the rubber on the bottom of the mugs. Although more expensive, this design was

	chosen because of its reliability, and invisibility to the user. As the RFID reader has a range of approximately 6cm if the tag is parallel to the reader, it is mounted in such a way that a mug tag is approximately 2cm from the reader . At this point, the machine will trigger the RFID reader to repeatedly attempt to scan until a value is read. The RFIDs are rated for 100,000 reads minimum*
Reference	* Appendix - Datasheets

III.   Measuring current capacity

RCG	FR8, NR5
Description	Infrared (IR) LED/photodiode pairs are used to track the approximate number of mugs in the machine
Design	This is done by placing the pairs at several locations along the storage area for mugs, to observe where there are no mugs. Given the size of a mug and the storage area, the percentage of mugs left can be approximated. This approximation is sufficient as it gives administrators a more qualitative idea of how close the machine is to empty which is all that is necessary. The LED photodiode pairs have an estimated lifetime of 10,000 hours based off the degradation of a low frequency wavelength LED*. The LED can degrade in it's intensity significantly and still work due to the tuning potentiometer in the receiver circuit.
Reference	* https://www.sparkfun.com/datasheets/Components/LED/YSL-R531FR2C-F1.pdf

2.3 Enclosure

The enclosure is the physical shielding around the machine. It provides safety for the internal components as well as aesthetic appeal. The enclosure can also be opened by staff by disengaging a lock to access the internal components for maintenance and reloading. Refer to Section 1.4 Electronics for lock information.
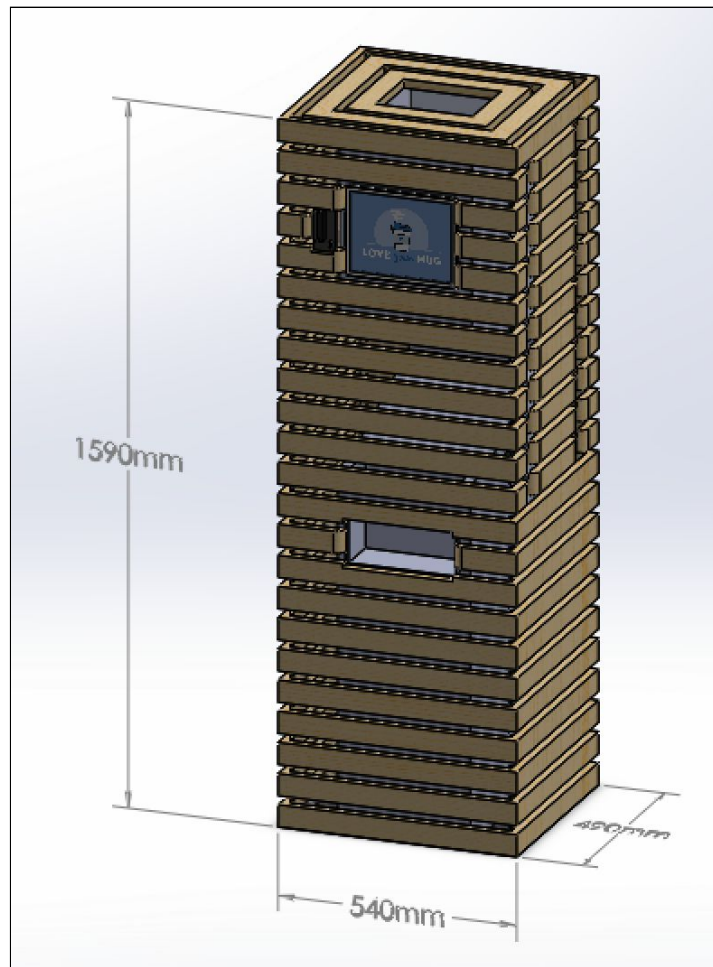

Figure 2. A sketch of the device enclosure, with key measurements shown.

I. Magazine capacity

RCG	FR4, NR2
Description	The magazine needs to accessible by mug share staff so it may be refilled with a suitable amount of mugs.
Design	The issue of accessibility is accomplished by an outward opening door on the side of the machine for refilling the device. The capacity of the magazine is upwards of 30 mugs*, mitigating the mug share staff from being required to refill the machine frequently.
Reference	* Validation V3.1

II. Machine Construction

RCG	NR4, C1, C2, G1
Description	The construction of the machine is designed to meet a variety of requirements, goals and constraints. These include strength, cost, and appeal
Design	The frame is constructed of ½ x ⅛ angle aluminium, a strong and rigid material that will easily be able to support the weight of the machines external and internal components. The frame is made of aluminium but the external enclosure consists of laminated maple plywood. This material is water resistant as well as cost effective as the total cost of the external enclosure would amount to $67.34 from a sales consultant at homedepot. The machine is designed to fit into a space near uppercase where it will serve their patrons. The machines dimensions are 450mm x 400mm x 1600mm (length, width, height respectively) which fits into the assigned space. The laminated Maple panels will feature stained wood planks horizontally spaced on its exterior. This will provide a more appealing visual to the machine then that which is provided by only the maple panels. This is shown in Figure 2.

Reference	Mug-Share mechanics manual

III.   Accessibility

RCG	NR3
Description	The machine is designed to be accessible by students at UBC including those presiding in wheelchairs
Design	The enclosure has the display, card reader, and dispensing tray located below 1450 mm so it is accessible to all people. The display and card reader will be at a height of 1400 mm relative to the bottom of the machine. The dispensing tray will be located 600mm from the bottom of the machine.
Reference	Mug-Share mechanics manual

2.4 Electronics

The mug-dispensing machine is controlled by a Raspberry Pi. The Raspberry Pi uses a state machine architecture and allows the machine to connect to the database through a wireless adapter. The Raspberry Pi is also responsible for managing the electronic lock, servos, infrared LED sensors, and a touchscreen. Behaviour and uses of the servos and sensors are explained in Section 1.1 Mug Movement and Section 1.2 Sensing & Identification. These design considerations and solutions follow.

I.   **Touchscreen monitor**

RCG	FR6, G2
Description	A 7" touchscreen monitor is installed on the front of the machine to communicate how the program works to the user, guide them to the appropriate location if they do not have a membership, and display the relevant waste reduction statistics due to the Mug-Share program.
Design	The size was determined based on pricing as the next standard size of touchscreens is 10" and cost over $200 for reasonable performance of having accurate touch tracking. In the event the monitor ceases to work, the machine will not be usable due to the lack of a UI and maintenance must be done once the problem is observed by staff.

II.   **Locking mechanism**

RCG	NR6
Description	An electronic lock was chosen to secure the mugs inside the device safely so they cannot be stolen.

Design	A 12V electric linear actuator is used as a lock to secure the refilling door. This lock takes the form of a standard bolt door lock* and will unlock only if the staff has been given permission from the database. To unlock the machine, a staff member swipes their UBC card, followed by selecting a 'Staff Menu' option on the touchscreen. Staff will then lock the door by selecting a 'Lock' option on the touchscreen. Permissions can be given by Administrators of the web application so if a non-admin swipes their card and tries to open the machine, it will not work**. This style of lock was chosen due to it's standard bolt lock configuration that gives it mechanical performance over other 12V actuators. The voltage level is chosen for increased mechanical strength over lower voltage models as well as an additional throw (bolt length) the actuator can handle.
Reference	*Mug-Share electronics manual **Validation V5.2

III.   Raspberry Pi

RCG	NR14
Description	The Raspberry Pi allows for simple software updates, as all that is needed is to upload the new code to the SD card.
Design	The Raspberry Pi has access to internet through the USB wifi dongle. Staff can then manually go to the repository and download the most updated code for the Pi and replace the old files.

IV.   Circuitry

RCG	C4
Description	A power distribution circuit is designed to allow the device to be powered entirely from the wall.

Design	A power circuit takes in the 120V 15A power from the wall through a store-bought adapter and converts it to a 5V, 6A power that is split between the Raspberry Pi, the touchscreen, and the other electronics powered through the circuit board*. All together, the max desired current draw will not exceed the supplied 6A under functioning conditions**. If the circuitry were to try and draw more than 6A, the adapter will not supply it and this is harmful to the adapter.
Reference	* Mug-Share electronics manual ** Validation V4.4

RCG	NR11
Description	A back up power circuit is designed to shutdown the Pi properly.
Design	The SD card in the Pi can lose its memory if not shutdown properly. To prevent corruption of the SD card within the Raspberry Pi in the event of power loss, a back up internal power supply is included to properly shut the Raspberry Pi down. This uses a 9V battery that will supply the Raspberry Pi via a Junction-gate Field Effect Transistor (JFET) switch when the main power line falls to 0V. *
Reference	* Mug-Share electronics manual

V. Return Device RFID

Description	Be able to scan a mug through a piece of wood.
Design	RFID allows the return device to scan the mug even if a piece of wood is in between the reader and the chip as opposed to an optical reader.
Reference	*Validation V4.5

3.0 SOFTWARE DESIGN

3.1 Device Controller

The flow diagram of the mug-dispensing device can be largely divided up into two sections, namely the Initialization (Start to Setup Complete) and the Main Body (everything after Setup Complete) illustrated in Figure 3.

The Initialization is used to set up the GUI and connect to the database to update information such as the total number of mugs dispensed from the device. It will try three times before going to an out-of-order state. The device will also check if a mug registration needs to be completed from a previous session and update the database accordingly. Refer to Section 2.2 Database & Web Application for more information on the database.

The Main Body is where the machine will begin normal operation. The machine begins by waiting for a card has been swiped. When a card has been swiped, the user ID is extracted and sent to the database to check if the card is registered in the database and if so, verifies if the card eligible for a mug. The device will attempt to send this information three times before entering an out-of-order state. During this time the card reader is deactivated to prevent users from repeatedly scanning their card. If the card is not registered or the card owner already has a mug, the machine will reject the request for a mug and display the reason for rejecting the request for a few seconds before returning to ask for a card. Otherwise, a mug is scanned by the RFID reader and registered to the card. Several update requests will be sent to the database.

The update requests will:

- Indicate the user has a mug

- Map the mug's ID to the user's ID

- Decrement the number of mugs stored in the machine

- Increment the total number of mugs dispensed by the machine

- Update the date of rental for the user

- Update the field indicating the user who last borrowed a specific mug

The machine will re-attempt to update the database again if the update requests have failed and enter an out-of-order state if the third attempt fails. The mug is then dispensed and the machine will trigger the IR sensors to check if the machine needs to be refilled. If the machine needs to be refilled, an email will be sent to the staff of the Mug-Share program. Finally, the machine will loop back to waiting for the user.

If the machine is out-of-order, it will not process mug returns and only allow users to attempt to access the staff menu. Staff menu is accessed by selecting the button on the bottom right corner of the GUI and swiping a UBC card. The machine will contact the Database to check if the card is assigned to a staff member. If so, a new menu will appear allowing the staff to unlock/lock, exit the staff menu, and exit the Mugshare application to access the Raspberry Pi Operating System. Exiting the staff menu resets the out-of-order status, allowing the machine to return to normal operation. Otherwise the machine will reject the card and remain out-of-order.

The following outline the software design decisions.

RCG	FR10
Description	Device will not stop service unless an error has occurred and resolve invalid inputs without producing incorrect outcomes.
Design	The device controller gives the bare minimum interfaces for the user to interact with to access either the staff menu or to rent a mug. Hence the user is only allowed to input what the device controller expects at any given time as the other interfaces are locked when unneeded. The device controller is also able to check the card reader for the correct format and ignore a request if the format does not match.
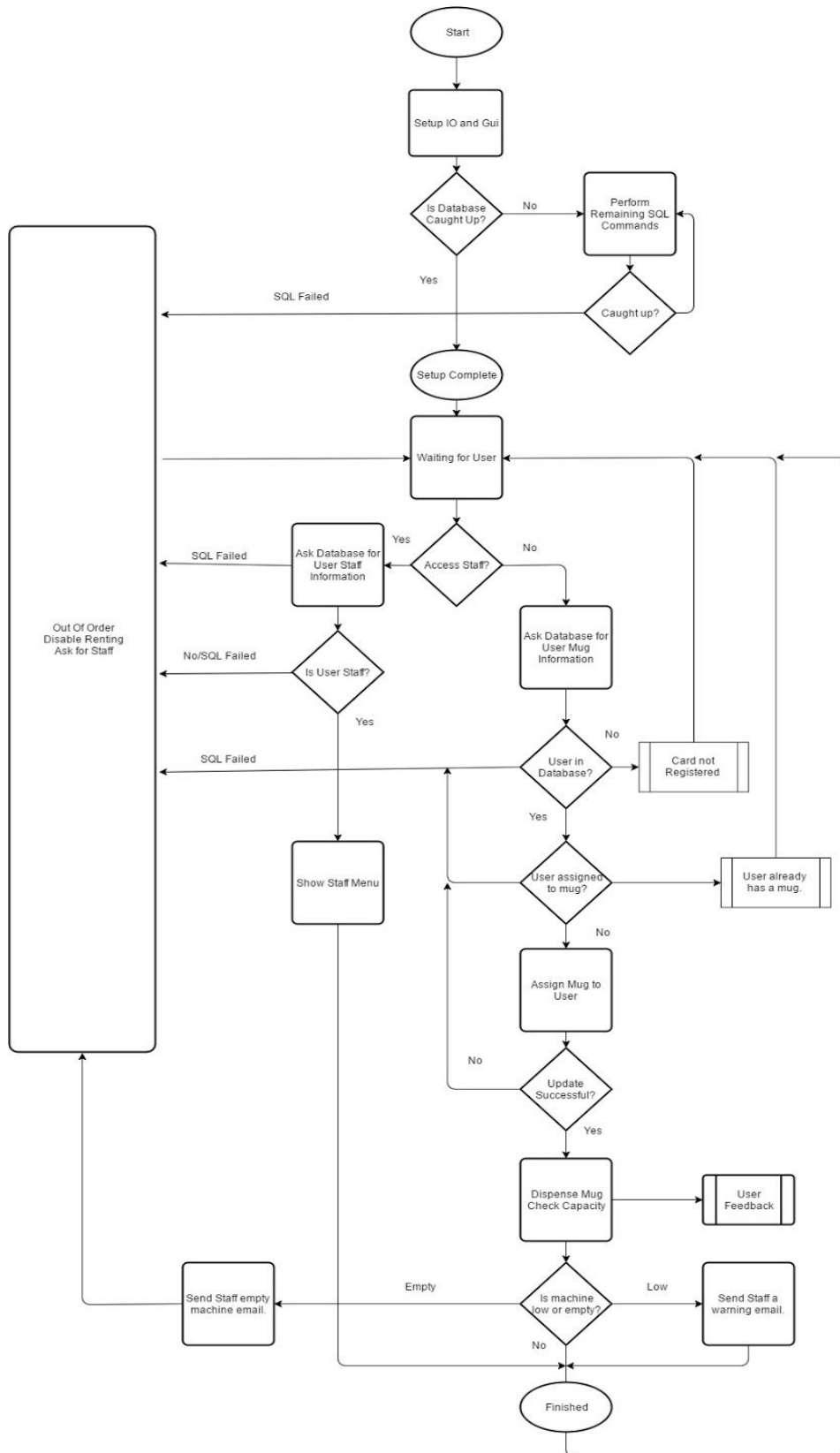
Figure 3. Flow Chart of the mug-dispensing machine, with data flow to sensors, motors, and

database.

3.2 Database & Web Application

Considering the future expandability of the Mug-Share program in terms of the number of access points for the data, storage using a standard SQL database held on an off-site server was chosen. It was decided that due to the number of devices accessing the data (i.e. multiple dispensing machines, computers utilizing the web application, and future return devices) local data storage was not an efficient option. Therefore, amalgamating all the data in one location to be accessed and updated by multiple devices was the best solution. When the program continues to expand and has more Mug-Share machines, multiple Mug-Share machines will be able to update to the same database. This gives users greater flexibility in choosing which Mug-Share machine they would like to use. The database is responsible for storing data, including Mug-Share user information, borrowing status of the mugs, and Mug-Share machine information, and a web application, located at www.mugshareubc.ca, will be used by the Mug-Share administrators and staff to display and maintain the data.

The following are the RCGs that the above mentioned design achieves:

RCG	FR11
Description	Web application must display up-to-date information
Design	All data used to construct graphs (i.e. monthly statistics and yearly statistics) and data tables (refer to Section 4.1) within the web application is pulled from the database on page load in order to provide the user with the most up-to-date content available. The web application's data tables are built to show the most relevant information immediately to the user with each record having the ability to be further investigated to reveal the remaining data entries. The

	tables are implemented using the bootstrap.js and datatables.js libraries due to their abundant documentation and quality, while the graphs are constructed using the Chart.js library for the same reasons.

RCG	FR12
Description	Ability to manage data in the database through the web application
Design	There will be several pages in the web application dedicated to managing the data tables in the database, with the exception of the *Hourly Statistics, Monthly Statistics,* and *Yearly Statistics* tables which have no need to be maintained manually.

These pages give staff useful information as follows:

1) Mug Share Users page: User's Mug In Use Status

2) Location Supply page: Machine's current supply of mugs

3) Mug Registry page: Mug's rental status

4) Security page: Staff's admin permission

The database will be updated if any records are created, edited, or deleted. The 30GB of storage space available is held on an offsite server maintained by CaCloud with 24/7 accessibility. The Mug-Share database currently takes up less than 4MB, however, if the program is successful and expands, more storage space can be purchased to accommodate for the growth. Backups of the database can be made manually through Microsoft SQL Management Studio or burned to an external USB hard drive, however, CaCloud has backup procedures in place in the event of a server failures. |

RCG	FR13
Description	Ability to handle mug returns using the web application
Design	There is a large round button on the homepage for processing mug returns as shown in Figure 4. Once it is pressed, a modal will be opened on the web page allowing staff to scan the bottom of the mug with an RFID reader which will automatically enter its 12-character RFID code into a text field, as shown in Figure 5. After obtaining the RFID code, staff are able to proceed with processing the return. The database will be updated to indicate that the associated mug has been returned, and the user it was attached to will have their mug in use status changed to returned. The mug will be associated by the last user's UBC ID number until it is rented by someone else in order to ensure responsibility for damage to the mug.

Figure 4. Home page of the web application with a large round button for mug returns
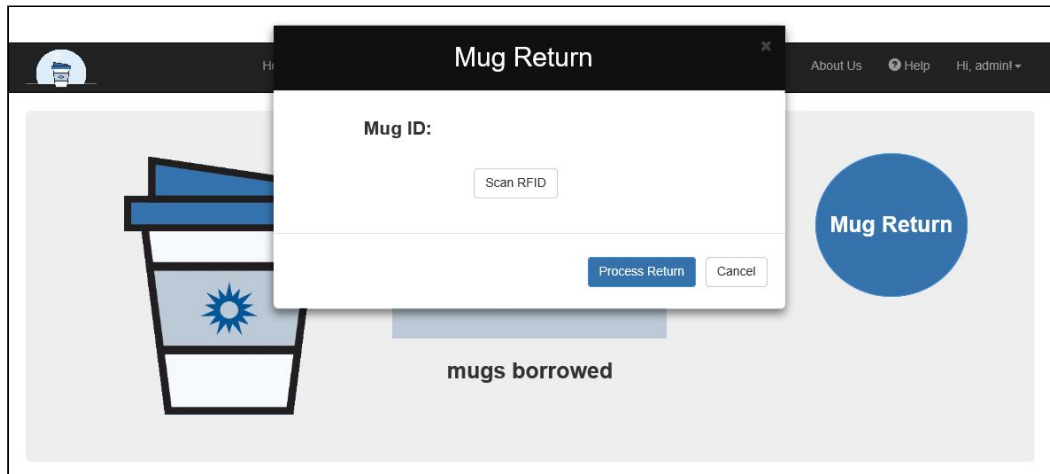
Figure 5. Mug return modal for processing mug returns

RCG	NR12
Description	Informative help menu to assist users in using the web application
Design	There will be a help menu available at the top right corner should staff need help with using the web application. The help menu will include the following sections: ● Mug Return - Processing mug returns ● Mug Share Users - Adding/removing users and editing user information ● Location Supply - Adding/removing machines, editing machine information, and viewing/deciphering the hourly statistics chart information ● Mug Registry - Adding/removing mugs ● Security - Adding/removing admin or staff users, and editing user information ● Email List - Getting email lists for specific groups of people

RCG	NR13
Description	Database should be updated whenever a change is made to the data
Design	The Raspberry Pi running the mug dispensing machine and web application both make use of the database and require that it is up-to-date. Therefore queries to the database need to be processed to avoid any incorrect data manipulation in the web application

RCG	NR14
Description	Proper documentation of source code for the web application to ensure readability and maintainability
Design	By documenting code as it is written and proofreading comments when it is complete, we will ensure that regular updates can be made to meet the future needs of the Mug-Share program. More complex sections of code requiring more description have been documented accordingly, however, every function in the source code has a section right above it with the following information: function name, description, input parameters, and return value. Below is an example of a documented functions: ```/* Function: ProcessReturn Processes mug return and alters database accordingly. Parameters: MugID - mug ID of mug we want to return Returns: model - object with user data */```

RCG	NR15
Description	Access to web pages depending on user permissions
Design	Upon opening the web application, Mug-Share administrators and staff will be greeted with a login page. Users are required to log into the web application using a username and password before he/she is able to access Mug-Share user information, Mug-Share machine information, or process mug returns. Based on the user's security permission status, they may have access to authorized control in the web application. For example, only administrators will be able to view the security data table web page, and create or delete existing users. Additional security measures were also added to ensure that unauthorized users are unable to access a page by simply entering the URL.

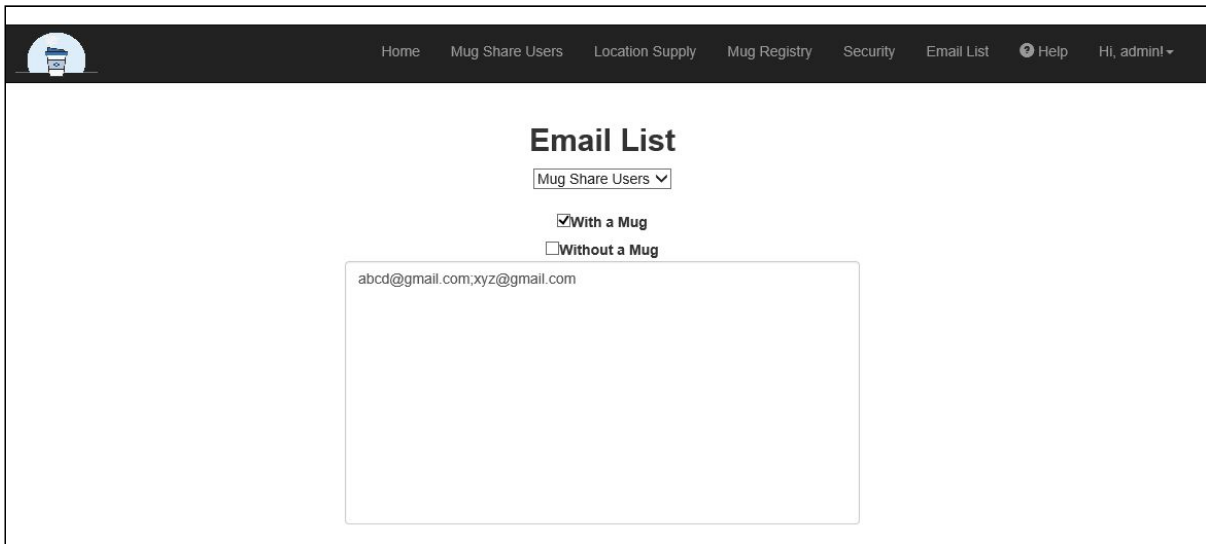| RCG	NR16
Description	Ability for users to obtain an email list based on the selected group of people
Design	There is a drop-down menu on the *Email List* page for Mug-Share administrators to select the desired group (i.e. Staff, administrators, Mug-Share users) of email addresses to be retrieved as shown in Figure 6. If Mug-Share Users are selected, the administrator can choose to retrieve the email addresses of the users with and/or without a mug. By further breaking down Mug-Share Users into these two groups, administrators will be able to send out different emails to these two groups. For example, at the end of a term, administrators may decide to send an email to Mug-Share Users with a mug to remind them to return their mugs on time. The email addresses obtained are separated by semicolons to allow administrators to simply copy and paste them in the emails.

Figure 6. Email list of mug share users with a mug separated by semicolon

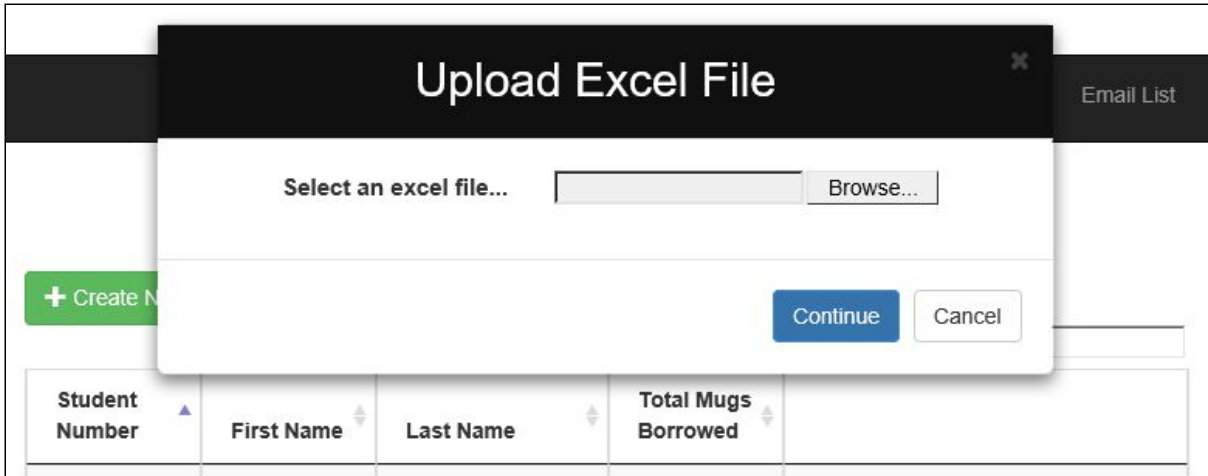| RCG	NR17
Description	Ability for users to import data from an excel document and upload it to the database to replace the existing Mug-Share user data.
Design	There is a blue button labelled "Upload From Excel" on the Mug-Share Users page which opens a modal containing a standard file browse field (Figure 7). Upon clicking the browse button, the user is able to search their local computer and then select any .xlsx excel file before pressing the continue button. If the excel file is formatted correctly, the *Mug Share Users Table* within the database is cleared, and the data within the excel file is uploaded to replace it. The program expects to receive an excel file from UBC at the beginning of every semester or school year containing student information. This feature allows the staff of the Mug-Share program to refresh the data held in the database automatically rather than entering it in manually with the "Create New" button on the Mug-Share Users page.

Figure 7. Upload excel file modal

RCG	G4
Description	Future expandability of the database to accommodate more machines on campus
Design	The *Location Supply Table* within the database contains one entry for every existing machine in the Mug-Share program. The machines are able to run in parallel by updating their respective record in the database and performing the same tasks for renting mugs, and updating the rest of the database accordingly.

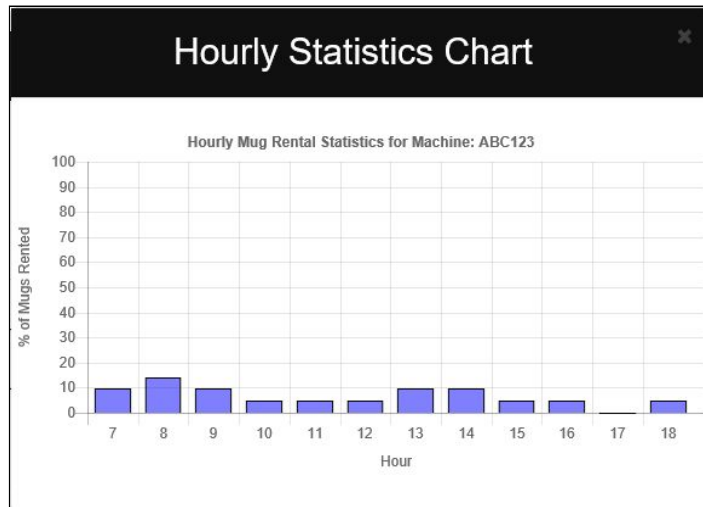| RCG	G5
Description	Track the output of mugs in the form of graphs
Design	Every time a mug is dispensed, the date, time, and machine location will be recorded and stored in the database. This information will be used to generate graphs detailing peak times of usage by hour per machine, month, and year (Figures 8-10).

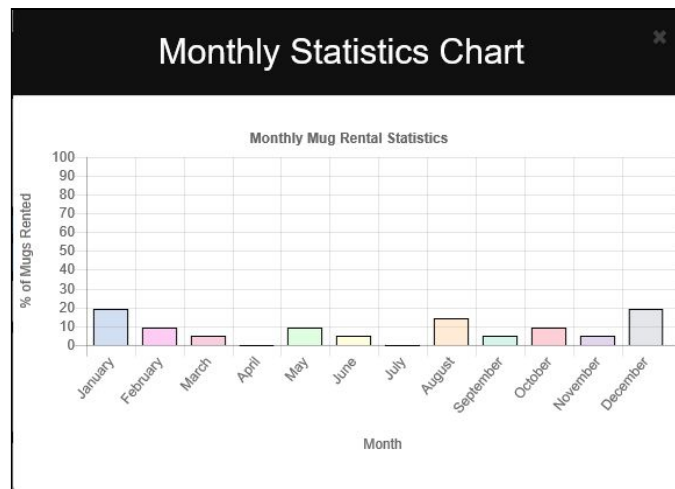Figure 8. Hourly Statistics of Mug Rentals for Example Machine ABC123
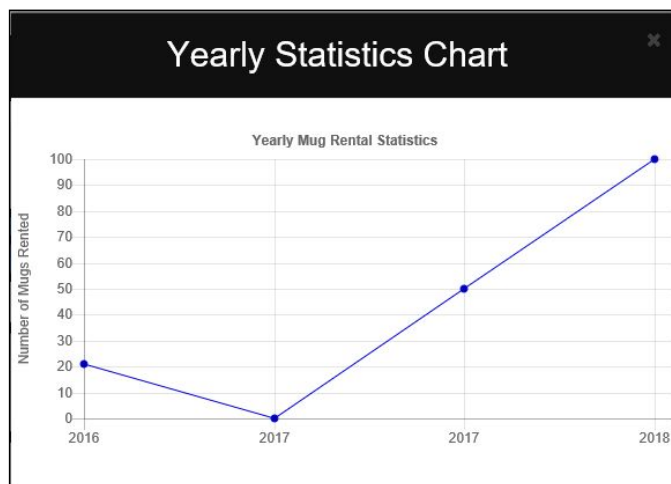

Figure 9. Monthly Statistics of Mug Rentals

Figure 10. Yearly Statistics of Mug Rentals

3.3 Return Device Software

The return device runs an application that runs an infinite loop to scan any mug that comes into range of the RFID reader and process a return request for the selected mug. The purpose was to make returning a mug easier as the user moves the base of the mug across the top of the device

Description	Ability to connect to Wifi
Design	Raspberry Pi model used for this device has a built in Wifi module.* Connection to UBC wifi was established.
Reference	*https://www.raspberrypi.org/products/raspberry-pi-3-model-b/ **Validation V2.3

4.0 RELATIONSHIP BETWEEN COMPONENTS

Our project consists of two main components that function independently from one another but are connected by the same SQL database.

i. Mug-dispensing machine which contains all the mechanical and electrical components controlled and operated by a Raspberry Pi

ii. Web application for maintaining the database and gathering information about the progress of the program

The block diagram shown in Figure 1 represents how the two components connect to the database, what kind of data is being transferred and where the data is being transferred to based on both color coding and direction. For example, all data being sent to and received from the *Mug Share Users Datatable* are blue arrows. All white arrows will be explained later in this section since they represent information gathered from:

i. Hardware components

ii. Transfer of data between the database and Raspberry Pi

iii. Transfer of data between the database and web application

4.1 Database

The mug-dispensing machine is used for dispensing mugs and is therefore responsible for updating user, location supply, and mug data in their respective datatables in the database through the Raspberry Pi. The datatables in the MugShareDB database are as follows:

I.   **Mug-Share Users Table**

RCG	FR1, FR2, FR7, FR11, FR12, NR13, NR17
Description	Contains all Mug-Share user information, and **can** be updated using the web application.
Design	The table consists of a 7 or 8-digit UBC student/staff ID number, name, email, rental status, date of rental (if any), total mugs borrowed, and any additional notes that staff need to include for that user. Each record in the datatable also contains an automatically generated, unique key in order to differentiate between records with similar data. An example record with column titles can be found in Figure 11.
	The mug-dispensing machine uses this table to check a user's rental status based on the card ID swiped through the mag stripe reader. A mug is only dispensed to the user if the ID is found in the StudentNumber column and their record has the MugInUse value set to 'False'.
	The return device, uses this table to update a user's rental status when they return a mug.
	The web application displays a portion of this table, including the UBC student/staff ID number, name, and total mugs borrowed columns (Figure 12). Users can be added/removed from the table, and the remaining information left out of the displayed datatable can be viewed and/or edited for individual

user records. 'View', 'Edit', and 'Delete' buttons can be found in the rightmost column for each record, while the 'Create New' and 'Upload From Excel' buttons are found above the table, to the left of the search bar. This is the only table that contains the upload from excel option since large updates will be made to this table at the beginning of every semester or academic year.

pKey	StudentNumber	FirstName	LastName	Email	MugInUse	DateOfRental	TotalMugsBorrowed	Notes
108	12345678	John	Doe	sample@gmail.com	1	2017-01-04	0	NULL

Figure 11. Mug-Share users datatable example

Figure 12. Mug-Share users web page

II.   Location Supply Table

RCG	FR5, FR8, FR9, FR11, FR12, NR9, NR13, G4
Description	Contains all Mug-Share machine information, and **can** be updated using the web application.
Design	The table consists of a unique machine ID, machine location, opening and closing hours, current supply as a percentage value, total capacity, total mugs dispensed from this machine, it's out of order status, and any additional notes that staff need to include for that machine. Each record in the datatable also contains an automatically generated, unique key in order to differentiate

between records with similar data. An example record with column titles can be found in Figure 13.

The mug-dispensing machine updates the current supply percentage value whenever a mug is rented, and the out of order status should the machine either run out of mugs or have any technical issues.

The web application displays a portion of this table, including the machine ID, machine location, current supply as a percentage value, and out of order status columns (Figure 14). Machines can be added/removed from the table, and the remaining information left out of the displayed datatable can be viewed and/or edited for individual machine records. 'View', 'Chart', 'Edit', and 'Delete' buttons can be found in the rightmost column for each record, while the 'Create New' button is found above the table, to the left of the search bar. This is the only table that contains the chart feature, which shows a bar chart of the hourly statistics for mug rentals for an individual machine.

pKey	MachineID	MachineLocation	OpeningHour	ClosingHour	CurrentSupply	TotalCapacity	TotalMugsDispensed	OutOfOrder	Notes
1	ABC123	Uppercase	7	18	100	30	15	0	NULL

Figure 13. Location Supply Datatable Example

Figure 14. Location Supply Web Page

III. Mug Registry Table

RCG	FR7, FR11, FR12, FR13, NR13, G4
Description	Contains all Mug-Share mug information, and **can** be updated using the web application.
Design	The table consists of a unique mug RFID code, the UBC student/staff ID of the last person to borrow it, the currently in use status, and any additional notes that staff need to include for that machine. Each record in the datatable also contains an automatically generated, unique key in order to differentiate between records with similar data. An example record with column titles can be found in Figure 15. The mug-dispensing machine updates this datatable whenever a mug is dispensed from the machine to a user. The last borrowed by field is set to the UBC student/staff ID of the user who swiped their card, and the currently in use field is set to 'True'. The return device, uses this table to update a mugs's rental status when a user returns a mug. The web application displays a portion of this table, including the mug ID, and last borrowed by columns (Figure 16). Mugs can be added/removed from the table, and the remaining information left out of the displayed datatable can be viewed and/or edited for individual mug records. 'View', 'Edit', and 'Delete' buttons can be found in the rightmost column for each record, while the 'Create New' button is found above the table, to the left of the search bar.

pKey	MugID	LastBorrowedBy	CurrentlyInUse	Notes
25	4F0012880ADF	NULL	0	NULL

Figure 15. Mug registry datatable example
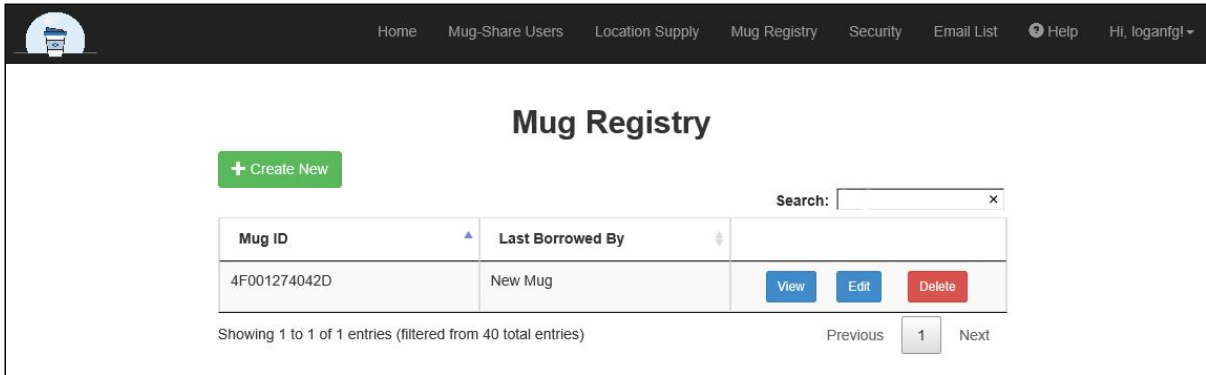
Figure 16. Mug registry web page

IV. Security Table

RCG	FR1, FR11, FR12, NR13, NR15, NR16
Description	Contains all Mug-Share staff information, and **can** be updated using the web application.
Design	The table consists of a name, staff UBC card ID, username, password, email, and admin permission status. Each record in the datatable also contains an automatically generated, unique key in order to differentiate between records with similar data. An example record with column titles can be found in Figure 17. The mug-dispensing machine uses this datatable to check if a user has staff access to the machine before unlocking the door panel when using the staff portion of the GUI. The web application displays a portion of this table, including the username, email, and admin permission columns (Figure 18). Staff/Admins can be added/removed from the table, and the remaining information left out of the displayed datatable can be viewed and/or edited for individual staff/admins. 'View', 'Edit', and 'Delete' buttons can be found in the rightmost column for each record, while the 'Create New' button is found above the table, to the left

| | of the search bar. This web page is only accessible to users with administrative privileges, additionally, admins are unable to edit or delete their own record using the web application. This table is also used to check username and password credentials when users try to access the web application. Usernames and passwords will also be encrypted in the database. |

Figure 17. Security datatable example
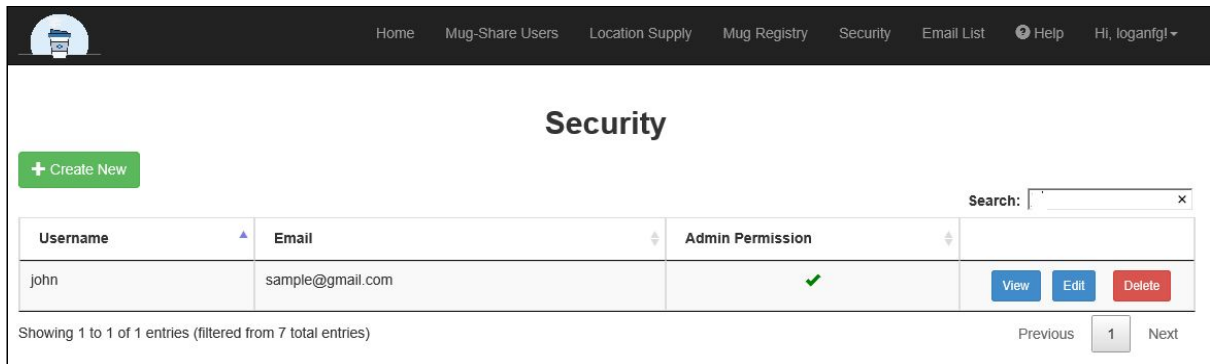
Figure 18. Security web page

V.   Hourly Statistics Table

RCG	FR11, NR13, G5
Description	Contains hourly statistics of rentals for each Mug-Share mug-dispensing machine.
Design	The table consists of a machine ID, and the total mugs dispensed during each hour of the day (represented in columns from 0-23, the hours of the day). Each record in the datatable also contains an automatically generated, unique key in order to differentiate between records with similar data. An example record with column titles can be found in Figure 19.

<table>
<tr><td colspan="2">The mug-dispensing increments the total mugs dispensed for the hour that the mug was rented from a given machine.

The web application uses this data to display an hourly statistics bar chart for each individual machine, showing only the hours the machine is open.</td></tr>
</table>

pKey	MachineID	00	01	02	03	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20	21	22	23
1	ABC123	0	0	0	0	0	2	0	152	202	200	150	50	50	78	58	23	52	65	4	3	0	3	4	13

Figure 19. Hourly statistics datatable example

VI.   Monthly Statistics Table

RCG	FR11, NR13, G5
Description	Contains monthly statistics of rentals for all Mug-Share mug-dispensing machines combined.
Design	The table consists of the total mugs dispensed during each month of the year. Only one record exists in the datatable since it is an amalgamation of the total mugs dispensed each month over the course of the entire length of the program. An example record with column titles can be found in Figure 20.

The mug-dispensing increments the total mugs dispensed for the month that the mug was rented.

The web application uses this data to display a monthly statistics bar chart, showing the monthly distribution of mugs rented throughout the year. |

pKey	January	February	March	April	May	June	July	August	September	October	November	December
1	202	153	102	83	25	15	15	30	75	90	100	180

Figure 20. Monthly statistics datatable example

VII. Yearly Statistics Table

RCG	FR11, NR13, G5
Description	Contains yearly statistics of rentals for all Mug-Share mug-dispensing machines combined for each given year.
Design	The table consists of a year, and the total mugs borrowed during that year. Each record in the datatable also contains an automatically generated, unique key in order to differentiate between records with similar data. An example record with column titles can be found in Figure 21.
	The mug-dispensing increments the total mugs dispensed for the year that the mug was rented. If no record occurs for that year (ie. at the beginning of each year), a new record is inserted into the datatable.
	The web application uses this data to display a yearly statistics line chart, showing the yearly growth of the Mug-Share program in terms of number of mugs rented each individual year.

pKey	Year	TotalMugsBorrowed
1	2016	502

Figure 21. Yearly statistics datatable example

4.2 Mug-Dispensing Machine

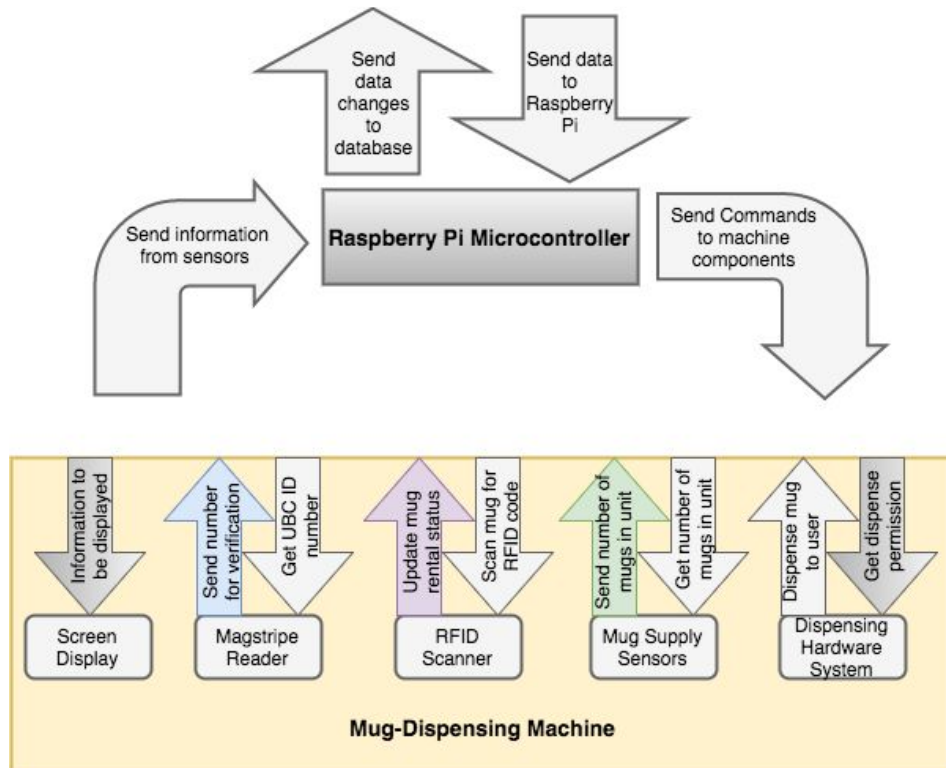The main hardware components run by the Raspberry Pi and represented in the *Mug Dispenser* in Figure 22:

Figure 22. Microcontroller and machine data direction

Hardware Component	Arrow In	Arrow Out
LCD Display	Represents information sent by the microcontroller to display messages to the user such as "Mug was dispensed successfully" or "UBC ID not found".	

Hardware Component	Arrow In	Arrow Out
Magnetic Card Reader	Represents the UBC ID number obtained after a card is swiped through the magnetic stripe reader.	Represents a call to the database to obtain a user's information using the UBC ID number that is received from the magstripe reader. This allows the machine to know whether or not this user has the valid permissions to rent a mug (i.e. is part of the program, and does not already have a mug rented).
RFID Reader	Represents the mug RFID code obtained after scanning the mug using the RFID reader. The reader is activated before a user requests a mug and the value is stored so the user does not need to wait for the mug to be scanned.	Represents the call to the database to change a mug's rental status to *In Use.*
Mug Supply Sensors	Represents information from the sensors in the machine that provide an approximation of the current supply of mugs in the machine. The microcontroller reads the sensors every time a mug is dispensed or the machine is opened for refilling.	Represents a call to the database to update the capacity of the machine.

Hardware Component	Arrow In	Arrow Out
Dispensing Hardware (i.e. servo motors)	Represents the command from the microcontroller to dispense a mug, once a user's UBC ID has been validated.	Represents the mug actually being given to the user.
Raspberry Pi Microcontroller	Arrow from Mug-Dispensing Machine represents the data coming from the hardware components. This includes the UBC IDs upon card swipe, mug RFID codes, and the current supply of mugs in the machine represented as a percentage. Arrow from MugShareDB represents data coming from the database. This includes verification from SQL calls to confirm UBC IDs upon card swipe, as well as total mugs borrowed to populate the information area of the GUI.	Arrow to the Mug-Dispensing Machine represents the commands from the Raspberry Pi to run the state machine described in Section 3.1. Arrow to the MugShareDB represents SQL commands to either get verification or to update the database. Verification includes looking up UBC IDs upon card swipe to check eligibility for a mug. Updates consist of incrementing total mugs borrowed in the hourly, monthly, and yearly statistics tables, and updating user and mug records to mug in use.

4.3 Web Application

The web application is responsible for handling mug returns and providing the staff of the Mug-Share program with a user friendly GUI to update and maintain the data in the MugShareDB database. The *Mug-Share Staff Web Application* is composed of 8 different web pages shown in the block diagram shown in Figure 23:
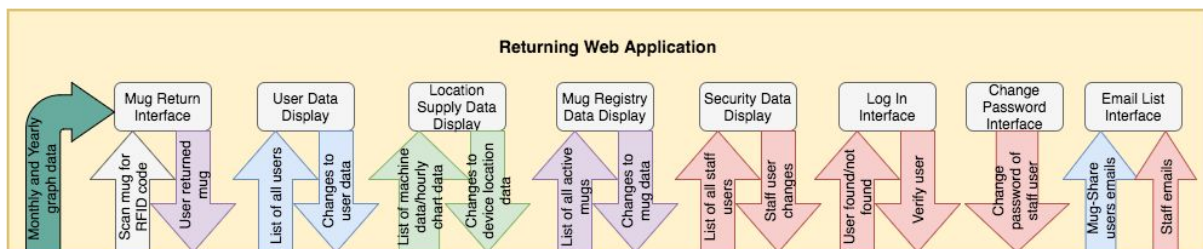

Figure 23. Returning web application data direction

I.   Log In Interface

Description	This web page is used to check the login credentials of the staff. A combination of username and password that has been added to the security datatable must be used in order for a user to gain access to the rest of the web application.
Arrow In	Represents validation data received from the database based on the username and password combination entered by a user. If the username and password are accepted, the user is taken to the Mug Return Interface, otherwise they are notified that the username and/or password is incorrect and to try again.
Arrow Out	Represents a call to the database to check if the username password combination entered by the user is valid.

II.   Mug Return Interface

Description	This is the home page of the web application and is used to display information such as total mugs saved, and statistical graphs on machine usage. There is also a button on this page used to open a modal to the mug return feature of the application. While in this modal, the staff is able to scan a mug to be returned with a RFID reader connected through a serial port and press a *Process Return* button in order to complete the return and update the database. This page also contains buttons for revealing the monthly and yearly statistics graphs for mug rentals.
Arrow In	Represents the mug's RFID code obtained from the RFID reader.
Arrow Out	Represents a call to the database to update the mug's rental status to "returned" in the *Mug Registry* table as well as change the respective user's mug in use status to "false" in the *Mug Share Users* table. If an error occurs where the mug ID is not recognized by the database, then staff can manually change the user's rental status and mark the mug to be added into the database by an administrator after inspection.

III.   Mug-Share Users Data Display

Description	This web page is used to display the *Mug-Share Users* data from the database and provide staff with a simple and efficient GUI to update and maintain the data.
Arrow In	Represents the datatable displayed on this web page being populated with the data from the *Mug-Share Users* datatable in the database.

Arrow Out	Represents data calls made to creating new users or editing/deleting existing users in the *Mug-Share Users* datatable. Additionally using the upload from excel button clears all the records in the *Mug-Share Users* datatable in the database and replaces it with the new data imported from the excel file.

IV. Location Supply Data Display

Description	This web page is used to display the *Location Supply* data from the database and provide staff with a simple and efficient GUI to update and maintain the data.
Arrow In	Represents the datatable displayed on this web page being populated with the data from the *Location Supply* datatable in the database.
Arrow Out	Represents data calls made to adding new machine locations, editing/deleting existing locations in the *Location Supply* datatable, or building the hourly statistics graph for a given machine.

V. Mug Registry Data Display

Description	This web page is used to display the *Mug Registry* data from the database and provide staff with a simple and efficient GUI to update and maintain the data.
Arrow In	Represents the datatable displayed on this web page being populated with the data from the *Mug Registry* datatable in the database.
Arrow Out	Represents data calls made to adding new mugs or editing/deleting existing mugs in the *Mug Registry* datatable.

VI. Security Data Display

Description	This web page is used to display the *Security* data from the database and provide staff with a simple and efficient GUI to update and maintain the data. This page is only accessible to staff with administrator level privileges, also, administrators are able to edit/delete all staff data except for their own. This includes other administrators.
Arrow In	Represents the datatable displayed on this web page being populated with the data from the *Security* datatable in the database. Requires the username to be decrypted.
Arrow Out	Represents data calls made to adding new staff or editing/deleting existing staff in the *Security* datatable. Requires usernames and passwords be encrypted before transferring to database.

VII. Email List Interface

Description	This web page is used for admins to get a list of emails. Admins have the option to select from the following groups to obtain the list of emails: 1. Admin 2. Staff 3. Mug-Share Users - With a mug, or without a mug
Arrows In	Represents data calls made to get the admins' email addresses from the *Security* datatable and/or mug share users' email addresses from the *MugShareUsers* table.

VIII. Change Password Interface

Description	This web page is used for admin or staff to change their passwords for accessing the web application.

Arrow Out	Represents data calls made to editing user password in the *Security* datatable. Requires passwords be encrypted before transferring to database.

5.0 BUDGET OUTLINE

5.1 Mug-Share dispensing machine

Item	Cost
Electronic circuit components	$ 57.29
Servo motors x 2	$ 31.98
Lock	$ 34.15
PCB x 2	$ 161.70
RFID reader	$ 31.20
RFID tags	$ 63.79
Raspberry Pi 2 Model B	$ 54.86
LCD touch display	$ 89.00
Power adapter	$ 39.44
Cables	$ 24.33
IR sensors and LEDs	$ 9.88
WiFi dongle	$ 52.12
SD card	$ 16.78
Mag-stripe card reader	$ 25.50
Batteries and charger	$ 24.40
Wood	$ 105.32
Metal	$ 155.27
TOTAL	**$ 977.01**

5.2 Mug-Share return device

Item	Cost
Raspberry Pi 3 Model B	$ 49.95
RFID reader	$ 31.20
TOTAL	**$ 81.15**

APPENDIX A - Figures
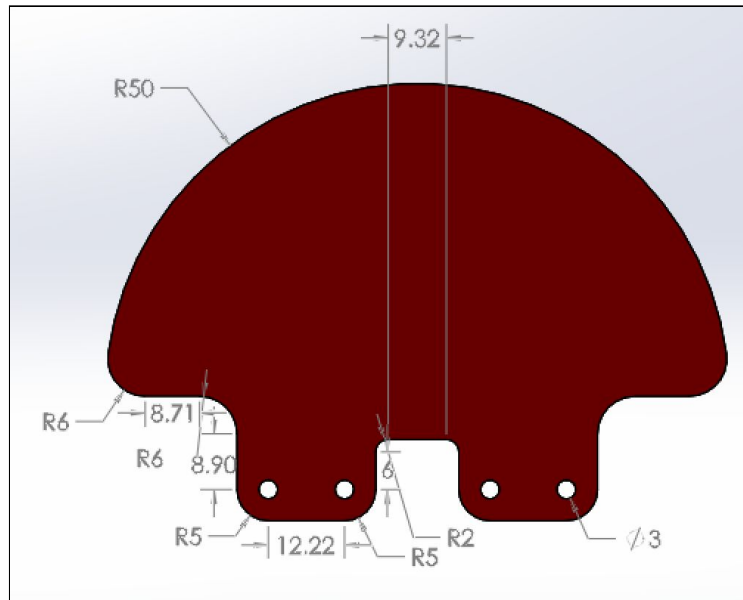
Figure A-1. Paddle servo attachments, with dimensions measured in millimeters.

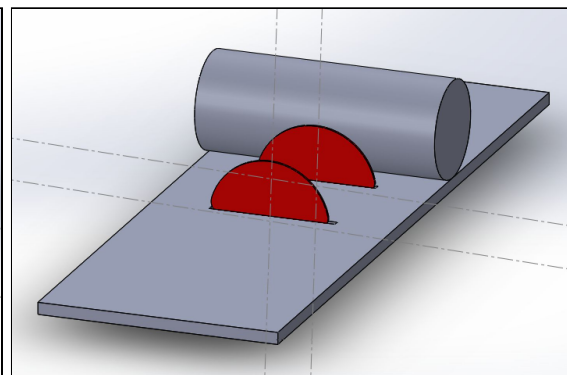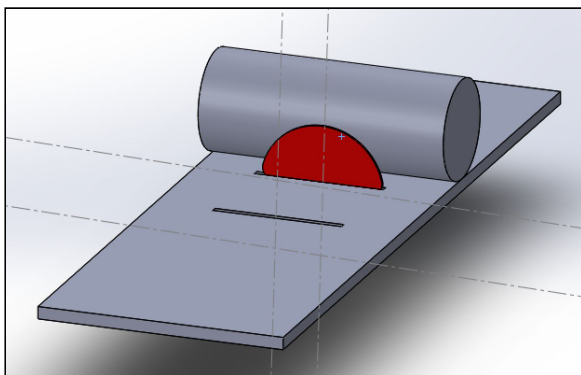(a)   (b)
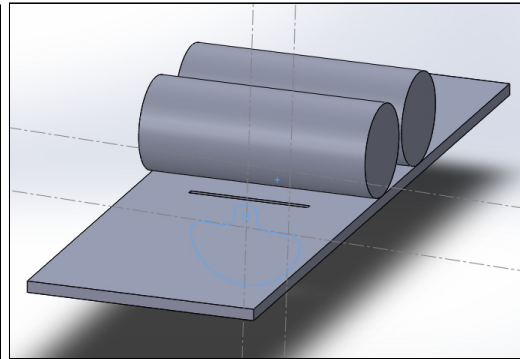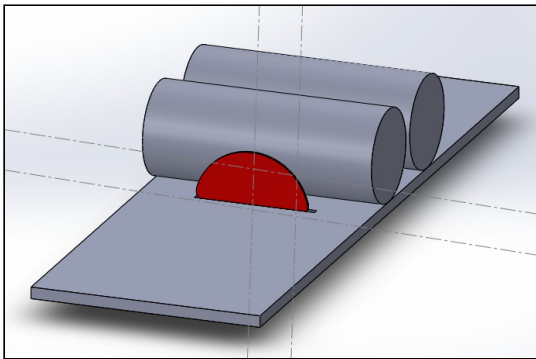
(c)   (d)

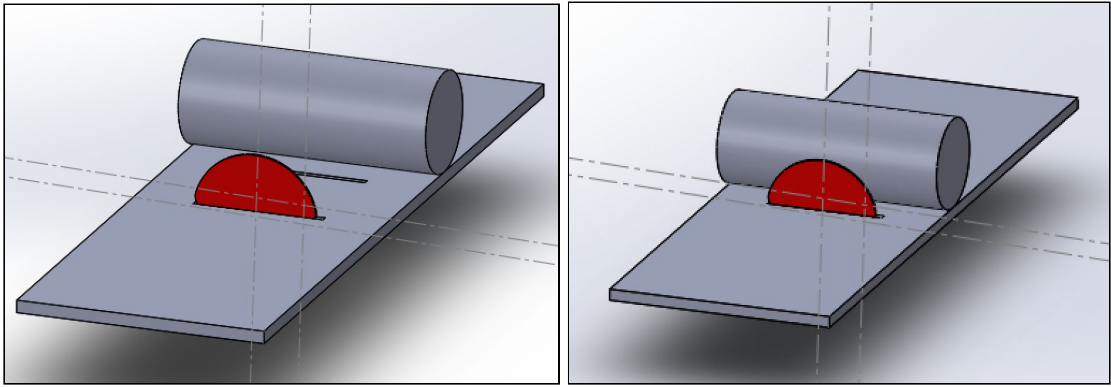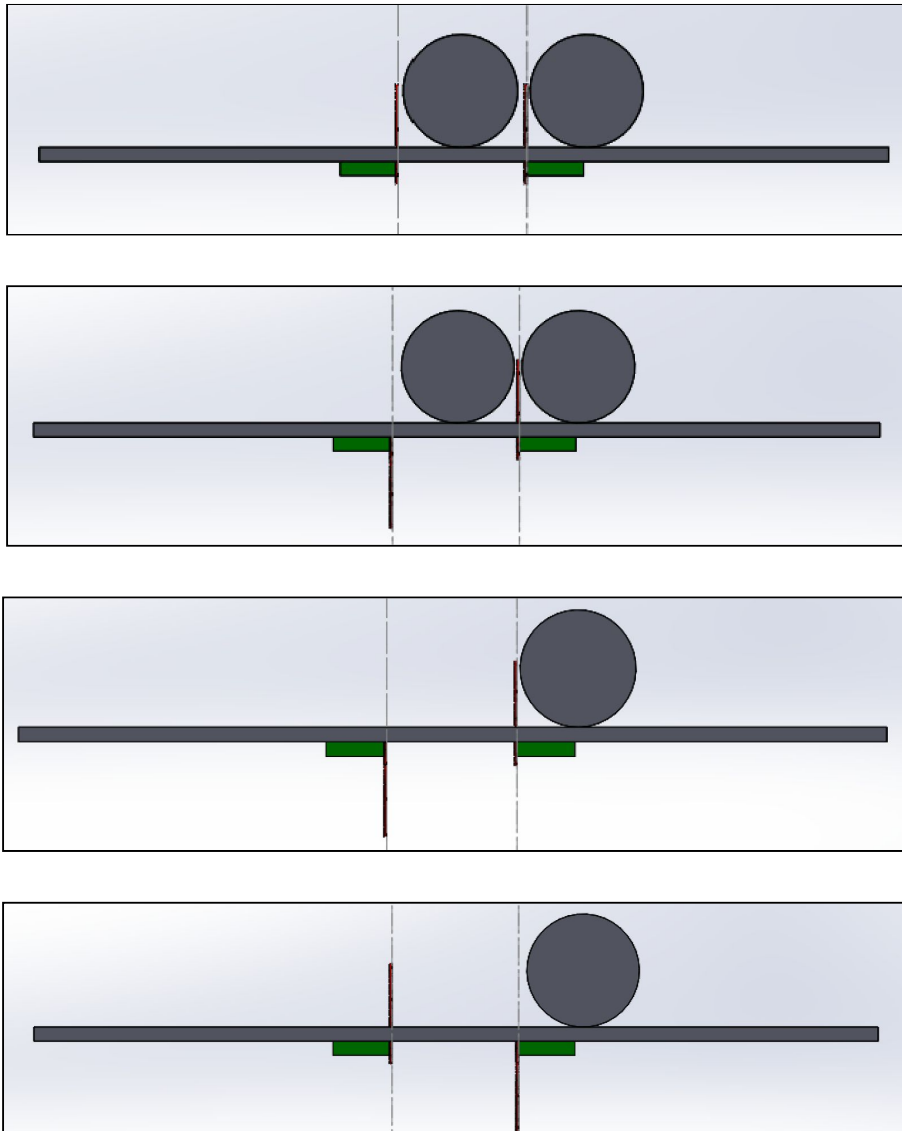(e)   (f)
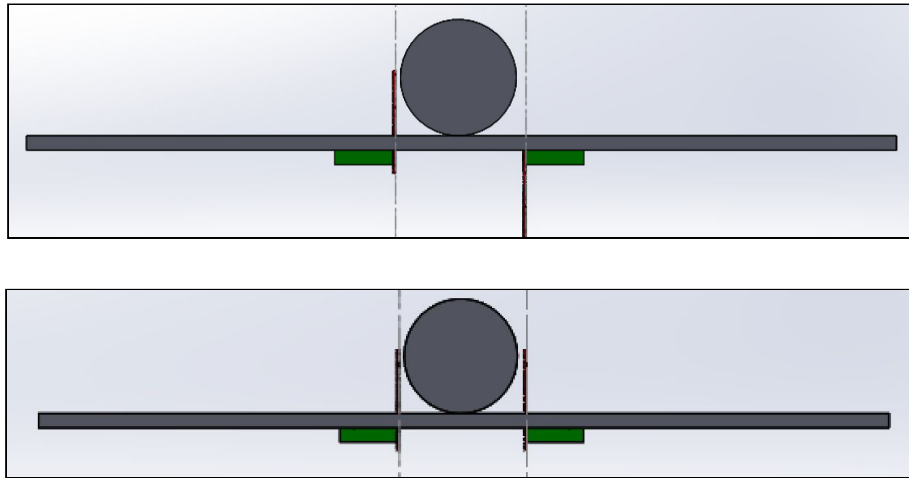
Figure A-2. Demonstration of dispensing mechanism

Figure A-3. Demonstration of dispensing mechanism (side view, incline not shown)