SANTA CLARA UNIVERSITY
DEPARTMENT OF COMPUTER ENGINEERING

Date: May 29, 2017

I HEREBY RECOMMEND THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

Davis Allen
Robert Bayer

ENTITLED

Communication Station

BE ACCEPTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF

BACHELOR OF SCIENCE IN COMPUTER SCIENCE AND ENGINEERING

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Department Chair

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Communication Station

by

Davis Allen
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Submitted in partial fulfillment of the requirements
for the degree of
Bachelor of Science in Computer Science and Engineering
School of Engineering
Santa Clara University

Santa Clara, California
May 29, 2017

Communication Station

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ABSTRACT

We are building a mobile application that will improve speed and personalization in conversations for people struggling with verbal communication. Many people diagnosed with Autism and other disorders face daily challenges involving communication due to speech impediments. Existing solutions allow users to communicate via speech cards or typing on a keyboard. However, these solutions make tradeoffs between personalization and speed, compromising what it takes to have fluid, natural, and rewarding conversations. Our solution will speed up personalized communication by applying machine learning principles. Our project will predict how a user will respond based on a combination of personal and collective language data, allowing the user to communicate quickly with their own voice.

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Chapter 1

Introduction

Communication is essential to building relationships. A person who has challenges speaking will face a lifetime of roadblocks in building friendships, connecting with family, and meeting daily needs. In the United States, 1 out of every 68 children will be diagnosed with some level of Autism (cite), and many of these children will face communication challenges or be rendered completely nonverbal, depriving these children of a voice. As this number continues to rise (cite), finding ways for everyone to clearly communicate is essential to enhancing the human experience.

Today, nonverbal children such as those diagnosed with autism or down syndrome communicate using many methods including gestures, sign language, and picture symbols. One of the most popular methods of communication is a device that generates speech. These devices come in many different forms. Some are similar to keyboards on which the child can type out what they want to say, while others have a list of buttons with pre-programmed messages from which the child can choose. Both of these options have also been incorporated into touchscreen devices such as the Apple iPad, so they are easily portable.

While the ability to type out any response gives a flexible voice to the children, it can be tedious to retype similar responses and frustrating for all involved due to the time it takes to construct responses using a keyboard. The solutions with pre-programmed messages solve this problem by speeding up communication, but they impede the expressiveness of the children by limiting their response options. These limitations do not allow subtleties in diction, syntax, and personal preference to be communicated, erasing the voice from the personality behind it.

Using Machine Learning principles, we want to develop an application that makes conversations quick but also personalized, giving people their own voice. We propose a solution that listens to

conversations and gives the child several quick options to speak. These options will be personalized to each child, so that they maintain their voice. Additionally, we will have the option to type out a response if the available quick options are not what the child wants to communicate. The typed answers will be used to help the system learn how the child responds, thereby improving future suggestions. We plan on testing this solution with nonverbal children at Hope Technology School in Palo Alto, California.

Our solution combines the benefits of both current solutions, while eliminating the problems. By having the system learn about the child on an individual level, this communication tool will allow children to share their voice with the world. The inclusion of the quick suggestions will drastically improve response time, easing the communication process both between children and between verbal adults, such as the teacher or parent, and the child. Communication is crucial to forming human connections. Our proposed solution will allow for seamless, fluid communication, giving everyone a voice.

Chapter 2

Requirements

Listed below are the Functional Requirements, Non-Functional Requirements, and Design Constraints of the project as gathered during the Requirements gathering phase.

2.1 Functional Requirements

Critical:

- Provide input via the keyboard.
- Capture audio via device microphone.
- Speak through device speaker.
- Suggest responses based on voice input.

Recommended:

- Provide input options via picture cards.

Suggested:

- Say keyword to activate microphone and save battery.

2.2 Non-Functional Requirements

Critical:

- The system will be able to handle multiple users.
- The system's user interface will be intuitively designed.

Recommended:

- The system will be secure when storing private data.

Suggested:

- The system's user interface will be able to use graphics that are intuitive and familiar.
- The system will be unaffected in loud environments.

2.3 Design Constraints

- The system must consist of a mobile application that runs on iPad devices.

Chapter 3

Use Cases

Use case diagrams demonstrate how different users will interact with our system. In our case, a verbal user will be able to speak to the mobile device, and the nonverbal user will be able to formulate a statement and use the device to speak.

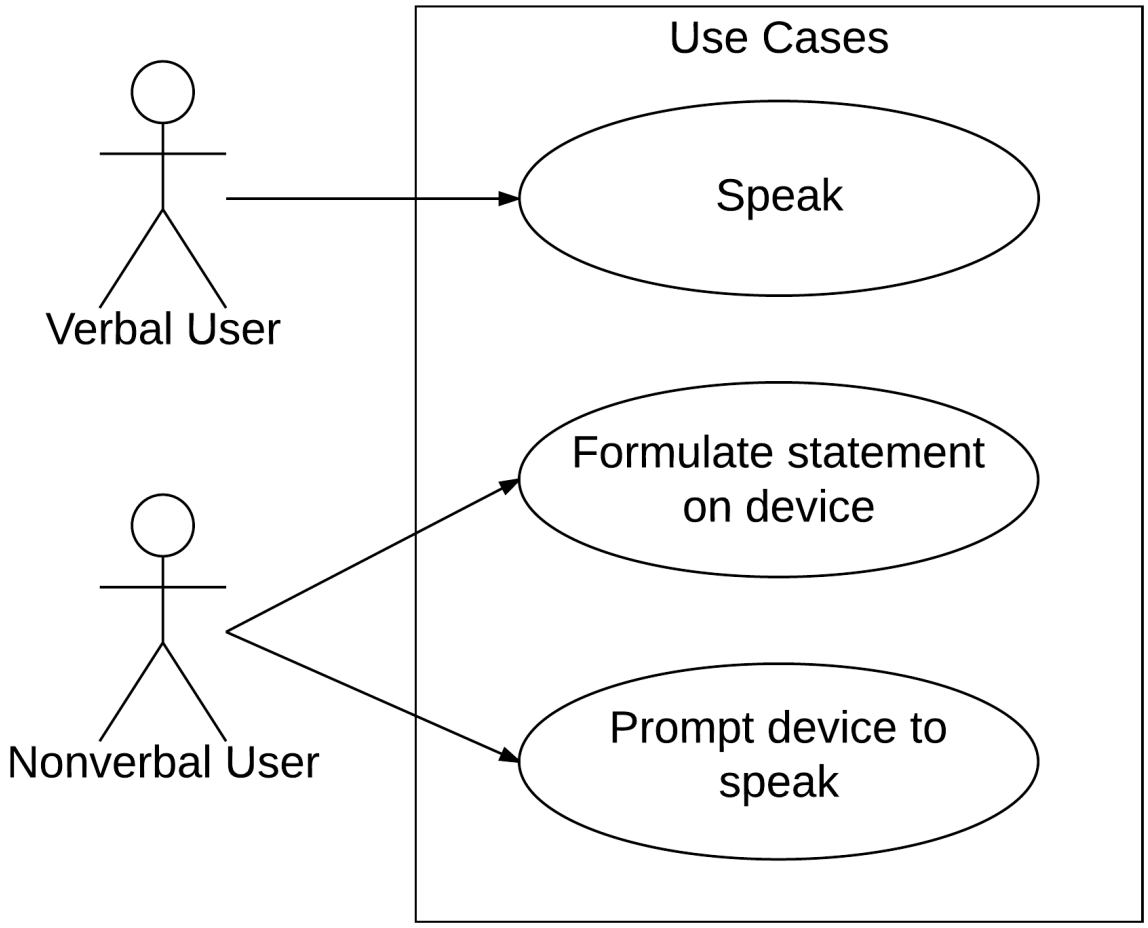


Figure 3.1: Use Cases

1. Speak
    - **Goal:** Ask a question for mobile device to record and process
    - **Actors:** Verbal User
    - **Pre-conditions:**
        (a) Application must be open on device
    - **Steps:**
        (a) Nonverbal user opens application
        (b) Nonverbal user presses button to record voice
        (c) Verbal user speaks and device records
        (d) Device translates audio to text and sends to server
    - **Post-conditions:**
        (a) None
    - **Exceptions:**
        (a) Application must have device permission to use microphone
2. Formulate Statement on Device
    - **Goal:** Create a statement to respond to or initiate with the verbal user
    - **Actors:** Nonverbal User
    - **Pre-conditions:**
        (a) Application must be open on device
    - **Steps:**
        (a) Open application
        (b) Uses keyboard or picture card to add a word
        (c) Add words until statement is complete
    - **Post-conditions:**
        (a) Application displays fully formatted statement

- **Exceptions:**
  (a) None

3. Prompt Device to Speak
   - **Goal:** Speak the statement that has been formulated by user
   - **Actors:** Nonverbal User
   - **Pre-conditions:**
     (a) Statement must be fully or partially made on device
   - **Steps:**
     (a) Open application
     (b) Formulate a statement (if necessary)
     (c) Press the speak button
   - **Post-conditions:**
     (a) Device will speak the statement
   - **Exceptions:**
     (a) Application must have device permission to use speaker
     (b) Device volume must be on or nothing will be heard

Chapter 4

Activity Diagram

The following flowcharts outline the workflow of both verbal and nonverbal users actions and interactions with the system. The diagram does not include the system actions, such as processing audible speech and displaying relevant suggestions.

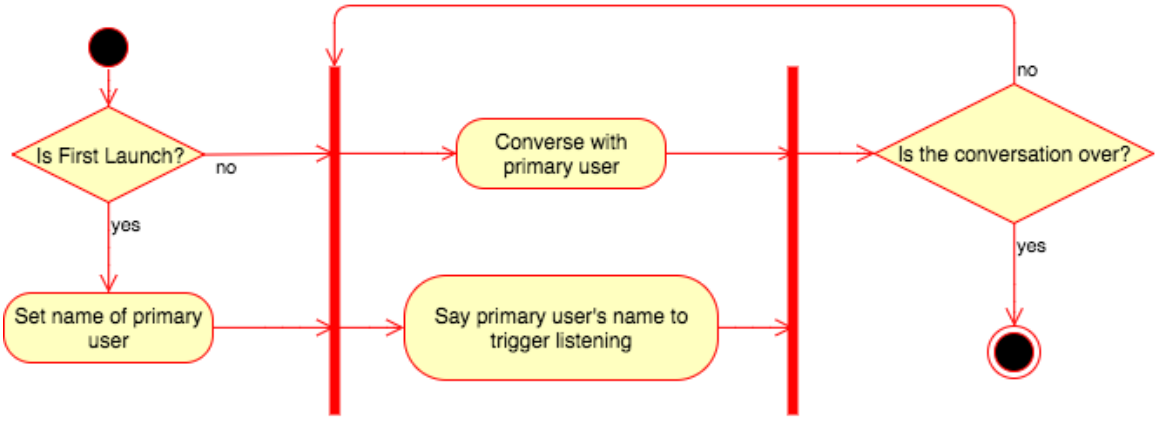


Figure 4.1: Work flow of the verbal, guardian user interacting with system

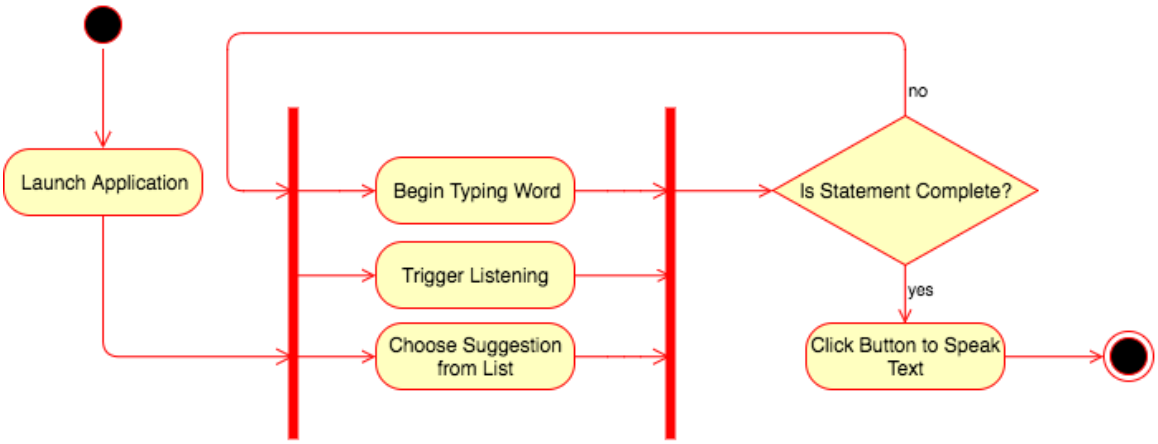


Figure 4.2: Work flow of the non-verbal, child user interacting with system

Chapter 5

Conceptual Model

Users will navigate to our application on an iPad tablet in order to use the system. Upon launching the app, they will be greeted with the keyboard view, as shown in Figure 5.1, which they can immediately start using to type what they want to communicate.

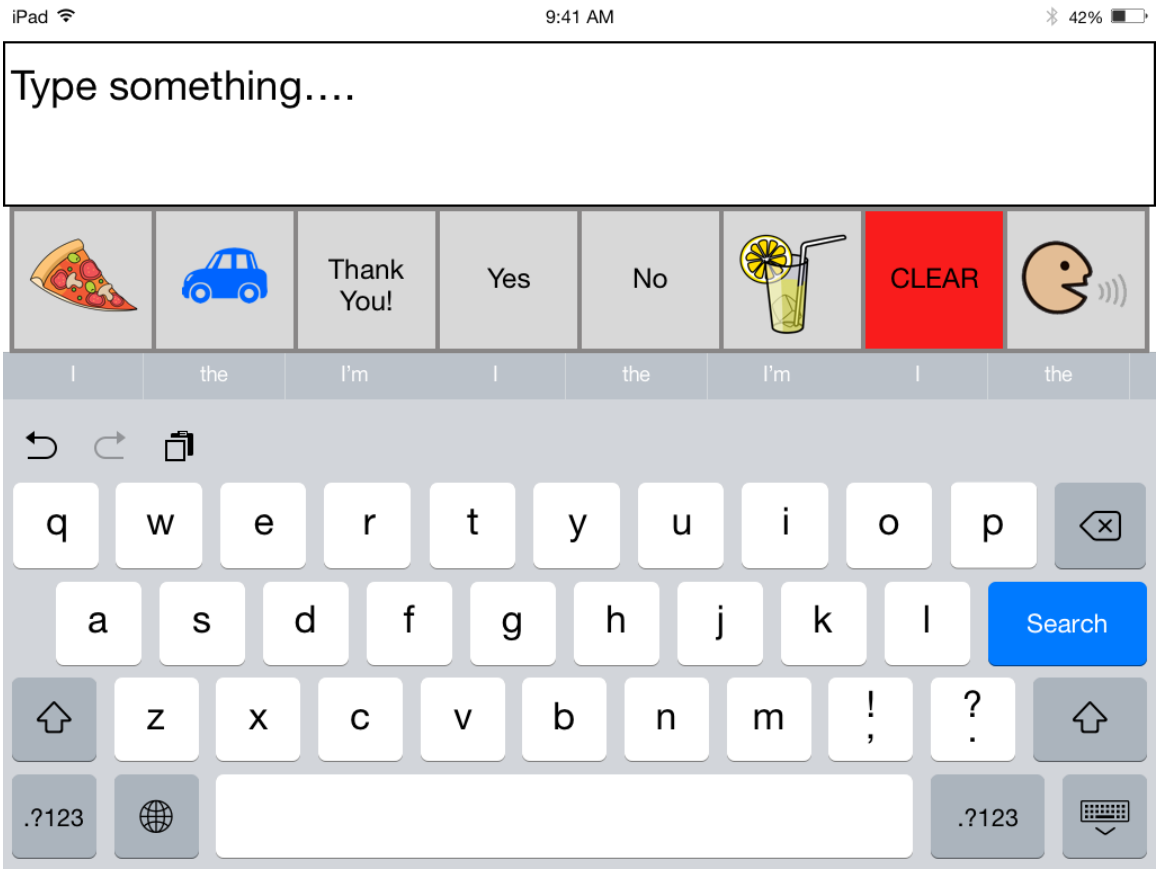


Figure 5.1: Mockup of text-entry user interface

As they continue to type, the suggestions will adjust dynamically to both their input and any verbal

feedback from the environment. The app will listen for audible speech, process the speech and prioritize the suggestions displayed to the user. The system will first look for previous personal responses from the user to this or similar questions. After, it will display possible global responses from our database. In this way, previous personal responses will be prioritized above the global responses. This will be reflected in the application's interface as shown in Figure 5.2.

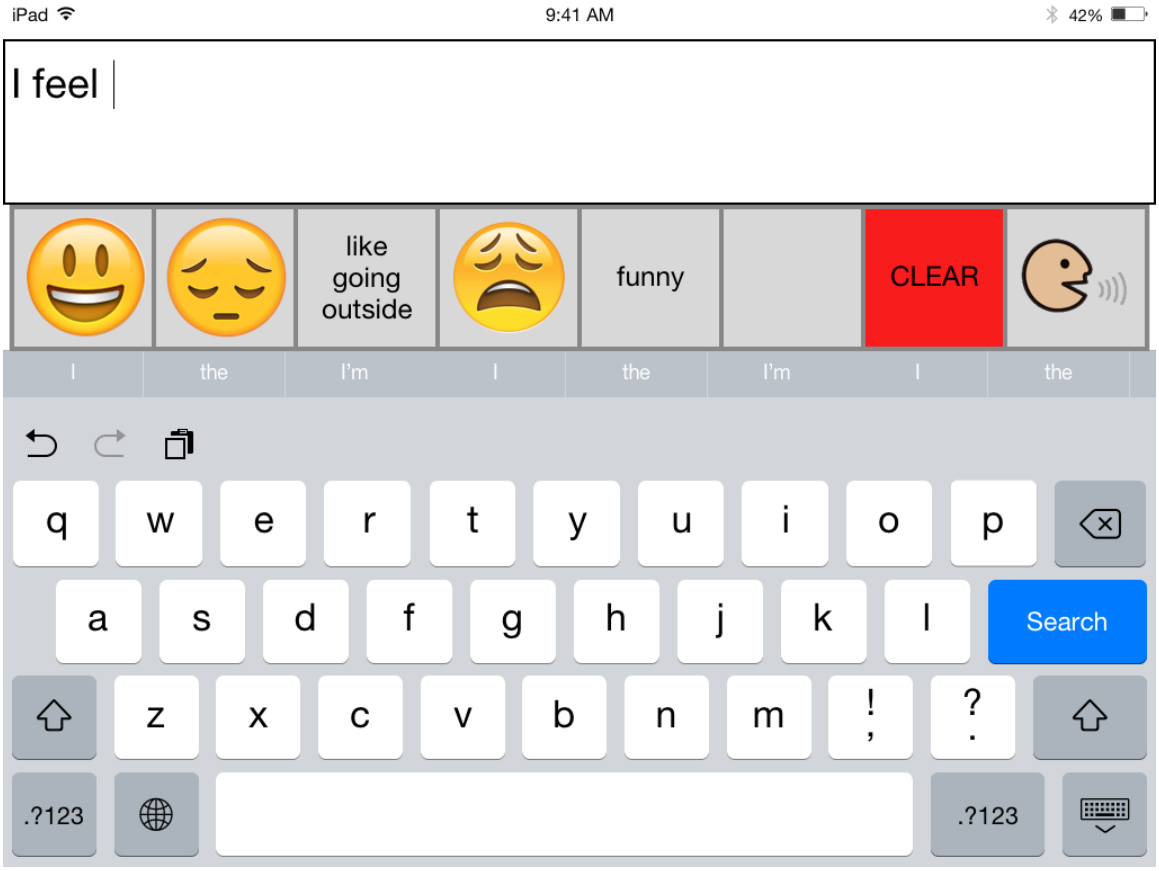


Figure 5.2: Mockup demonstrating the dynamic nature of suggestions

Whenever the user has completed either typing or selecting what they want to communicate, they will press the button on the right of the screen, which will speak what they have selected aloud. If the user then wants to clear the selection, they can use the clear button on the left of the speak button. This will allow the user to restart the process.

Chapter 6

Architectural Diagram

We plan to utilize a basic client-server architecture to complete this project as shown in Figure 6.1.

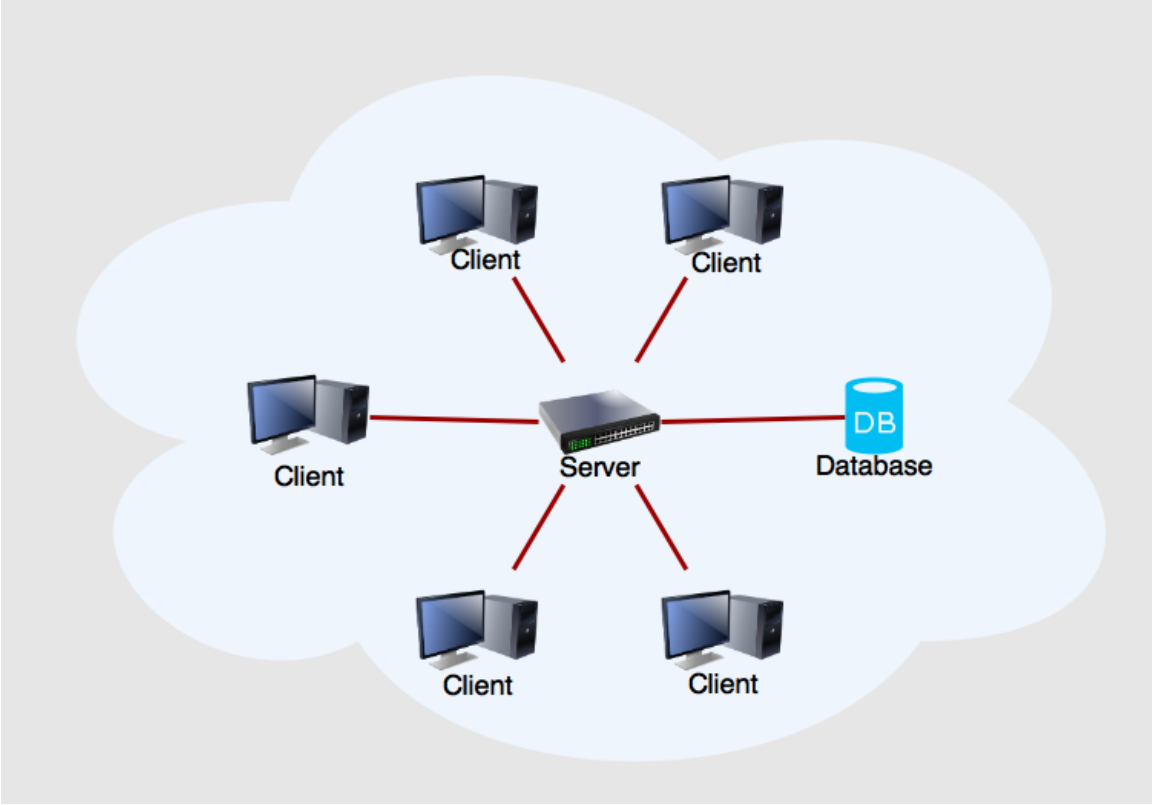


Figure 6.1: Client-Server Architecture

Users will be able to use our application on their mobile device, acting as a client, in order to access our site. The server in our system will be responsible for storing data for each child in the database, formulating a list of prioritized potential responses, and delivering these results to the client. The

database will be relational, and the server will write to and read from it order to access data.

Chapter 7

Technologies Used

- Hardware
  - Development
    - Macbook Pro
    - Macbook Air
  - Application Testing
    - iPads
    - iPhones
  - Server Processing
    - Engineering Computing Center Servers
    - Google App Engine
- Programming Languages
  - Swift
    - For iOS Programming
  - Objective-C
    - For iOS Programming
  - Python
    - For web server programming

  - JSON
    * For communicating with REST APIs
- IDEs
  - XCode
  - MySQLWorkbench (or the like)
- APIs
  - TensorFlow
  - Cloud Natural Language API
  - speech-to-text API
- Database
  - Relational (depends on API integration)
    * mySQL
    * SQLite3

Chapter 8

Design Rationale

We are leveraging a client-server model in order to minimize impact on the client mobile devices. In our model, a client will collect audial data and translate it into text to send to the server. The server will use NLP tools such as Google's Cloud Natural Language API to process the text and generate suggested responses to send back to the device as a JSON object. Having the server do the processing will minimize the use of the device's battery life, and will also decrease the disk space our app will require to be stored on the device.

We are using iPads and other iOS devices for our testing because that is what our partners, the Hope Technology School, primarily uses in their classroom. This will eliminate the need for us to buy iPads for beta testers to use; saving money, time, and scheduling complexity.

Making use of the existing APIs like TensorFlow and Cloud Natural Language allows us to avoid re-inventing the wheel, and focus on how those tools can be used to fulfill our purpose.

We will develop the application in XCode, using the Swift and Objective-C languages because they are the designated languages compatible with iOS to make applications. We will use Python to design the web server because we have experience using Google App Engine to make web servers specifically in Python and the APIs are well documented for the language.

Finally, we will use a relational database like SQLite and MySQL to store conversation data for the user. The data will be stored privately on the user's device and not in our servers because it is less vulnerable to attacks and will make minimal size impact in modern mobile devices.

Chapter 9

Test Plan

Our testing process can be broken into three main sections: an alpha release, two versions of a beta release, and unit testing. Unit testing will be done throughout the development process by the developers from Week 1 - 10 of Winter Quarter. Our alpha testing will take place between Weeks 3 and 7 of Winter Quarter. At this point, the system will be able to be used as a replacement for keyboard-to-speech generating devices and will have the ability to listen to conversations, but will not generate response suggestions. This will allow us to generate a baseline of both ends of a conversation. The feedback from this stage will help us refine our interface and move into the first beta, which will take place from Weeks 5-7 of Winter Quarter. This beta stage will be the first iteration of all features of the application. Feedback from this stage will be processed and incorporated into our last beta from March 27th to April 10th.

Chapter 10

Risk Analysis

Table 10.1, shown below, depicts the risks and consequences involved in completing the system. The table also includes probability of the risk involved along with a severity ranking between 1 and 10. The probability and severity are then multiplied to receive an impact measurement. For each risk, there are at least two mitigation strategies that are included to avoid the issue.

Risk	Consequences	Probability	Severity	Impact	Mitigation Strategies
Illness	Team member(s) will not be able to work on project for a period of time.	.5	4	2	1. Get a lot of sleep. 2. Stay hydrated.
Insufficient Development Knowledge	The system will not be adequate and may not be finished on time.	.4	5	2	Get a lot of sleep and stay hydrated.
Insufficient Web Development Knowledge	The system will not be adequate and may not be finished on time.	.4	5	2	1. Use online tutorials. 2. Revisit past notes/projects.
Team Coordination Failure	The team will not finish the project or certain aspects of the projects in time.	.15	8	1.2	1. Keep an organized schedule of due dates. 2. Follow Development Timeline. 3. Hold team members accountable for what they need to get done.
Requirements are Incorrectly Communicated	Extra time gathering requirements. Customer doesn't agree with the end system.	.1	8	.8	1. Meticulously develop requirements with customer. 2. Regularly hold update meetings with customer to make sure on the right path.
Server Failure	The system will not have a server to host the client-server architecture and will therefore fail.	.02	10	.2	1. Research other hosting strategies in case of DC server failure. 2. Use local resources for backup storage and processing.
File Loss	Lost work up to the date of the file loss.	.01	10	.1	1. Use github to manage source code and versioning. 2. Update project tree after every development session.

Table 10.1: Risk Analysis Table

Chapter 11

Ethical Analysis

Even though our project can seem benevolent, there are several ethically ambiguous scenarios that must be considered and weighed prior to making decisions.

First, at an organizational level, our team has a couple of ethical dilemmas to consider. One such dilemma is how to ensure workload is being divided evenly among teammates. Like many problems, there seems to be a simple solution, by making a list of the work to be done and divide it evenly by number of tasks. But this process and judgment gets trickier with added complications, such as certain tasks requiring different amounts of time or team members missing deadlines. There are an infinite amount of potential situations to assess, so a global solution must be developed that can be applied across multiple scenarios. A good solution template would begin with a group discussion to try to work out the issue. If not everyone is satisfied with the results, we should schedule a meeting with our advisor to ask for him or her to mediate the discussion, allowing the experienced advisor to offer advice or make decisions for the team if necessary. Though this mediation strategy is generic it can be applied across multiple scenarios, which makes it a good basis for resolving ethical issues.

Secondly, concerning the social aspects of our project, there are many more ethical scenarios to consider in order to ensure that our application maximizes social benefits while minimizing concerns. One question we must consider is if we, as the developers, should have the power to control someone's voice. Our application will try to predict what a user will typically say and how he or she would respond to a question. This gives us the capability to influence what options the user will choose in speaking. This feature can be potentially misused to influence and control someone's voice in an extreme case. Questions determining the extent of control this application need to be evaluated to determine what kind of control the application should have in determining how a user will say

something or respond to a question.

Thirdly, we have to consider the ethical implications of how our product system will be implemented. Our application will need to save records of the user's conversations to remember the interests and voice patterns of the user. One situation to evaluate is the option to save that personal information locally on the user's device or on our servers in the cloud. Both options have their respective pros and cons, namely that the cloud storage will improve speed and battery usage, and local storage will improve security. These trade-offs will force us to evaluate the situation and have us weigh the priority of features to determine how secure we need to store the user's data. Likely, these priorities will be shifted as the application gets tested by users and they give feedback, so it will be important for our team to come back to this dilemma and re-evaluate the best storage option from time to time. The extent and implementation of features need to be evaluated and assessed in the development of our application with user safety in mind.

Chapter 12

Development Timeline

The development timelines shown in Figures 15.1, 15.2, and 15.3 below depict a set of tasks that need to be completed throughout the year. We used a Gantt Chart to break down our project into smaller deliverables. The horizontal blue lines split our work into three main sections: development, relationship, and documentation. We separated the larger chart into three individual charts, each corresponding to an individual academic school year.

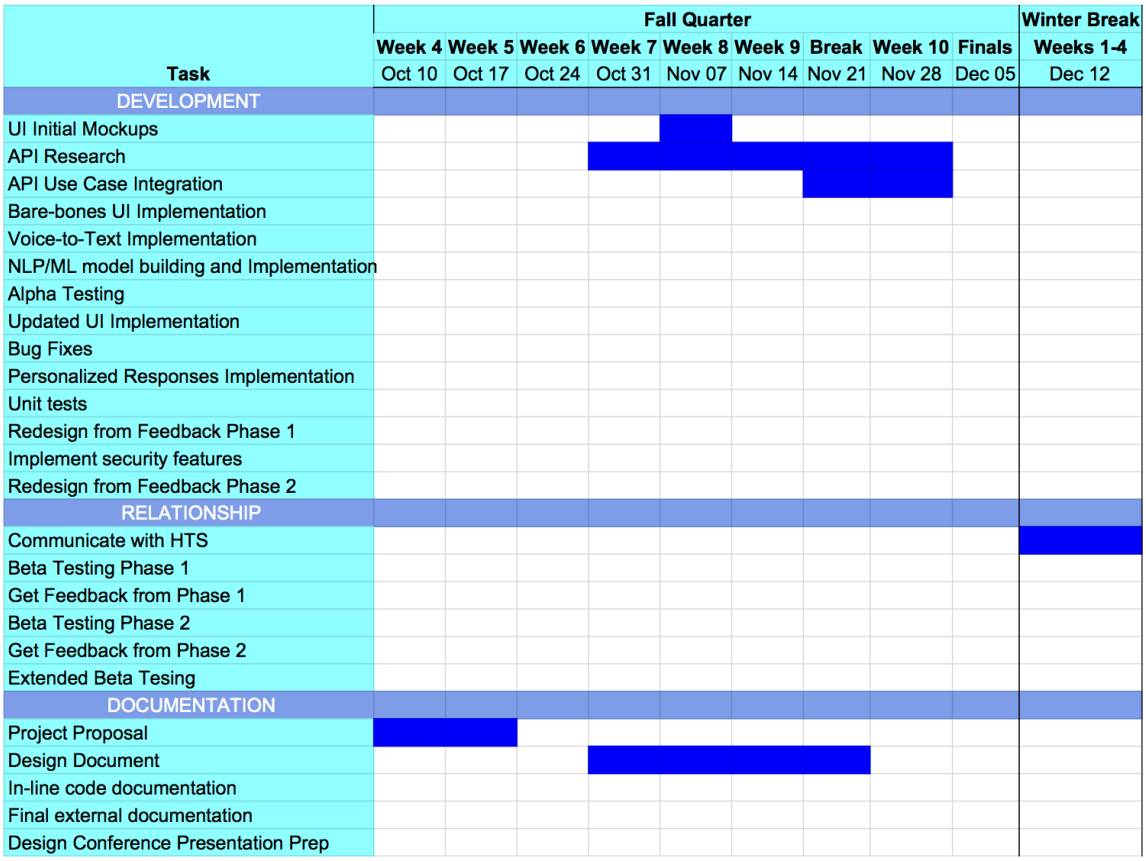


Figure 12.1: Fall Quarter Development Timeline Gantt Chart

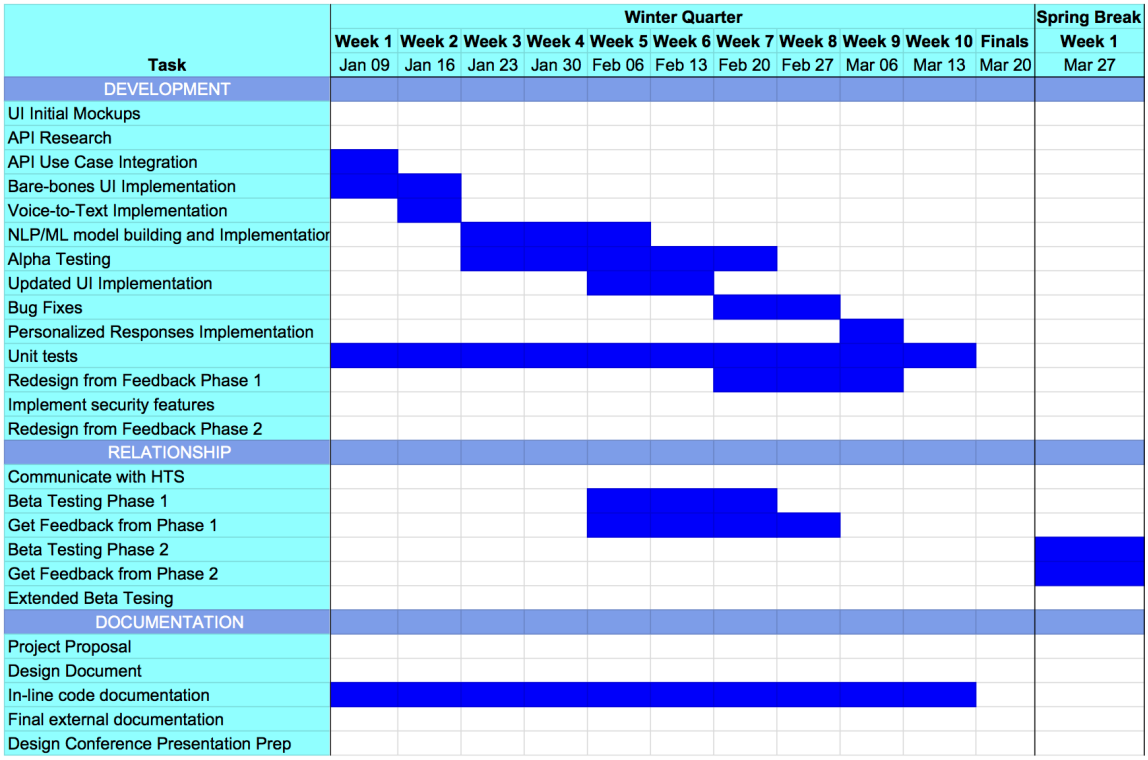


Figure 12.2: Winter Quarter Development Timeline Gantt Chart

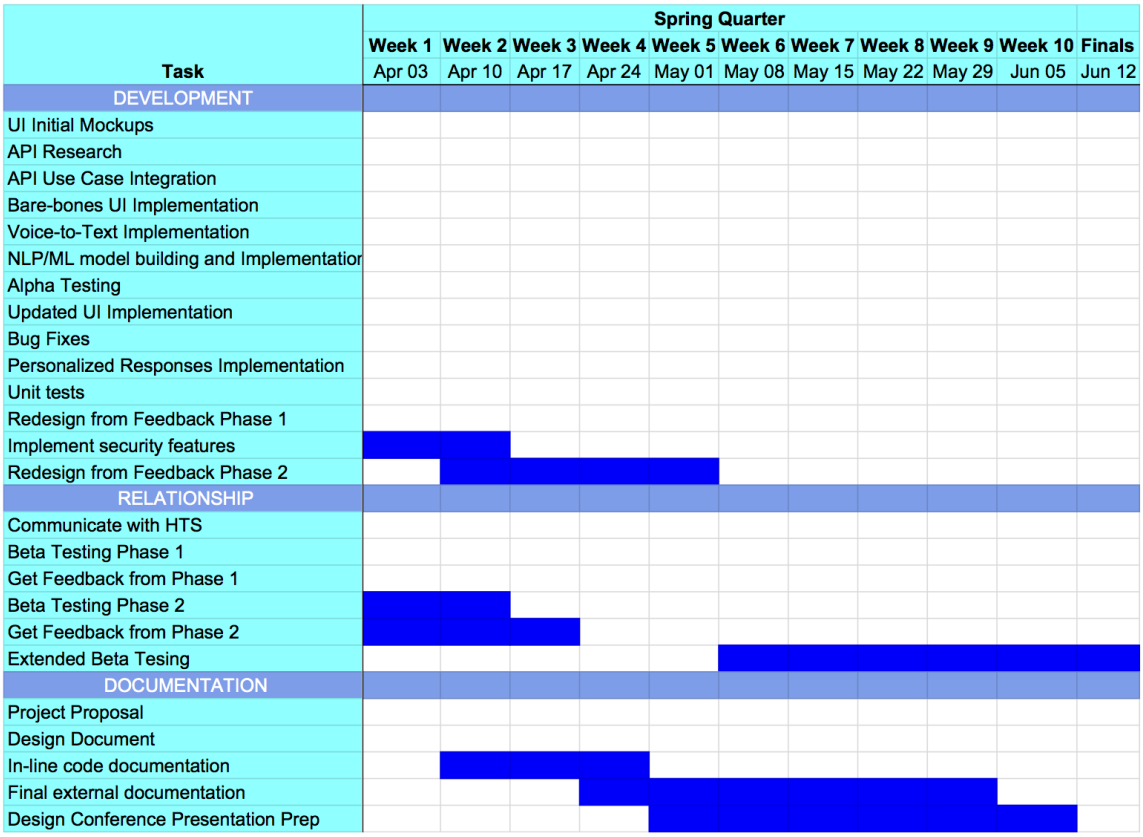
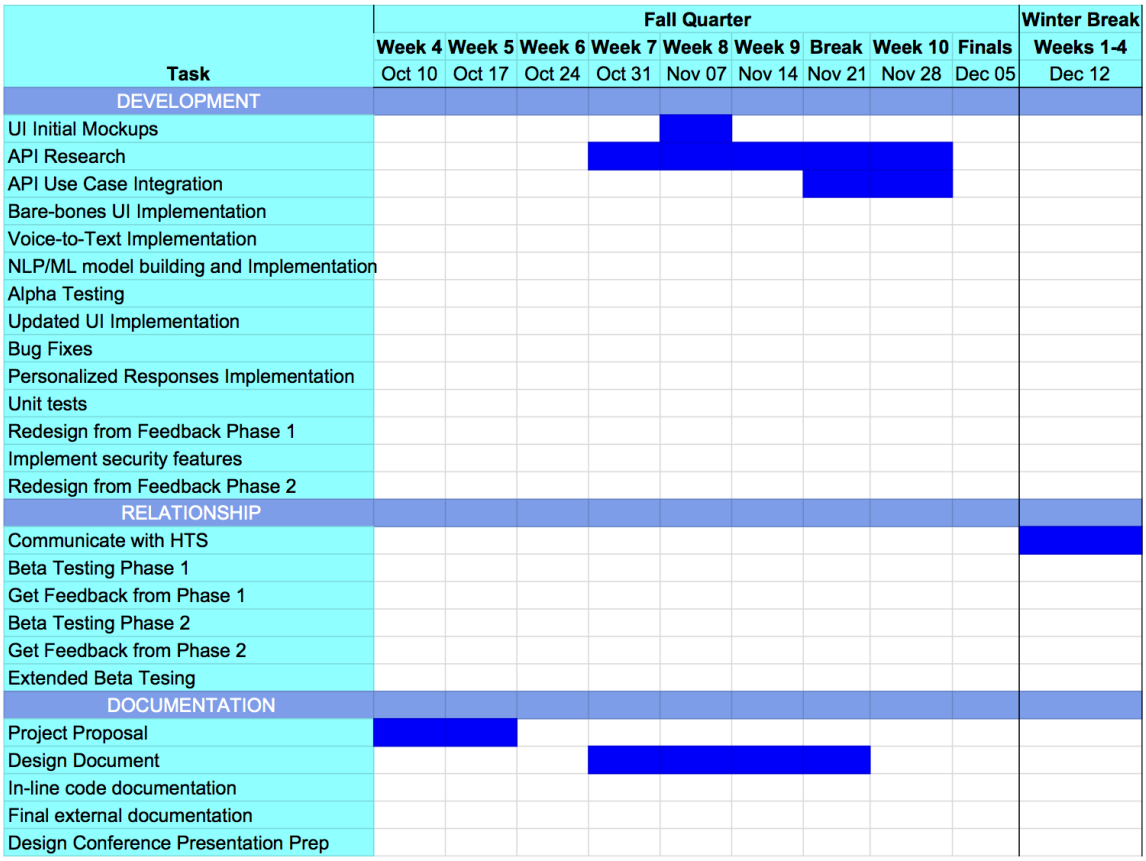


Figure 12.3: Spring Quarter Development Timeline Gantt Chart

Chapter 13

Lessons Learned

The development timelines shown in Figures 15.1, 15.2, and 15.3 below depict a set of tasks that need to be completed throughout the year. We used a Gantt Chart to break down our project into smaller deliverables. The horizontal blue lines split our work into three main sections: development, relationship, and documentation. We separated the larger chart into three individual charts, each corresponding to an individual academic school year.



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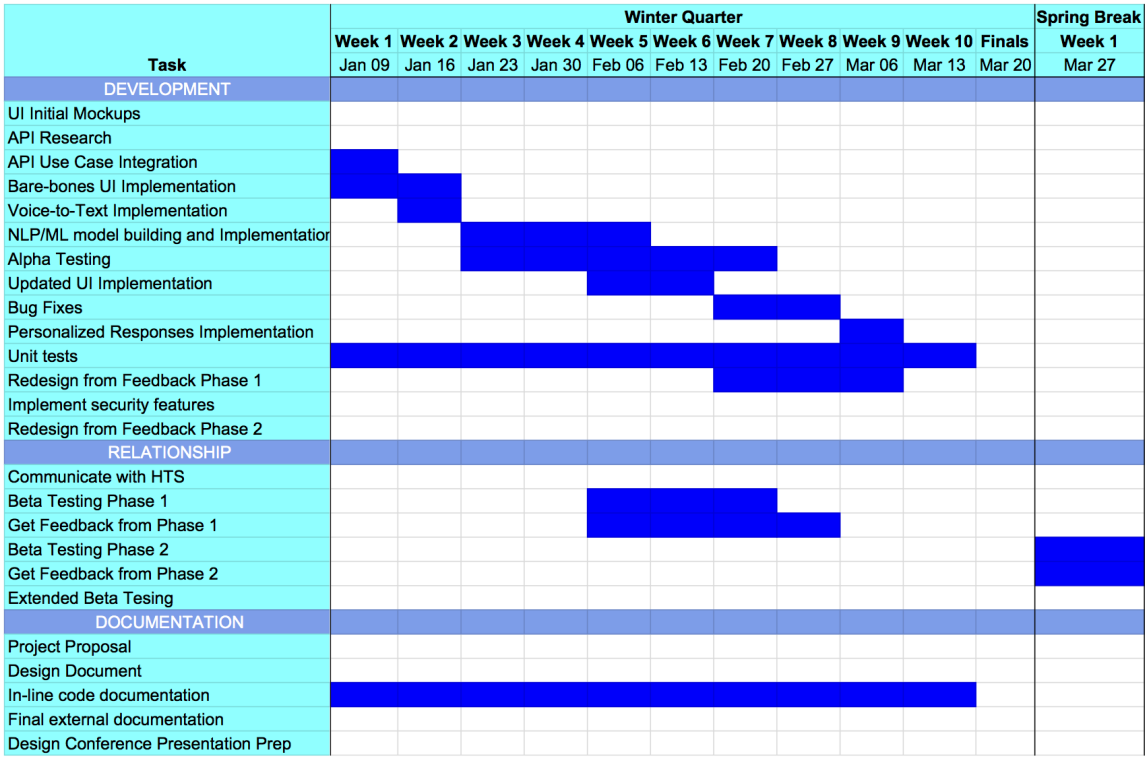

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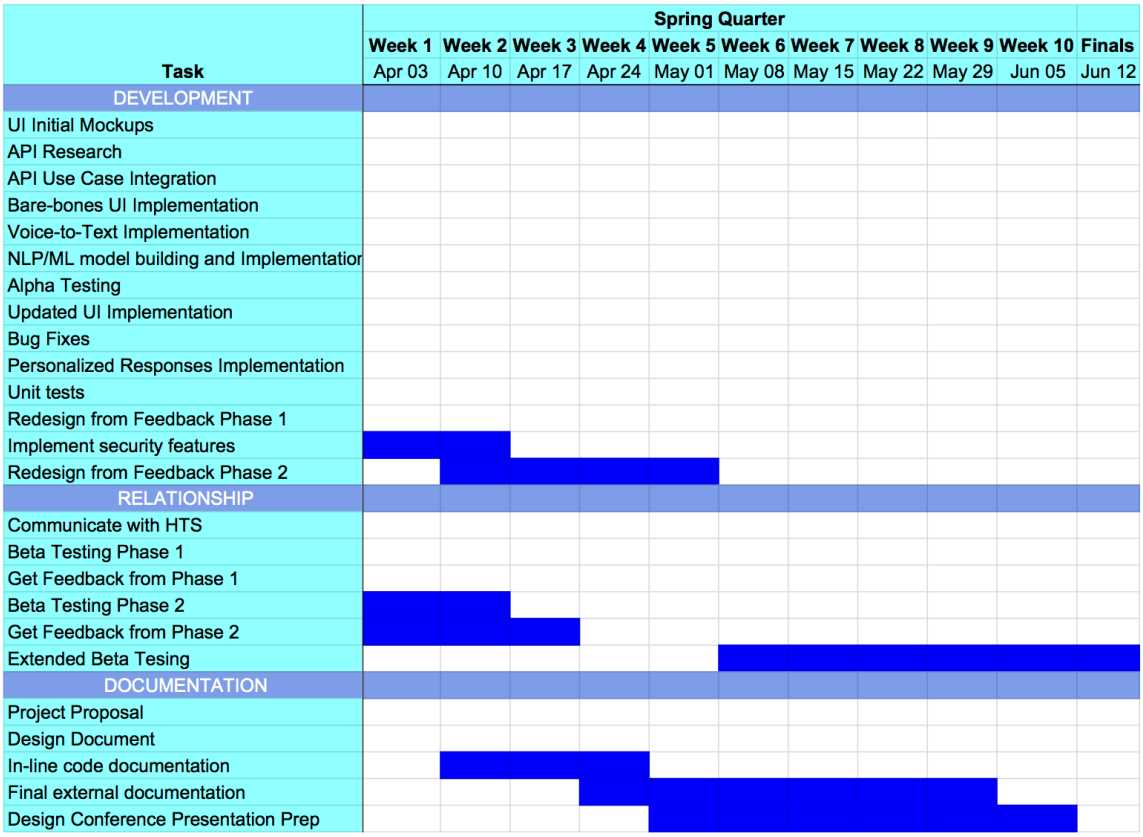


Figure 13.3: Spring Quarter Development Timeline Gantt Chart

Chapter 14

User Manual

The development timelines shown in Figures 15.1, 15.2, and 15.3 below depict a set of tasks that need to be completed throughout the year. We used a Gantt Chart to break down our project into smaller deliverables. The horizontal blue lines split our work into three main sections: development, relationship, and documentation. We separated the larger chart into three individual charts, each corresponding to an individual academic school year.

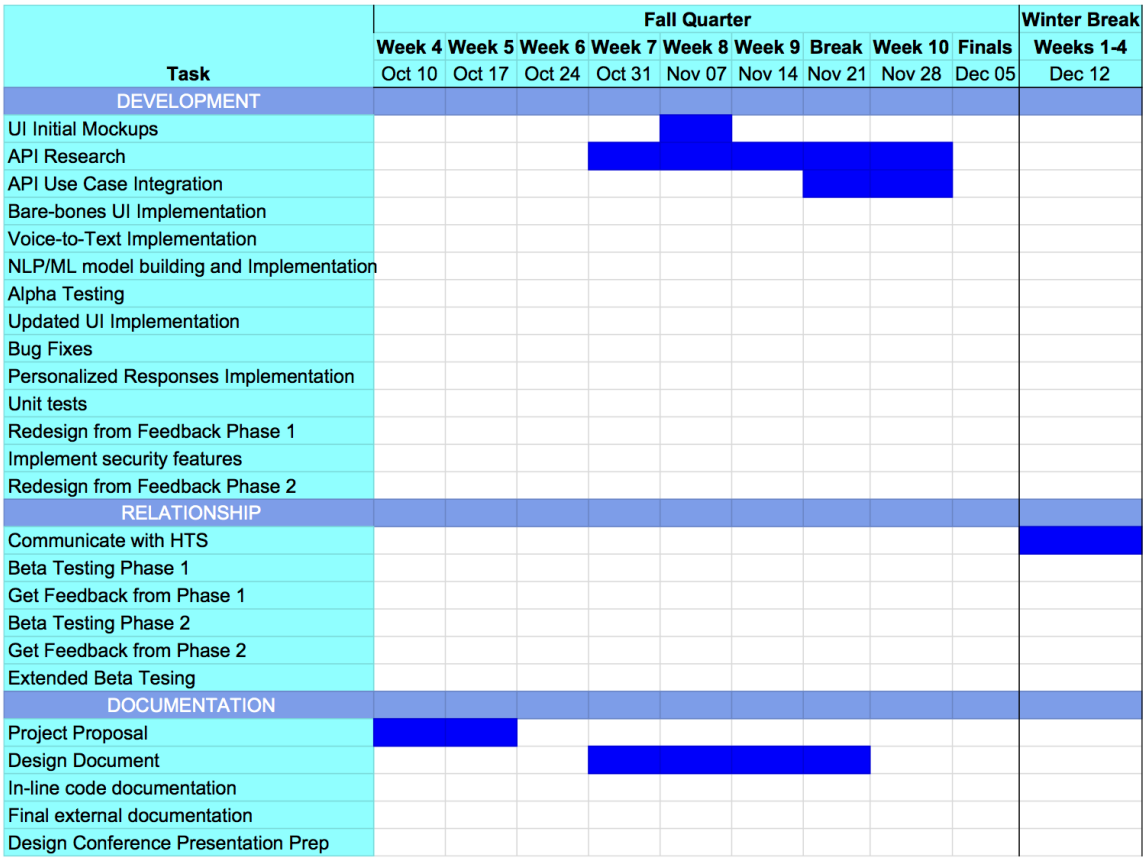
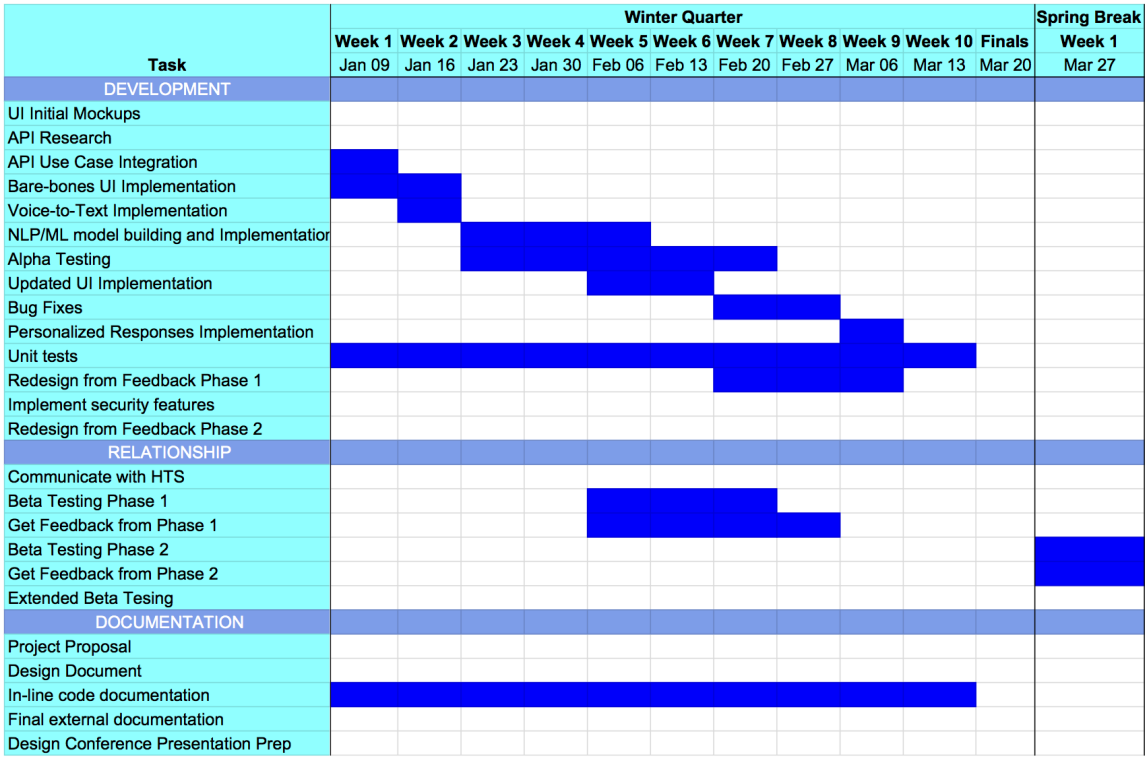


Figure 14.1: Fall Quarter Development Timeline Gantt Chart



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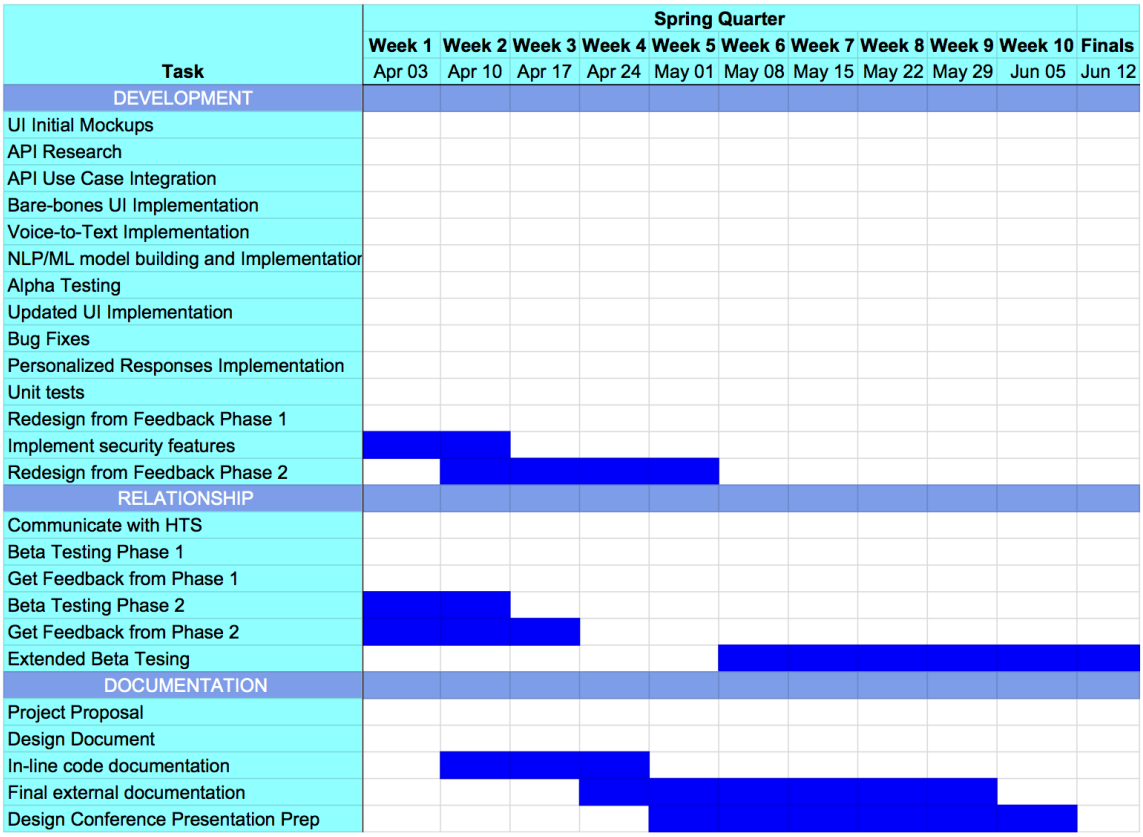

Figure 14.3: Spring Quarter Development Timeline Gantt Chart

Chapter 15

Install Guide

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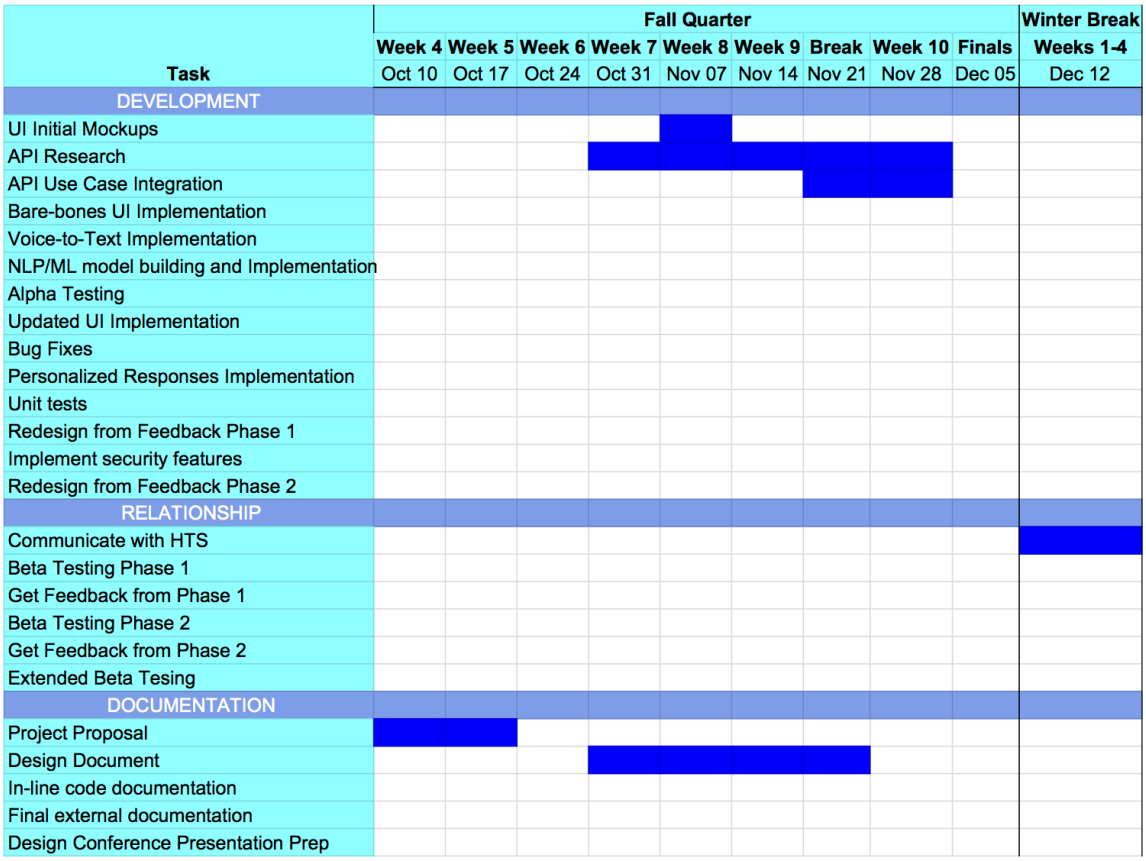

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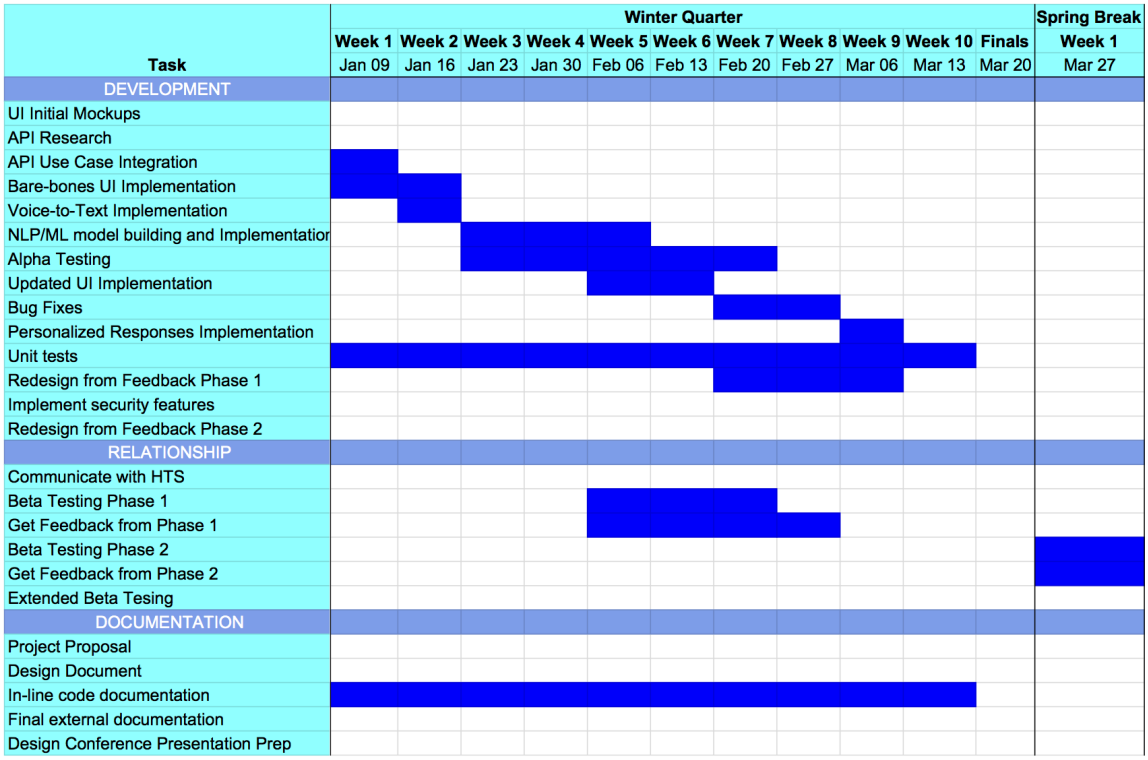

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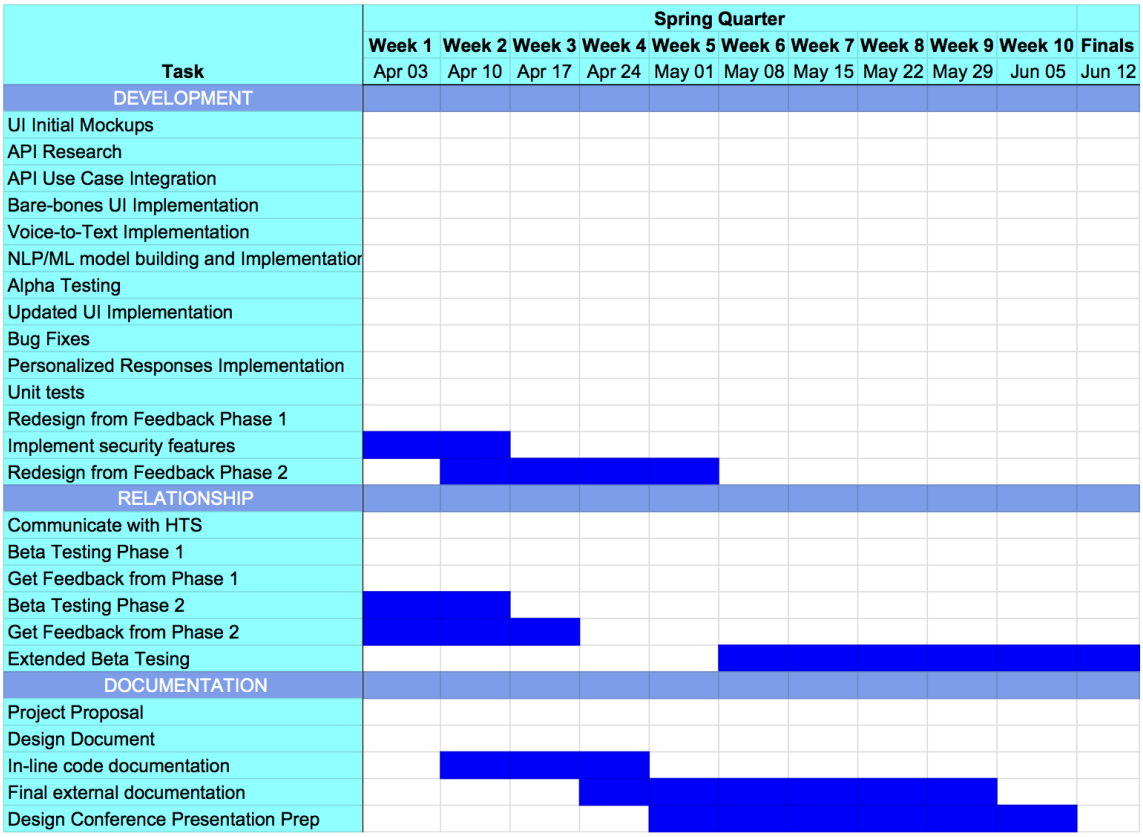

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