RecipeCart

Initial Project Documentation — Divide and Conquer I

UNIVERSITY OF CENTRAL FLORIDA

College of Engineering and Computer Science

Department of Electrical and Computer Engineering

Dr. Lei Wei & Dr. Chung Yong Chan

Department of Computer Science

Dr. Matthew Gerber & Mr. Richard Leinecker

EEL4914 – Group 35

Darren Ha — Computer Engineering

Quan Nguyen — Computer Engineering

Bryan Ha — Computer Science

Reviewers

Dr. Tanvir Ahmed — CS

Mr. Arup Guha — CS

Dr. [...] — ECE

Project Context and Narrative

Consumerism has always dominated and shaped the modern global economy. In response to increasing consumption and demands, customer-centric companies often find themselves relentlessly upscaling supplies to meet consumer demands. However, demands do not directly translate to needs, and several supply chains often end up producing surpluses. The common consumer's spending habits are a microcosm of this exact development. A consumer's speculation of their needs often leads to them buying more supplies than necessary, increasing the ratio of unused resources going to waste.

Correcting spending behaviors would most effectively address this overconsumption problem but is not realistically achievable in the short term. Rather, the simpler approach would be to accommodate the current spending habits. Our project, the RecipeCart, attempts to encourage the usage of leftover resources in the kitchen by generating a collection of personally tailored recipes given an assortment of ingredients.

Project Goals

The primary goal of the RecipeCart is to simply reduce the waste of leftover ingredients by creatively repurposing them with novel recipe suggestions. To make the RecipeCart as user-friendly as possible, the RecipeCart will intelligently identify the ingredients being placed into its container and subsequently produce a list of user-relevant recipes. The classification will be done via an ensemble of pre-trained deep convolutional neural networks (CNNs). The recipes will be queried from an existing database, custom-filtered and sorted based on user needs, and displayed on a mobile platform for user interaction.

A more ambitious goal involves extending the recipe list to also include suggested grocery locations where the missing ingredients may be purchased. This development might entail bridging the RecipeCart with the Google Maps API and all relevant grocery store databases. Another advanced goal would be to integrate a scaling system into the RecipeCart to quantify the ingredients and suggest recipes that would more accurately reflect the state of the leftovers.

In designing a seamless input process for the end user, video streaming the food items should be strongly considered. Using images as input would imply having the user take pictures of the ingredients after they have been placed into the container. Video streaming the input would allow for dynamic addition and removal of select food items from the container without the user having to directly modify their collection. However, running machine learning models in tandem with a video-based input would pose an extreme challenge in both complexity and resource, making this feature a stretch goal.

The project would be incomplete without mentioning AI-generated recipes. Although generating creative and composite recipes through AI has already been done multiple times, adding this feature would be a stretch goal because the resulting recipes do not necessarily guarantee a similar level of delicacy. Not only would the AI-inspired recipes need to be vetted for adequacy, some ingredients are simply incompatible and may result in a pungent smell or taste. Incorporating this feature would require a significantly more advanced generative model and also a system to determine the validity of the recipe.

Project Objectives

An ensemble of pre-trained convolutional neural networks balancing between simple object detection, text extraction, and barcode parsing would be implemented to accurately identify the input ingredient. The simple object detection CNN could generally classify visually distinct ingredients such as fruits, vegetables, and certain meats. The text extraction model would be best suited for labeled food items since they tend to include the specific name of the ingredient on the package. The final model would specifically search for barcodes and look them up in the appropriate database for the food product metadata. All three neural network outputs would be weighed against each other to narrow down the possible identities of the food item.

Given its heavy reliance on image input data, this project would feature a singular high-resolution wide-angle camera to capture pictures of the food item from a central view. The camera would be mounted at the front of the container, pointing inwards at an appropriate tilt and would be connected to a pre-built, single board computer (SBC) for centralized power and control. The SBC itself would be equipped with the appropriate network adapters for easy communication with the server hosting the machine learning backend. The appropriate batteries and power sources would be embedded onto the sides of the container unit without excessive protrusion.

A wide-area scale would be embedded into the cart container to retrieve the quantity of a detected ingredient. The scale would be wired to the rest of the cart body and would wire its results to the SBC for data cleaning and processing.

A server would be developed to host the ensemble learning model as well as the backend business logic to pre-process the input images and query the external ingredient and recipe databases. The server would also host its own database to maintain the basic client user metadata and also track common recipe selections, food preferences, and dietary needs to gradually tune the recipe recommendation engine.

The mobile user interface would feature a customizable catalog of all previously queried recipes, fronted by a basic login and sign up page. The app would allow the user to dynamically update their recipe preferences and also initiate a request to the main RecipeCart container to retrieve its current contents. The app would evidently include the function to generate recipe recommendations based on the retrieved ingredients.

A recommender system would be added to the recipe generation backend to provide more personalized recipe recommendations. The model will base its inferences on a variety of inputs such as recipe popularity, user ratings, recommendation histories, and frequently retrieved ingredients.

Analysis of Related Works

The following literature reviews highlight some launched applications that implement inventory tracking and self checkouts, including the applications functions, practicality and impact on the current consumer's market.

Cust2mate's Automated Smart Cart is a smart shopping cart with automatic item identification, weighing and checkout. These functions also attempt to address measures against theft or any error when taking items in and out of the cart (Lenovo, 2022). This greatly improves the users' shopping experience by omitting the waiting checkout time that regular buyers experience. Cust2mate's carts are shelf-ready and operational, so they can be deployed quickly. The company currently administers pilots with several food chains around the world with the intention of significantly increasing their operations even further (Slater & Kreizman, 2022). The smart carts, as a launched product, are yielding significant returns on investments and gross profit.

Samsung's advanced smart fridge, the Smart Hub, integrates with other Samsung devices and has AI assistance with Alexa. The fridge contains an inventory tracker, streaming services, convenient apps such as memoing and shopping list (Samsung, 2023). The Family Hub acts more than a conventional smart fridge; it is a centralized medium for smart houses as it integrates with other Samsung smart-home devices, as well as a computer itself with advanced user interface.

Both sources exemplify successful launches of a product that eases a consumer's shopping and life experience by allowing them to monitor what they buy or what is inside their inventory without going through the hassle of shuffling through their cart/fridge. Cust2mate designs a well-functioning cart with a simple user interface with a variety of virtual payment methods, and omits the annoying waiting time for check-out with the. Samsung's Family Hub contains built-in inventory tracker, as well as integration of different Samsung devices that makes the fridge one of the core items in a smart home. Our project aims to utilize the inventory tracking features such as the two above sources to maximize resources in the inventory, allowing the user to explore different recipes they can make based on what they have or bought.

These existing applications provide a ground of how high-tech reliance products are employed to help consumers with inventory and bill management. Drawing inspiration from these, we intend to further enhance our user's daily experience by maximizing their resources and reducing waste. Our project aims to create a product as an add-on to the existing technology, helping with meeting the user's needs while adding meaning and excitement to their daily lives by suggesting different options with existing resources.

Project Specifications and Constraints

Specifications	Description	Value
Object Classification Time	Time to identify the object and return a list of ingredients	< 5 seconds
Object Classification Accuracy	A measure of the ML model's performance	> 70 %
Recipe Recommendation Time	Time to return a list of recipes given user preferences and a list of identified ingredients	< 10 seconds
Minimum Number of Recipe Outputs	Number of recipe recommendations guaranteed to generate	> 1 recipe
Absolute Weight Error	A measure of the tolerated error margin from the scale	< 50 grams
Weight and Quantity Retrieval Time	Time to calculate and obtain weight and quantity of an ingredient	< 2 seconds
Broadcast Delay	Time to broadcast output from hardware to the server	< 2 seconds
Product Weight	Weight of the hardware	< 4 kg
Power Consumption	Power intake of hardware	< 40 Watts
Battery Life	Battery life before next recharge	~ 4 hour
Budget Management	Total estimate price of the whole production process	< $500

Table 1. Engineering Design Specifications

General Hardware Block Diagram

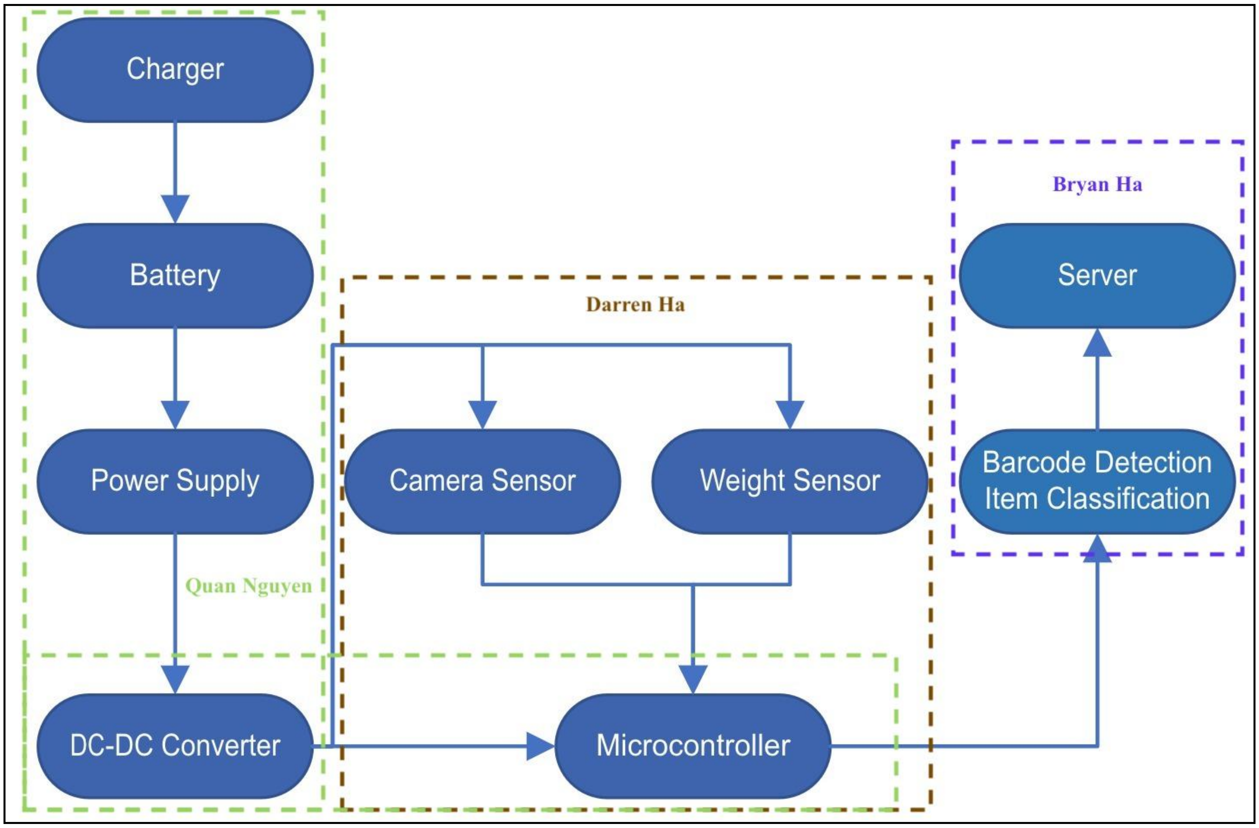

Figure 1. General Hardware Block Diagram

General Software Flowchart

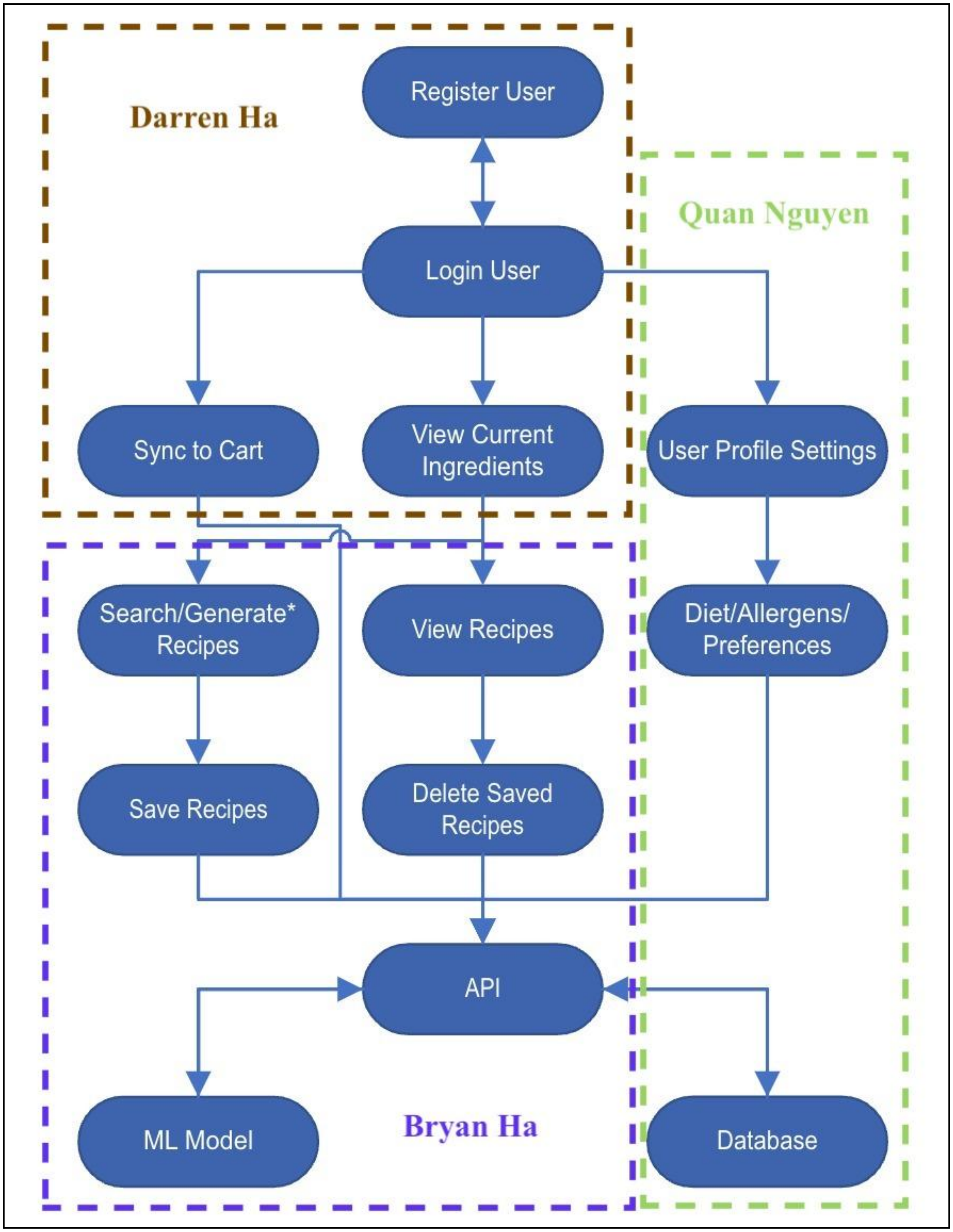

Figure 2. General Software Use Case Diagram

House of Quality

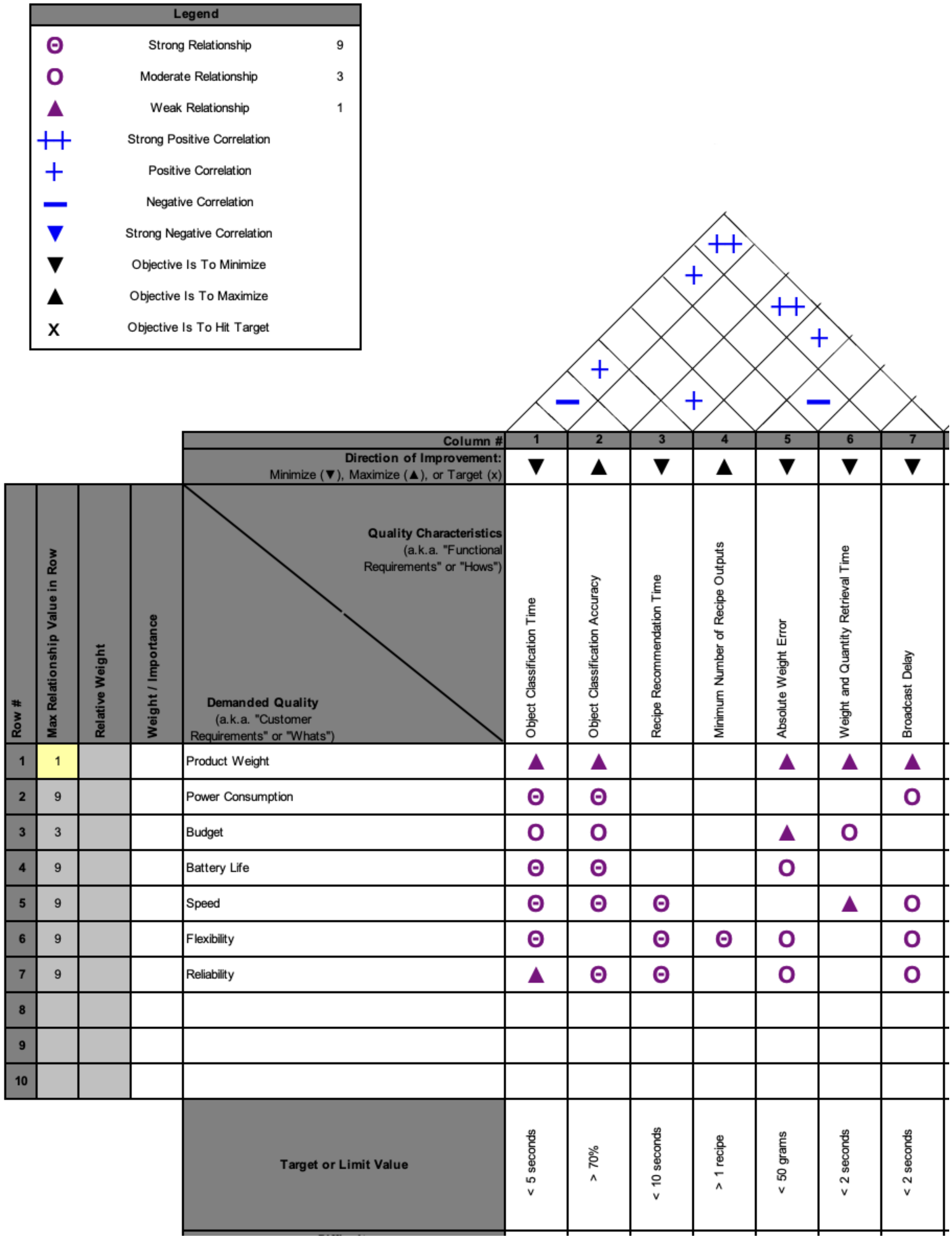

Figure 3. House of Quality Diagram

Estimated Budget and Financing

Parts name	Description	Price
SBC Module	For data pre-processing, basic machine learning computations, and system control	$150
Wide-Angle Camera Module	3280x2464 resolution cameras	$36
Wide-Area Digital Scale	Digital scale that can integrate with PCBs and MCUs	$40
Wireless NIC module	For connecting the SBC to the internet	$22
Batteries (x4)	To provide power	$100
Wires (x100)	Wires for connecting hardware components	$15
Large Plastic Container	Plastic container wide enough to simulate a tray in the fridge or a shopping cart	$20
Miscellaneous Items	Tape, glue, etc.	$20
	GRAND TOTAL:	$403

Table 2. Estimated Budget

The proposed budget assumes the higher-end estimated values of the listed parts. Depending on additional needs for barcode and object detection, an extra camera module may be needed. Achieving advanced and stretch goals would also entail a more extended budget. Currently, this project does not have any sponsors; funding will be at the expense of the individual team members.

Project Timeline and Milestones

Milestone	**Start Date**	**End Date**
Brainstorm, pitch ideas, and form groups	21-Aug-2023	29-Aug-2023
Flesh out ideas and do preliminary research	29-Aug-2023	04-Sep-2023
Invite ECE professors and faculty to join the senior design reviewer committee	01-Sep-2023	15-Sep-2023
Complete the first 10 pages of the Divide & Conquer Document	04-Sep-2023	15-Sep-2023
Design the group website and upload the initial D&C	17-Sep-2023	06-Oct-2023
Meet with senior design coordinator(s) and perform the necessary edits to the 10-page D&C	19-Sep-2023	22-Sep-2023
Draft up the first 60 pages of the D&C	30-Sep-2023	03-Nov-2023
Meet with senior design coordinator(s) and perform the necessary edits to the 60-page D&C	06-Nov-2023	12-Nov-2023
Draft up and finalize the Final Report	12-Nov-2023	05-Dec-2023
END OF SENIOR DESIGN I		
Gather relevant hardware parts, including cameras, SBC, wires, batteries, and suitable container	12-Dec-2023	29-Dec-2023
Acquire permissions for necessary software, including pre-trained ML models, APIs, and database access	12-Dec-2023	29-Dec-2023
Build physical architecture prototype	08-Jan-2024	28-Jan-2024
Integrate relevant ML APIs for ingredient detection	08-Jan-2024	28-Jan-2024
Integrate physical architecture with backend software	28-Jan-2024	11-Feb-2024
Develop and integrate recipe recommender system	05-Feb-2024	04-Mar-2024
Develop mobile frontend and connect backend database	11-Feb-2024	11-Mar-2024
Debugging and testing until working and presentable	11-Mar-2024	15-Apr-2024
Finalize report, website, presentation, and demo	15-Apr-2024	28-Apr-2024

Table 3. Project Milestones

References

Lenovo. (2022). Revolutionizing the shopping experience. *Lenovo.Com*. Lenovo. Retrieved September 15, 2023, from https://www.lenovo.com/content/dam/lenovo/dcg/global/en/customer-stories/case-study-cust2mate.pdf.

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