Foodlocker: an Online Marketplace for Automated Meals

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Food Locker: An Online Marketplace for Automated Meals

by

Josiah Buxton

B.S. Computer Engineering, Elizabethtown College, 2015

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This thesis entitled:
Food Locker: An Online Marketplace for Automated Meals
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has been approved for the Department of Computer Science

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Date ________________

The final copy of this thesis has been examined by the signatories, and we find that both the
content and the form meet acceptable presentation standards of scholarly work in the above
mentioned discipline.
Josiah Buxton,  (M.S., Computer Science)

Food Locker: An Online Marketplace for Automated Meals

Thesis directed by Professor Shivakant Mishra

Food waste is a major problem for the human race, particularly in "rich" industrial countries. We propose a creative, partial solution to this problem through the development of an online marketplace for left-over food and a physical infrastructure to secure the food throughout each transaction.

The software platform will consist of three separate portions: a mobile food consumer application, a mobile food provider application, and a web food provider application. Restaurants and other licensed food distributors can utilize the food provider applications to broadcast available left-over meals, which can be purchased at a discounted price. The hardware infrastructure will be composed of "food lockers," refrigerated units that automatically dispense food to consumers.

As this vision is ambitious, the goal of my thesis was to develop the software platform and a small prototype with two individual lockers to demonstrate the functionality of the entire system. An experiment was constructed to validate the correctness of multiple, synchronous calls to consumer/provider functions. Results indicate that this system is near ready for small scale deployment.
Dedication

To my family.
Acknowledgements

I want to thank the entire Computer Science department, but also a few influential faculty/staff who supported me throughout my time at the University of Colorado Boulder.

First, Rajshree Shrestha who answered any/all questions impeccably pertaining to the degree I was pursuing. She was an invaluable resource, particularly when I was pursuing avenues in professional development. Second, Shivakant Mishra who taught my favorite course in the CU Boulder Computer Science department (Distributed Systems) and who advised me throughout the last year. His advising strategy gave me an ownership mentality in my thesis and he always provided me with gentle direction at pivotal points throughout the process. Finally, Rhonda Hoenigman for whom I was a Teaching Assistant in two courses (Data Structures and Algorithms). During meetings and other interactions with Rhonda, I observed true leadership and management skills. Her ability to make just decisions on controversial issues in a timely manner led to incredibly smooth semesters. Also, her ability to understand a multitude of perspectives and communicate them, made the class feel cohesive and led to satisfaction for everyone who participated in the course.

I also wanted to thank my family and friends who have supported me always and they are the main reason why this thesis was completed.
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Chapter 1

Introduction

1.1 Motivation

Food waste is a recent problem for the human race and already, there are mind-baffling statistics that demonstrate the scope and severity of it. The Environmental Protection Agency released a graphic that demonstrates the rate at which food waste is growing in the United States.

Since the 1980’s, food waste estimates for the United States more than tripled. Even though this statistic is sensitive to a variety of variables (human population, food generated, etc.), the magnitude is enough to illuminate the growing problem of food waste. Another statistic from the Food and Agricultural Organization of the United Nations estimates that over a third of all
produced edible food is either lost or sent to a landfill [11]. Pair this, with a statistic from the World Food Programme that estimates one in nine people go to bed on an empty stomach every night [14]. The paradoxical nature of these statistics indicates that the human race has the opportunity to solve a major logistical problem of diverting food which would normally be thrown away in a landfill, to hungry individuals. As there is not a single optimal solution that will solve this logistical problem entirely, multiple partial solutions can be applied to mitigate both food waste and world hunger.

1.2 Overview

The goal of this thesis was to provide a creative, partial solution to the food waste problem. After performing preliminary research and a multitude of empathy interviews [17] with food providers and consumers, our solution was the development of a platform to facilitate the transactions of residual food. I will begin by presenting related works, each of which heavily influenced our design decisions of the system. Next, I will introduce the design and implementation of the platform along with an experiment to validate the correctness of different functions within the system. Finally, I will present and analyze results of the experiment which will serve as an indication of the system being ready for small-scale deployment. Future work in this area could result in a fully functional, world wide platform for residual food transactions.
Chapter 2

Related Work

2.1 Introduction

There has been an enormous amount of research performed in the area of food waste, so this section will focus more particularly on previously implemented systems (hardware/software) pertaining to food waste/sharing. Restaurants throughout the world have been integrating more and more technology into their daily processes, due to its ability to drive revenue. A recent study proves this, where the authors analyze the effects of implementing different food sharing models (through technological systems) into existing restaurants. After a hierarchical cluster analysis of over 50 companies, the authors came to the conclusion that implementing one of the food sharing models at an organization lead to a larger social impact for the organization [10]. A few of the companies which are very similar to the idea of Food Lockers will be presented in this section, along with a few peer-reviewed publications.

2.2 Organizations

Waste No Food is a registered non-profit organization whose mission is to reduce the amount of food waste at different organizations. They do so, by providing a web-based marketplace application which connects organizations with excess food to charities in need of food [12]. Some of the problems addressed in their application are similar to potential problems in the scope of this thesis. For example, Waste No Food must validate registered charity organizations which is analogous to Food Locker validating registered restaurants with the state. Also, in order to increase the acces-
sibility to the marketplace they created, Waste No Food has developed two mobile applications in addition to the web application. Because Waste No Food is a national organization and has partnerships with large well-known companies, their applied solutions to the stated problems seem successful.

Food For All is another organization that hosts a food-sharing platform for leftover food at different restaurants and organizations. Their business model gives organizations with leftover food the opportunity to broadcast it on a web-based application and have consumers purchase and pickup the food within a designated time interval [6]. The organization seems mostly geared towards restaurants who prepare food in large quantities and tend to have a lot of leftover (hotels, bakeries, etc.). Purchases give consumers a digital coupon to show participating restaurants. Feedback was gathered from a primary source who described the entire transaction process as "clunky and inconvenient." Currently, the startup company has participating restaurants in Boston and New York City and is continually expanding.

Eatsa is a company whose mission is to integrate technology into the restaurant business to lower costs and improve food quality. Rather than focusing on food waste, they focus on streamlining the dining experience. They provide a variety of scalable solutions for restaurants, which include hardware and software to support the business needs. A web and mobile application platform are both options that can be selected to be apart of a solution for a restaurant. One unique feature they offer, is a solution for order pickup called the "cubby pickup system" where fulfilled orders can be picked up by their owners at a secured location in the restaurant. Eatsa has been successful after re-branding from a "robot-run" fast casual eatery to a technology manufacturing company [3].

2.3 Peer Reviewed Publications

Timothy Richards and Stephen Hamilton recently published an article pertaining to food waste in the sharing economy [15]. They performed a study which investigated the "potential for commercial peer-to-peer mutualization systems (CPMSs)" by analyzing a current CPMS firm,
Imperfect Produce. After developing an empirical model using data from Imperfect Produce, they were able to make empirical estimates for supply and demand in the market. There were many findings in testing for the viability of a secondary market which included "ugly foods." First, they found that increasing the variety of foods food suppliers had to offer led to a rise in consumer demand. Inversely, the food suppliers were more likely to become users on the site if there were more consumers present. The study also was the first to document "indirect network effects" in CPMS organizations which is an early indicator of success for startup companies.

A group of professors from independent universities in Australia worked together to build a conceptual smart food container for food suppliers to fill when donating food to charity [2]. The container is designed with a multitude of sensors (proximity, temperature, humidity, RFID, vision) in order to detect when food is added to the containers and to maintain the correct environment for different foods. While the container was not physically built, design documentation was provided to conceptualize the entire system.

Professors from independent universities in Austria developed a public cooling system that would facilitate food sharing between individuals and organizations [13]. Focus groups and a field test was performed to gauge the general interest of these cooling stations. The team found that many people were hesitant to participate in using the system because of "trust" issues with the food they would purchase. The focus groups gave valuable feedback on the design of the system, particularly the registration process and gamification of the system. The registration process was found to be too bulky, the system required too much information from the user. All of the individuals in the focus groups believed that gamification/rewards system would be a great feature to be added to the system. They also found that the most difficult hurdles in developing the system were the legal and hygienic issues.
Chapter 3

Methodology

3.1 Introduction

After initial research was performed, much time was spent in developing the architecture for the proposed system. Within this section, the final architecture, which includes all subsystems, will be presented as well as the experiment, which validates the correctness of the functions implemented in system.

3.2 Design Development

Before the system was even proposed, primary data was gathered to determine what features were desired by the potential users. Over seventy-five different undergraduate students from the University of Colorado Boulder were interviewed. The first few questions pertained to a student’s willingness to purchase food, which was considered ”left over”, at a discounted rate. The responses from students were overwhelmingly positive in the sense that they were very willing to purchase this type of food. This may have been due to the narrow demographic of people we targeted in interviews, but regardless the responses made it clear there is a market for leftover food. Along with asking the students about their willingness to purchase leftover food, questions were asked about the largest complaint they had with their current meal plan on campus. The questions were designed to allow the interviewee to reflect on some sort of experience that invoked much emotion. A recurring theme was heard in the responses: students were disappointed with the time that the dining halls closed. They are unable to access the food they are paying for when they are awake.
and hungry. The feedback received from the students led to the design of an automated system that would make leftover food from universities’ dining halls available to students twenty four hours a day.

Primary data was also gathered from restaurants/organizations to determine whether there was enough wasted food for a solution to be developed. Five to ten minute interviews were conducted with general managers at over twenty restaurant locations. In the interviews, questions about how much food waste was generated at a restaurant and if they thought it would be worth them addressing the problem (if it existed). From the interviews, it was clear that small restaurants who employed long term employees were the least likely to have large amounts of food wasted whereas larger restaurants with a high turnover rate were the most likely. This discovery led to multiple talks with the University of Colorado Boulder who fit the profile of a food provider that generated a lot of food waste. The university confirmed that they generated a lot of food waste but tried to donate as much as possible to different charities. They were willing to help pilot ideas to address food waste but they were adamant about having anything physical certified before adapting it into their current operations.

From all the feedback gathered, a potential solution was proposed to address food waste as well as address the problem of food inaccessibility different students at the University of Colorado Boulder experienced. Food lockers would provide a storage location for excess food that the University’s dining halls possessed, and it would allow students to access meals that they’ve already paid for after the dining halls closed. The idea would be for dining hall employees to package up the excess food at the end of the day into individualized meals, host the meals on FoodLocker’s online marketplace, and drop off the meals into the lockers so students could claim them. Design decisions were made to make this process as streamlined as possible, so as to be unobtrusive when introduced into dining hall employees’ processes.
3.3 System Design

3.3.1 Firebase

Before development of any of the subsystems could begin, a database needed to be selected to hold the information associated with the system. Some major features which were required to be present in the database included: offline functionality of the applications utilizing the database, ability to upload pictures, scalability, analytics, and error reporting. The features are ordered by importance from greatest to least. Firebase is a NoSQL database which exhibits all of the required features to some extent, as well as a multitude of other features. Food Locker only utilizes three of the major modules in Firebase: Authentication, Cloud Storage, and Realtime Database. The authentication module allows the Food Locker system to create, store, and manage unique users associated with the application. The Cloud Storage module gives the system the functionality to store and retrieve different photos related to users/organizations. The Realtime Database module stores almost all of the other information associated with the system formatted in Javascript Object Notation (JSON). All of the modules utilized in Firebase are under the ”Pay to Scale” marketing model, which means the service will be free of cost until a certain threshold of traffic is met. Firebase is the core service which every other subsystem interacts with.

3.3.2 Consumer Mobile Application

The first subsystem that was developed was the consumer mobile application. This application allows consumers to browse available meals within different food lockers, purchase the meals, and pickup the meals. The application was developed on the React Native framework mainly due to the astonishing amount of documentation and 3rd party packages on the web, which allowed for rapid troubleshooting of bugs/issues and agile development of components. Also, the framework utilizes a single source of Javascript and compilers can be downloaded, which will convert the Javascript to IOS and Android applications. This means that one code base needs to be maintained in order to develop an application for both mobile platforms.
Table 3.1: Suite of the functions implemented in the consumer mobile application.

<table>
<thead>
<tr>
<th>List of Functions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Search Food Locker locations using Google Maps API</td>
<td>Search different available meals using a phrase (Categorically)</td>
</tr>
<tr>
<td>Login</td>
<td>Logout</td>
</tr>
<tr>
<td>Signup</td>
<td>Search all available meals</td>
</tr>
<tr>
<td>Search available meals in a particular Food Locker</td>
<td>Search available meals by meal category (Asian, American, etc.)</td>
</tr>
<tr>
<td>Purchase a meal using Stripe API</td>
<td>View order history</td>
</tr>
<tr>
<td>Navigate to Food Locker location from current location/specified location using Google Maps API</td>
<td>View/edit personal information including custom headshot</td>
</tr>
<tr>
<td>View/edit billing information</td>
<td>View/edit application specific settings</td>
</tr>
</tbody>
</table>

Table 3.1 lists the functions implemented in the consumer mobile application. The application grants the user the ability to search for meals in a variety of different contexts. This was done to ensure that the user can easily view and purchase the available meals. Refer to Appendix A to view screen shots of all the screens in the application.

The entire consumer mobile application consists of 38 different packages (Refer to appendix B for a complete listing). Two of the major development packages that were used were expo and babel. Expo is a toolchain specifically developed for React Native applications. It provides a framework for hosting the application as it was being developed and offers "hot-reloading" functionality which automatically reloads the mobile application on a test device when changes are saved to the code base. This saved an enormous amount of time during the development process. Babel is another tool chain that transcribed code written in newer versions of JavaScript (ES2015+) to older versions of JavaScript in order to provide functionality to older operating systems. It also transcribes JSX and React syntax (which is the base of React Native) into JavaScript.

Four of the major packages that provided a lot of functionality to the overall system were Stripe, React, Yaqrcode, and Firebase. Stripe is a package that provides a channel of communication to an existing stripe database. The database stores sensitive user information, including
credit cards, and allows users to make purchases from different organizations. Currently, when a transaction is initiated, money sent from the consumer is deposited into a bank account associated with Food Locker Technologies LLC. The information is recorded and revenue generated will be sent to their respective organizations at the end of each month.

React is a JavaScript library for building different user interfaces. It provides almost all of the visual components and helped expedite the development process. Yaqrcode is a package that generates QR codes after given a string of characters. This package was used to streamline the processes of picking up a meal at a food locker and loading a meal into the food locker. Firebase is the package that provides a channel of communication to each of the Firebase modules: authentication, cloud storage, and realtime database. Each of the 38 packages installed in the project either provides some sort of functionality or enhances the user experience.

### 3.3.3 Restaurant Mobile Application

The second subsystem that was developed was the restaurant mobile application. This application allows restaurant employees to generate different virtual meals that can be broadcasted to consumers. After a meal is generated, a QR code is associated with the meal and it is used to open an empty locker door on a food locker. After the meal is placed in the locker and the door is closed, the meal is then broadcasted to consumers on a first come, first serve basis. Much of the codebase from the consumer mobile application was used in the development of the restaurant mobile application. To accentuate this point, all of the packages in the restaurant application are present in the consumer application. The only differences in the applications are the functions provided to the user and the screens themselves.

Table 3.2 lists all of the functions implemented in the restaurant mobile application. Refer to Appendix C to view all of the screens associated with the restaurant mobile application.
Table 3.2: Suite of the functions implemented in the restaurant mobile application.

<table>
<thead>
<tr>
<th>List of Functions</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Generate a unique, virtual meal to be placed in a food locker</td>
<td>Generate a new template to save time when generating meals</td>
</tr>
<tr>
<td>View/edit existing templates</td>
<td>View food locker information (claimed meals, active meals, recently picked up meals)</td>
</tr>
<tr>
<td>View/edit application specific settings</td>
<td>View/edit personal information including custom headshot</td>
</tr>
<tr>
<td>Navigate to Food Locker location from current location/specified location using Google Maps API</td>
<td>View organization associated with current user</td>
</tr>
<tr>
<td>Login</td>
<td>Logout</td>
</tr>
</tbody>
</table>

### 3.3.4 Restaurant Web Application

The third subsystem that was developed was the restaurant web application. This application was developed in order to provide restaurants with an alternative method of accessing FoodLocker’s online marketplace platform. Feedback was received from restaurants after building the restaurant mobile application, and the largest concern from the managers of the restaurants was that the mobile application would give an excuse for employees to be on their phones an unreasonable amount of time. Since almost all restaurants own some sort of computerized POS system that already contains a web browser, the web application was a less intrusive solution to accessing the online marketplace as well.

The restaurant web application contains all of the same functionality laid out in Table 3.2 (functions implemented in the restaurant mobile application). The web application also implements a statistics screen, which allows restaurant employees to view data associated with the meals broadcasted and sold through the FoodLocker framework. It also implements a calendar screen, which is still in the development phase, and will eventually be connected to a restaurant’s inventory. It will show restaurant employees when raw ingredients were purchased and will provide notifications to the users when ingredients are reaching the end of their shelf life.

The web application utilizes 44 total packages (refer to Appendix F for a complete listing).
Most of the packages were similar to the packages implemented in the mobile applications. Two major unique packages that were required for the web application to function properly were Redux and CoreUI. Redux is a state container that helped maintain a user’s “state” throughout the application. This stored all of the relevant data pulled from Firebase and allowed the application to access this data as the user browsed between different pages. CoreUI was a free template for an administrative dashboard. It provided the styling of the web application.

Refer to Appendix E to view all of the screens associated with the restaurant web application.

3.3.5 Food Locker

The final subsystem that needed to be designed and constructed was the physical food locker that secures meals during each transaction. Due to time constraints, the food locker was designed to minimally demonstrate the functionality of the entire system. Note that this means the prototyped locker is not currently temperature controlled.

The locker is a 44” x 17” x 13” wooden box that is compartmentalized into two individual lockers and an electrical component container. Each individual locker contains an electromagnetic locking mechanism that is controlled by a Productivity 1000 PLC (programmable logic controller). The locking mechanisms are powered by a 60 watt 12V power supply and can supply up to 600 lbs of locking force.

A Honeywell MK7580 2 dimensional barcode scanner is mounted on top of the locker. The scanner is connected via USB to the computer which runs the C# application and Python script which allows users to interface with the locker. When users scan their QR code associated with an order, the information is retrieved over USB through the python script. The python script then communicates with Firebase to determine which individual locker the meal is stored in. When the locker is determined, the python script communicates over Modbus TCP/IP to the PLC, which then sends a control signal to the electromagnetic locking mechanisms to open the correct door.

The bill of materials for the food locker is specified in Appendix G. User manuals for any component are available by request. An initial 3D model was developed in Google Sketchup and
screenshots are available in Appendix H. Pictures of the finished locker are also available in Appendix H.

3.3.6 Experiment

After spending a few months developing the system, an experiment was developed to validate the correctness of the functions implemented within the software sub-systems. The three day experiment consisted of a multitude of users creating accounts, performing a set of daily functions, and logging data associated with the functions into a Google Sheet. The data logged from the users was then cross-referenced with the data within the Firebase database at the end of the experiment which provided an indication of which functions were correct/incorrect.

In order to perform the experiment, first a list of twenty eight users was compiled. The list consisted of the name of the participant, his/her email address, a simulated user category (Consumer or Restaurant Employee), and a user ID. Five out of twenty eight participants were placed in the restaurant employee category and twenty three participants were placed in the consumer category. This was done to simulate an accurate ratio of consumers to restaurant employees when the system is publicly available. Because the participants both used iOS and android devices, the mobile applications were hosted on both Apple’s App Store and Google’s Play Store. Apple provides a tool called TestFlight, which allows for closed beta testing of an application before making it publicly available. Google offers the same functionality and both these tools were utilized for this experiment.

Next, a list of twenty one unique functions for the participants to perform was developed. Fourteen out of twenty one functions were implemented functions in the consumer application and the same is true for the restaurant application. There were seven functions associated with a user’s profile which were implemented in both applications.

Finally, schedules were compiled and shared to each individual user. Users who were in the consumer simulated user category were asked to complete five different tasks each day, that would take them no longer than ten minutes to complete. Conversely, users in the restaurant
employee simulated user category were given ten daily tasks to complete which mainly consisted of hosting meals in order to ensure there was enough meals hosted for consumers to virtually purchase (the payment system was disabled so no money was transferred during virtual transactions). The schedules contained columns for logging pertinent data and feedback associated with the performed functions. The data collected in these columns were used to generate the results in the next section. To view templates of these schedules, refer to Appendix I.
Chapter 4

Results

The performed experiment returned data that allowed us to understand the current state of the developed system and how the system performed with a multitude of users using different devices. Twenty five out of the twenty eight participants in the experiment installed the application. 56% of those users installed the iOS application from TestFlight and 44% installed the android application from the Play Store.

![Pie Chart](percentage.png)

Figure 4.1: This graph is a depiction of the percentages of iOS, Android, and no installations associated with the mobile applications during the course of the 3 day experiment.

After all of the applications were downloaded the first day, the simulated consumers were asked to test updating their personal information associated with their account. For a portion of iOS users, the consumer application exhibited a bug where the navigation drawer would appear as a blank white screen. This behavior rendered six out of the fourteen functions unavailable
to the user. The simulated restaurant employees were tasked with uploading 5-10 meals so that they would be available the next day for the consumers to virtually purchase. Over the next two days, consumers mainly were tasked with purchasing meals and testing two other functions associated with navigating to the locker that held their order. Restaurant employees were tasked with uploading more meals/templates and testing out updating information in their user profile. Below are two different graphs that show different statistics associated with the number of meal purchases and listings over the course of the experiment.

Figure 4.2: This graph is a depiction of the number of meals listed vs the number of meals purchased per 8 hour periods over the course of the experiment.

Figure 4.3: This graph is a depiction of the number of meals purchased by all of the users over the course of the experiment.
In figure 4.2, the shape of the data gathered was expected, but the magnitude of the meals purchased was half of the expected value. This was due to a bug in the iOS mobile consumer application. Users could purchase a meal but the payment information field was undefined due to the disabling of the payment system immediately before hosting to TestFlight. The undefined field invalidated the entire transaction but did not crash the application. Figure 4.3 also gave unexpected results due to this bug in the iOS mobile consumer application. Because 56% of all the participants were using iOS, Figure 4.3 showed less than half of the participants made a transaction.

After the experiment completed, all of the Google Sheets containing the participants’ schedules and feedback were collected. Each of the "Relevant Information" cells from completed actions was then verified in the database at the appropriate depths. All information from successful transactions were present within the Firebase database and information from the unsuccessful transactions were not present. This was because of unit tests that were implemented within the mobile applications to verify the data before uploading to the database. This ensured that an error would not propagate to the database and therefore potentially crash the applications that interface with it. In figure 4.4 below are two different stacked bar charts that depict the number of correct vs incorrect functions tested in the experiment in both mobile applications. The large amount of incorrect functions in the iOS application were due to the development of the original application on an Android device. When the application was going to be hosted to the App store and Play store, compiling the iOS application led to finding an incompatible package. When I removed the incompatible package, I introduced a few bugs in the payment and profile information update process.
Figure 4.4: This graph is a depiction of the number of correct vs incorrect functions that were tested in the experiment. Data is shown for both iOS and Android applications.

Figure 4.5: This graph is a depiction of the number of correct vs incorrect functions that were tested in the experiment. Data is shown for both iOS and Android applications.
Chapter 5

Discussion

The data presented in the results section makes it clear that there is still work to be done before this system will be able to be tested in a professional environment. The experiment illuminated a list of fourteen bugs to fix and functionality to add into the next version of the consumer application. Since the experiment, thirteen out of the fourteen items have been addressed and new versions have been posted to the Google Play Store and App Store. A table depicting these fourteen issues are available in Appendix J. The results from the experiment also indicate that the database is well suited to support the traffic generated from a single small-sized restaurant (around twenty transactions per day). Users reported a snappy interface, even during transactions when information is being transferred to and from the Firebase database. More experiments will need to be run in the future with a larger participant pool in order to determine whether this system is ready for full-scale deployment.

Future work could include another experiment to test the hardware developed. The hardware has been tested on a small scale with only two to three users, but not formally, and with a larger user pool. Running another small scale experiment in a professional environment will give us the opportunity to test the social utility of the system and gauge how much food a single locker can save as well as how much extra revenue could be generated for the restaurant. We estimate small restaurants could generate a few hundred dollars of extra revenue and save twenty to thirty meals a day (five to twenty pounds of food). Also, the mobile applications could have gamification implemented within them to motivate users to utilize the application more. Design reviews must
be done with state food safety departments in order to get the physical hardware to a certifiable state. After becoming certified, the lockers will be able to be sold to restaurants on a large scale.

All in all, Food Locker has been developed to a point where it’s almost ready to be dispensed into a small-scale professional environment. Most of the functions implemented in the mobile applications are correct and a physical prototype of a food locker has been built. Work will be continued in the future to gauge the social utility of the system before it’s administered to restaurant locations around the country.
[1] C. R. Chen and Rachel J. C. Chen. Using two government food waste recognition programs to understand current reducing food loss and waste activities in the u.s. Sustainability, 10(8):2760, 2018. Name - Environmental Protection Agency–EPA; Copyright - 2018. This work is licensed under https://creativecommons.org/licenses/by/4.0/ (the License). Notwithstanding the Pro-Quest Terms and Conditions, you may use this content in accordance with the terms of the License; Last updated - 2019-02-05; SubjectsTermNotLitGenreText - United States–US.


[8] Lisa Jennings. What restaurants can do to reduce food waste. Food management, Feb 08 2018. Name - Aramark Corp; Twitter Inc; Cornell University; Bon Appetit; Copyright - Copyright Penton Media, Inc., Penton Business Media, Inc. Feb 8, 2018; Last updated - 2018-06-14; SubjectsTermNotLitGenreText - United States–US; New York; Massachusetts; San Francisco California.


Appendix A

All Consumer Mobile Application Screens

Figure A.1: Home Screen after a user has logged in. Shows different food lockers (using map markers) in a radius around the user’s current location. Meal radius is specified in user’s settings. A search bar is present at the top to search meals/location/categories using a phrase.

Figure A.2: Screen displaying the overlay that opens when a user begins typing a phrase in the search bar. The inputted phrase is searched over three different categories: locations, meals, and categories. Each line item is touchable and links a user to the associated item’s screen.
Figure A.3: Login screen, which allows users to log into their personal account. They have the option to sign up which sends them to a different screen almost identical to this one but with an extra confirm password input text box. A successful login sends the user to the home screen.

Figure A.4: Drawer overlay screen that enters the user’s view when the upper right hand icon is touched (present on almost every screen). Lists different links that enable the user to navigate to most of the screens in the application.
Figure A.5: Location screen that shows the information associated with a particular food locker. You can get directions to the locker using the Google Maps API or view all of the meals currently in the food locker.

Figure A.6: Meal search screen that allows users to choose to browse meals filtered by cuisine categories or without a filter.
Figure A.7: Cuisine categories screen that shows the 7 different available cuisine categories. Touching one of the categories links the user to the meals within the cuisine category, which are within the user’s meal radius.

Figure A.8: Meals screen that displays a list of meals. Meals change based on what was the user’s previous screen. Touching one of the meals links the user to more information about the meal and gives the option to the user to purchase the meal.
Figure A.9: Meal radius screen that allows user to select the radius (in miles) of the searching filter. All information within the foodlocker system that is outside of the radius is not shown in the consumer mobile application’s screens.

Figure A.10: Directions screen which utilizes Google Maps API. Destination location is sent from the previous screen. Source location is populated with the current location of the phone.
Figure A.11: Profile information screen which allows users to view/edit 5 different attributes associated with their user profile: head shot, name, email address, phone, and password.

Figure A.12: Billing information screen which allows users to view/edit billing information data so the user can purchase meals. All data is stored and retrieved through the Stripe API in order to ensure security.
Figure A.13: Screen that allows users to add a new credit card to their profile. Credit card information is dynamically updated on the virtual card as the user enters it. All data is stored and retrieved through the Stripe API in order to ensure security.

Figure A.14: Orders screen that allows users to view current orders or a history of orders. A snippet of order information is displayed on each of the cards and touching one of the cards links the user to a screen containing more information about the associated order.
Figure A.15: Order screen that gives information about a particular order. Also, shows a QR code associated with the order’s/meal’s unique identification number. First of two screen shots.

Figure A.16: Order screen that gives information about a particular order. Also, shows a QR code associated with the order’s/meal’s unique identification number. Second of two screen shots.
Appendix B

Packages Utilized in Consumer Mobile Application (package.json)

```json
{
  "name": "fudlkr_consumer",
  "main": "node_modules/expo/AppEntry.js",
  "private": true,
  "scripts": {
    "start": "expo start",
    "android": "expo start --android",
    "ios": "expo start --ios",
    "eject": "expo eject"
  },
  "dependencies": {
    "dateformat": "^3.0.3",
    "email-validator": "^2.0.4",
    "firebase": "^5.7.0",
    "firebase-admin": "^6.3.0",
    "firebase-functions": "^2.1.0",
    "firebase-tools": "^6.1.2",
    "material-design-icons": "^3.0.1",
    "payment-icons": "^1.1.0"
  }
}
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"react": "^16.6.1",
"react-native": "^0.57.7",
"react-native-awesome-card-io": "^0.8.1",
"react-native-checkout": "0.0.8",
"react-native-credit-card-input": "^0.4.1",
"react-native-elements": "^0.19.1",
"react-native-fbsdk": "^0.8.0",
"react-native-firebase": "^5.1.1",
"react-native-google-maps-directions": "^2.0.0",
"react-native-keyboard-aware-scroll-view": "^0.7.4",
"react-native-maps": "^0.22.1",
"react-native-parallax-scrollview": "^3.0.0",
"react-native-rate": "^1.1.6",
"react-native-router-flux": "^4.0.5",
"react-native-search-filter": "^0.1.4",
"react-native-super-grid": "^2.4.3",
"react-native-vector-icons": "^6.0.2",
"react-navigation": "^3.0.9",
"react-redux": "^5.1.0",
"redux": "^4.0.1",
"stripe": "^6.18.1",
"toggle-switch-react-native": "^2.0.2",
"yaqrcode": "^0.2.1"
},
"devDependencies": {
"babel-eslint": "^10.0.1",
"babel-preset-expo": "^5.0.0"}
"eslint": "^5.10.0",
"eslint-plugin-react": "^7.11.1",
"expo": "^31.0.6",
"expo-gl": "^1.1.0",
"schedule": "^0.4.0"
},
"rnpm": {
  "assets": [
    "./assets/fonts/
  ]
}
}
Appendix C

All Restaurant Mobile Application Screens

Figure C.1: Login screen, which allows users to log into their work account. Users do not have the option to signup. When a new organization partners with FoodLocker, the organization will provide a technical representative with a file containing all of the information associated with the employees of the organization. A successful login sends the user to the locations screen.

Figure C.2: Screen displaying all of the lockers associated with a particular organization. Allows the user to select a locker to bring them to a dashboard, which provides relevant information associated with the locker.
Figure C.3: Screen displaying three categories of information associated with a particular locker. Claimed Inventory contains meals that have been purchased by a consumer but have not yet been picked up from the locker. Active Inventory contains meals that are currently within the locker but have not been purchased. Recently picked up meals are meals that have been purchased and picked up by the consumer in the past 24 hours.

Figure C.4: Screen displaying all of the templates associated with an organization. The templates can be selected to quickly add common meals that are made and hosted by the organization. Selecting a template will send the user to the "Add Meal" screen. Selecting the plus icon in the top left corner will send the user to the "Add Meal" screen as well, but with no pre-populated information.
Figure C.5: Screen that allows users to add a brand new template and/or a new meal to the locker. After the user populates the information associated with the meal, which is being hosted, the user can press the "Add New Template" button at the bottom of the screen to save the template for future use. An algorithm checks to ensure the template is unique before saving the template to the database.

Figure C.6: Screen which allows a user to host a new meal and add the meal to the locker. After the user populates the information associated with the meal, the user can press the "Add meal to locker" button. An algorithm is run to ensure the locker unit, which the meal is potentially being added to, has space, and selects an empty individual locker where the meal can be placed.
Figure C.7: Drawer overlay screen that enters the user’s view when the upper right hand icon is touched (present on almost every screen). Lists different links that enable the user to navigate to most of the screens in the application.

Figure C.8: Screen which allows a user to view the settings associated with his/her personal account. Also allows the user to view information about FoodLocker or FoodLocker’s application.
Appendix D

Packages Utilized in Restaurant Mobile Application (package.json)

```json
{
  "main": "node_modules/expo/AppEntry.js",
  "scripts": {
    "start": "expo start",
    "android": "expo start --android",
    "ios": "expo start --ios",
    "eject": "expo eject"
  },
  "dependencies": {
    "dateformat": "^3.0.3",
    "email-validator": "^2.0.4",
    "expo": "^31.0.2",
    "firebase": "^5.7.0",
    "firebase-admin": "^6.3.0",
    "firebase-functions": "^2.1.0",
    "firebase-tools": "^6.1.2",
    "react": "16.5.0",
    "react-native": "https://github.com/expo/react-native/archive/sdk-31.0.0.tar.gz"
  }
}
```
"react-native-checkout": "0.0.8",
"react-native-elements": "^0.19.1",
"react-native-fbsdk": "^0.8.0",
"react-native-keyboard-aware-scroll-view": "^0.8.0",
"react-native-parallax-scrollview": "^3.0.0",
"react-native-rate": "^1.1.6",
"react-native-router-flux": "^4.0.6",
"react-native-snap-carousel": "^3.7.5",
"react-native-super-grid": "^2.4.3",
"react-navigation": "^3.0.9",
"toggle-switch-react-native": "^2.0.2",
"yaqrcode": "^0.2.1"
},

"devDependencies": {
    "babel-preset-expo": "^5.0.0"
},

"private": true
Appendix E

All Restaurant Web Application Screens

Figure E.1: Login screen, which allows users to log into their work account. Users do not have the option to signup. When a new organization partners with FoodLocker, the organization will provide a technical representative with a file containing all of the information associated with the employees of the organization. A successful login sends the user to the dashboard screen.

Figure E.2: Screen displaying pertinent information associated with the lockers owned by the organization. The "Locations" section displays cards associated with each individual locker. The cards show the amount of meals sold, meals currently in the locker, locker meal capacity, and the name of the locker. The "Active Order List" shows all of the recent meals that have been purchased. Scrolling down the screen, displays more information laid out in the next screenshot.
Figure E.3: Continuation of the Dashboard screen. The "Daily Sales Report" displays all of the completed transactions in the last 24 hours.

Figure E.4: Screen displaying all of the templates associated with an organization. The templates allow restaurant employees to quickly host different meals to the online marketplace. Selecting a meal sends the user to the "Add Meal" screen.

Figure E.5: Screen displaying information associated with a meal that is about to be added to a locker. The user can change information in the fields to correctly describe the meal they are trying to host on the online marketplace. Users can either save the template or add the meal to the locker. Both of the functions are identical to the functions implemented in the restaurant mobile application.

Figure E.6: Screen displaying a calendar. Currently under development...
Figure E.7: Screen displaying statistics associated with meals sold by the organization through the FoodLocker platform. The first graph shows the total sales for a given time period. The bar graph shows the percentage of meals sold that belong to a particular meal category for a given time period. The time period can be changed in the upper right hand corner and the graphs are dynamically updated in real-time.

Figure E.8: Continuation of the statistics screen. Shows a list of the highest frequented users. Shows the total meals purchased by each user in the list. Changing the time period at the top of the page, filters the highest frequented users list.
Appendix F

Packages Utilized in Restaurant Web Application (package.json)

```json
{
    "name": "fudlkr",
    "version": "2.1.3",
    "description": "Fudlkr Restaurant Web Application",
    "author": "Josiah Buxton and ukasz Holeczek",
    "homepage": "http://fudlkr.com",
    "copyright": "Copyright 2018 creativeLabs ukasz Holeczek",
    "license": "MIT",
    "private": true,
    "repository": {
        "type": "git",
        "url": "git@github.com:coreui/coreui-free-react-admin-template.git"
    },
    "dependencies": {
        "@coreui/coreui": "^2.1.5",
        "@coreui/coreui-plugin-chartjs-custom-tooltip": "^1.2.0",
        "@coreui/icons": "0.3.0",
        "@coreui/react": "^2.1.3"
    }
}
```
"@material-ui/core": "^3.9.2",
"bootstrap": "^4.2.1",
"chart.js": "^2.7.3",
"classnames": "^2.2.6",
"core-js": "^2.6.1",
"dateformat": "^3.0.3",
"enzyme": "^3.8.0",
"enzyme-adapter-react-16": "^1.7.1",
"filepond": "^4.2.0",
"filepond-plugin-file-validate-size": "^2.1.1",
"filepond-plugin-file-validate-type": "^1.2.2",
"filepond-plugin-image-exif-orientation": "^1.0.4",
"filepond-plugin-image-preview": "^4.0.3",
"firebase": "^5.8.2",
"flag-icon-css": "^3.2.1",
"font-awesome": "^4.7.0",
"lodash": "^4.17.11",
"node-sass": "^4.11.0",
"prop-types": "^15.6.2",
"react": "^16.7.0",
"react-app-polyfill": "^0.2.0",
"react-calendar": "^2.18.1",
"react-chartjs-2": "^2.7.4",
"react-datepicker": "^2.1.0",
"react-dom": "^16.7.0",
"react-filepond": "^7.0.1",
"react-grid-layout": "^0.16.6",
"react-loadable": "^5.5.0",
"react-modal": "^3.8.1",
"react-redux": "^6.0.0",
"react-router-config": "^4.4.0-beta.6",
"react-router-dom": "^4.3.1",
"react-test-renderer": "^16.7.0",
"reactstrap": "^7.0.2",
"redux": "^4.0.1",
"redux-logger": "^3.0.6",
"redux-persist": "^5.10.0",
"redux-thunk": "^2.3.0",
"simple-line-icons": "^2.4.1"
},
"devDependencies": {
  "react-scripts": "2.1.3"
},
"scripts": {
  "start": "HOST=127.0.0.1 && react-scripts start",
  "build": "react-scripts build",
  "test": "react-scripts test",
  "test:cov": "react-scripts test --coverage",
  "test:debug": "react-scripts --inspect-brk test --runInBand",
  "eject": "react-scripts eject"
},
"bugs": {
  "url": "https://github.com/coreui/coreui-free-react-admin-template/issues"
"eslintConfig": {
  "extends": "react-app"
},

"browserslist": [
  ">0.2%",
  "not dead",
  "not ie <= 9",
  "not op_mini all"
],

"jest": {
  "collectCoverageFrom": [
    "src/**/*.{js,jsx}",
    "!*/*/index.js",
    "!src/serviceWorker.js",
    "!src/polyfill.js"
  ]
}
Appendix G

Locker Bill of Materials

<table>
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<th>Part Name and Description</th>
<th>Manufacturer</th>
<th>Qty</th>
<th>Unit</th>
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<tr>
<td>YH067</td>
<td>YANHEM 600bS Electromagnetic Lock Holding Force for Access Control Single Door 12V</td>
<td>YangHu</td>
<td>EA</td>
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<td>P3-4840</td>
<td>Productivity2000 Standalone Micro PLC</td>
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<td>P3-15102D</td>
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<td>Productivity2000</td>
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<tr>
<td>P3-3AC50</td>
<td>Productivity1000 DC Input Module</td>
<td>Productivity1000</td>
<td>EA</td>
<td>$15.00</td>
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<td>22979353</td>
<td>50 ft. 1/4&quot; Black Standard (U) Tubing x Valve</td>
<td>Home Depot</td>
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<td>HB20DC 3N-0</td>
<td>Satin Nickel Overlay Cabinet Hinge without Spring (2-Each)</td>
<td>Home Depot</td>
<td>EA</td>
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<tr>
<td>2964998</td>
<td>DIN Rail Power Supplies QUANTITY: 3/4/14 DC/240V C 2-12V</td>
<td>Phoenix Contact</td>
<td>EA</td>
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<td>5/2&quot; Construction Sleeves</td>
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<td>EA</td>
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Figure G.1: Bill of Materials for the built Food Locker prototype. All components were purchased on a budget of $600. $300 was received from “Get Seed Funding” on CU Boulder’s campus and the other $300 was contributed by family and friends. The last $110 was contributed by myself.
Appendix H

Initial 3D Model of Food Locker and Finished Prototyped Food Locker

Figure H.1: Finished prototype of the food locker.
Figure H.2: Finished prototype of the food locker.

Figure H.3: 3D model of a food locker. The model was built using Google Sketchup. Front angle.

Figure H.4: 3D model of a food locker. The model was built using Google Sketchup. Back angle 1.
Figure H.5: 3D model of a food locker. The model was built using Google Sketchup. Back angle 2.
Appendix I

Consumer/Restaurant Data Input Templates

**Figure I.1:** This is the Google Sheet template that was sent out to each of the participants in the experiment who were apart of the "Consumer" category. Participants were asked to perform each of the functions listed in the first column, and provide feedback in the last three columns. The "Relevant Information" column was cross referenced with values in the database to verify the correctness of functions.
Figure I.2: This is the Google Sheet template that was sent out to each of the participants in the experiment who were apart of the "Restaurant Employee" category. Participants were asked to perform each of the functions listed in the first column, and provide feedback in the last three columns. The "Relevant Information" column was cross referenced with values in the database to verify the correctness of functions.
Appendix J

List of Issues Gathered from Experiment

Figure J.1: This is a table of compiled issues from the restaurant and consumer mobile applications. These issues were illuminated during the experiment and were addressed prior to finishing this thesis.