ParkinSense

Parkinson's Disease Detection Project

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CS 472 - Software Product Design and Development I

Fall 2023

Introduction

Abstract

ParkinSense is an iPad application that uses machine learning to detect early signs of Parkinson's disease from voice recordings and hand-drawn inputs. This app identifies subtle changes in vocal and motor functions. Patients can spot potential symptoms early, and healthcare providers can track disease progression non-invasively. This tool aims to reduce reliance on the current subjective diagnosis approach and improve management of Parkinson's disease. In our endeavor to achieve this, we are also incorporating proposed functions, a UML diagram, an initial prototype, and a report detailing individual contributions to date.

Executive Summary

Parkinson's disease is the second most common neurodegenerative disease, affecting more than 1 million patients in the United States, trailing only Alzheimer's [1]. Forecasts suggest a rapid increase in the number, potentially doubling the global count of 7 million in 2020 by 2040 [2]. The financial strain is also significant, with the yearly costs of supporting a person with Parkinson's Disease (PPD) estimated to be $10,000 higher than individuals without, culminating in an annual expenditure of 23 billion US Dollars in the US [3]. Furthermore, many PPDs report psychological distress, diminished quality of life, and increased dependency on caregivers [4].

While there's currently no proven treatment [5], early diagnosis offers substantial benefits. It is highlighted by recent studies that early-stage PPDs who promptly undergo certain treatments can significantly reduce the worsening of symptoms like resting tremor [6]. Hence, detecting the disease at its early stages can be instrumental in slowing its progression, preserving the patient's quality of life, and mitigating socio-economic costs.

A distinct characteristic of Parkinson's disease is its influence on speech [7] and fine hand movements [8]. Individuals with Parkinson's often face motor-related challenges, exhibiting symptoms like monotone speech, dysarthria [9], and subtle inconsistencies in hand-drawn patterns due to muscle rigidity [10].

The traditional diagnostic method, Movement Disorder Society - Unified Parkinson's Disease Rating Scale (MDS-UPDRS), necessitates in-person visits and evaluations by healthcare professionals [11]. This method can be prone to errors from human interpretation [12] and poses a logistical challenge for many patients seeking medical attention. We are in a quest to make a non-intrusive software to capture both speech and handwriting data in routine settings. By utilizing machine learning, our solution aims to assist in identifying early signs of Parkinson's, offering both enhanced convenience for patients and a means for healthcare providers to manage the disease more efficiently.

Motivation

Competitive Analysis

The Movement Disorder Society - Unified Parkinson's Disease Rating Scale (MDS-UPDRS) is the predominant approach employed to evaluate diverse facets of Parkinson's disease. This method amalgamates patients' self-reported data on daily living behaviors with examiners' observations of motor examination [11]. Despite its rigorous foundation backed by extensive research and a robust examiner qualification process [13], skepticism about the method persists. The primary concerns revolve around the absence of objective lab tests and a reliance on patient-reported data, which raises questions about its ability to reliably detect the early stages of PD [14]. Additionally, some argue that the rating system is marred by a significant amount of error variance [15]. It's pertinent to note, however, that our software will integrate MDS-UPDRS ratings as a crucial input for machine learning. Critics of this approach argue that it may be hindered by the absence of an objective "ground-truth" score [16] and a lack of environmental supervision [17].

Figure 1. *PD Me* app's launch screen

Upon searching for "Parkinson Disease" in the iOS App Store, we identified an app called "PD Me." This application attempts to diagnose PD based on users' self-assessed inputs through questionnaires, covering areas like mood, tremor, voice, and limb coordination. Notably, the last update for this app was seven years ago and failed to run on modern devices. Beyond "PD Me", the majority of available apps are geared towards assisting patients in tracking disease progress, scheduling, or rehabilitation.

Parkinson's Disease-related apps on the market [19]

Name	Operating System	Users	Brief Description
cloudUPDRS	Google Play	Professionals and patients	App to measure gait, tremor, and reaction time.
MyTremorApp	Google Play	Professionals and patients	App to measure hand tremor and bradykinesia.
ParkinsonAI	Google Play/iOS	Patients	App to measure tremor and posture and proposes exercises and diets for the control of symptoms.
Tremor Measurement	Google Play	Professionals	App to assess tremor in amplitude and frequency.
Cepha	iOS	Professionals and patients	App to measure dysphonia, resting tremor, action tremor, and postural tremor.
CYPD	iOS	Professionals and patients	App to monitor symptoms and medication effectiveness. This information is sent to the clinician.
Parkinson's LifeKit	iOS	Patients	App to manage PD. Presents cognitive and motor tests (voice, tapping, and tremor); a personal diary; medication reminders; and a result graphic to see variations in symptoms.
Patana AI	iOS	Professionals	App to evaluate tremor, posture, and movement.
StudyMyTremor	iOS	Professionals and patients	App to evaluate tremor in amplitude and frequency.
Tremor Analysis	iOS	Professionals and patients	App to assess tremor in frequency. It can be customized by choosing which parameters you want to measure.
Tremor Measurer	iOS	Professionals	App to assess tremor quantitatively.
Tremor Measurer Lite	iOS	Professionals	App to assess tremor quantitatively.
TREMOR12	iOS	Professionals	App to measure tremor parameters and analyze them later.

In academic circles, a noteworthy effort from Australia deemed their PD diagnostic initiative as having "potential." However, they cited challenges related to the "accents" factor, attributable to the strong localization of their data source [18]. A follow-up search revealed that their application hasn't been published on any app stores. Further, a 2022 paper highlighted that, in their market research encompassing apps with a similar focus, only 1 out of 13 apps actively measured PD symptoms and offered predictions [19]. The rest were either dedicated to disease management or had been removed from the store at the time of our review.

Journal Articles

Numerous studies have tackled the issue from diverse angles, focusing on various symptoms. Analytical methods encompass speech signals, handwriting patterns, gait, tremor, SPECT, MRI, ultrasound, PET, and combinations thereof [20]. Among these, voice and handwriting data have shown accuracies of 90.9% and 87.6%, respectively, yet combining them remains a less explored territory. Based on Amato's recent survey, insights in speech analysis include: (1) the prevalent use and reliability of MFCC features across learning models, (2) the non-impact of the recording device on performance while highlighting the significance of session supervision, and (3) the frequent use of DARTH-VAT for feature extraction [21]. For handwriting analysis, challenges abound, often linked to various factors corresponding to human input variations. Its image-based nature also necessitates a significantly larger dataset [22][23].

In developing our application, we derive key insights from existing research. When formulating hypotheses, it's important to question the feasibility of acquiring inputs like speech and handwriting in unsupervised settings and seek expert opinions on potential pitfalls. Data collection should span multiple avenues: from online public domains to grassroots community sources. In terms of modeling, it's essential to consider metrics beyond accuracy since both false positives and false negatives carry significant implications. For the application's implementation, the user interface is paramount. It should be designed to minimize user errors, particularly since our target demographic primarily consists of senior citizens.

Requirements

ParkinSense will be used to detect early signs of Parkinson's disease through the use of voice recordings and hand-drawn inputs. The given inputs are then used to give the user a score on the MDS-UPDRS. The user can also refer to past results, and test again if they choose to. Lastly, since it is recommended that they take tests every six months, there will also be an option to have notification reminders.

Functional Requirements Table

ID	Title	Requirement Description	Date	Done
F1	Verification System	A screen that will prompt the user for their FaceID or device passcode.	10/23	
F2	Audio Recording Screen	A screen that will record and store a series of audio recordings from the user.	11/2	X
F3	Spiral Drawing	The user will be prompted to trace a spiral on the screen, and the input will be stored as an image.	11/2	X
F4	Show Test Results	A screen that displays the user's test results.	11/7	X
F5	Python Integration	Integrate the Python language into Swift. Initially done using Beeware. Then done using the main workspace.	11/26	X
F6	Extraction	A Python script to extract the audio recordings into MEL-spectrograms. Initially done using Beeware. Not done in the workspace.	11/26	
F7	Model	A Python script that uses the RNN and CNN models for the MEL-spectrograms and hand-drawn images respectively to output a positive or negative test result. It can also be a Swift model converted from a Keras Tensorflow H5 model.	12/1	
F8	Auto-Logout	The app should automatically log out the user after 30 minutes of inactivity.	11/23	
F9	Dim/Obscure App When Switching Apps	The app window will dim while the user is switching between apps.	11/23	

Functional requirements description

F1: Verification System

A screen that will prompt the user for their FaceID or device passcode, depending on what they have set up for their device. This is to ensure privacy.

F2: Audio Recording

This will record a series of audio recordings from the user during the voice test portion of the test. These audio recordings will need to be stored in the system for users to refer to, and so that they can be used to judge the user's score on the MDS-UPDRS scale. However, after ParkinSense 2.0, it now returns a positive or negative result.

F3: Spiral Drawing

The user will be prompted to trace a figure on the screen three times during the line drawing portion of the test. The user's inputs will be stored as an image in the system for users to refer to, and so that they can be used to judge the user's score on the MDS-UPDRS scale. However, after ParkinSense 2.0, it now returns a positive or negative result.

F4: Show Test Results

A screen that displays the user's test results for a completed test; this includes both the most recent completed test, as well as past tests. The screen will allow the user to listen to the audio recordings taken during the voice test section, view their inputs for the line drawing section, and view the assigned result based on the tests.

F5: Python Integration

Integrate the Python language into Swift. Initially done using Beeware. Then done using the main workspace. This was tricky to incorporate for one reason: Swift is a compiled language while Python is an interpreted language. Therefore, we need a way to make Python code compilable. There were 2 options for this. One of them was a framework called BeeWare. This allowed us to execute Python code. The problem was it was a separate workspace from our main, so while it did get us closer to fixing our problem, it was separate from our app. The second option was another framework called PythonKit. This is exactly what we wanted since Python code can run in the Swift programming language and inside our workspace.

F6: Extraction

A Python script to extract the audio recordings into MEL-spectrograms. Initially done using BeeWare. Not done in the workspace. A good portion of time was spent getting the extraction script to work in the BeeWare environment. The first problem was installing third party libraries that were required to make the script work. This took about a week to solve and proved to be fairly easy as it was learned that the entire Python environment was inside of BeeWare itself, including every standard library. After that, the script was modified to run exactly the code that is required (there were many options for what it could do, but we only needed a particular MEL-spectrogram) and then we had a file upload portion. However, all of this was done with

BeeWare. The third-party library challenge proved to be fatal when attempting to install it with PythonKit because some libraries have required signed binaries like NumPy, and such, aren't as simple to implement. Therefore, while BeeWare proved it to be possible, this was not a completed functional requirement.

F7: Model

A Python script that uses the RNN and CNN models for the MEL-spectrograms and hand-drawn images respectively to output a positive or negative test result. It can also be a Swift model converted from a Keras Tensorflow H5 model. The models themselves work as Python scripts. However, since even F6 proved to be challenging, getting a machine learning model to work within Swift is much more difficult comparatively speaking.

F8: Auto-Logout

For security reasons, the app should automatically log out the user after 30 minutes of inactivity. This was never implemented.

F9: Dim/Obscure App When Switching Apps

For privacy reasons, the app window will dim while the user is switching between apps. This was never implemented.

Non-functional Requirements Table

ID	Title	Requirement Description
NF1	Operating System	The application will be designed and tested on iOS for the scope of this project.
NF2	Application Programming Language	Swift will be used to program the application.
NF3	Data Programming Language	Python will be used for the machine learning aspect of the project to train data.
NF4	Software License	At the moment, this application will use the MIT License.

Non-functional Requirements Description

NF1: Operating System

The application will be designed and tested on iOS for the scope of this project. It will primarily be tested on an iPad.

NF2: Application Programming Language

Swift will be used to program the application because it was made for iOS development.

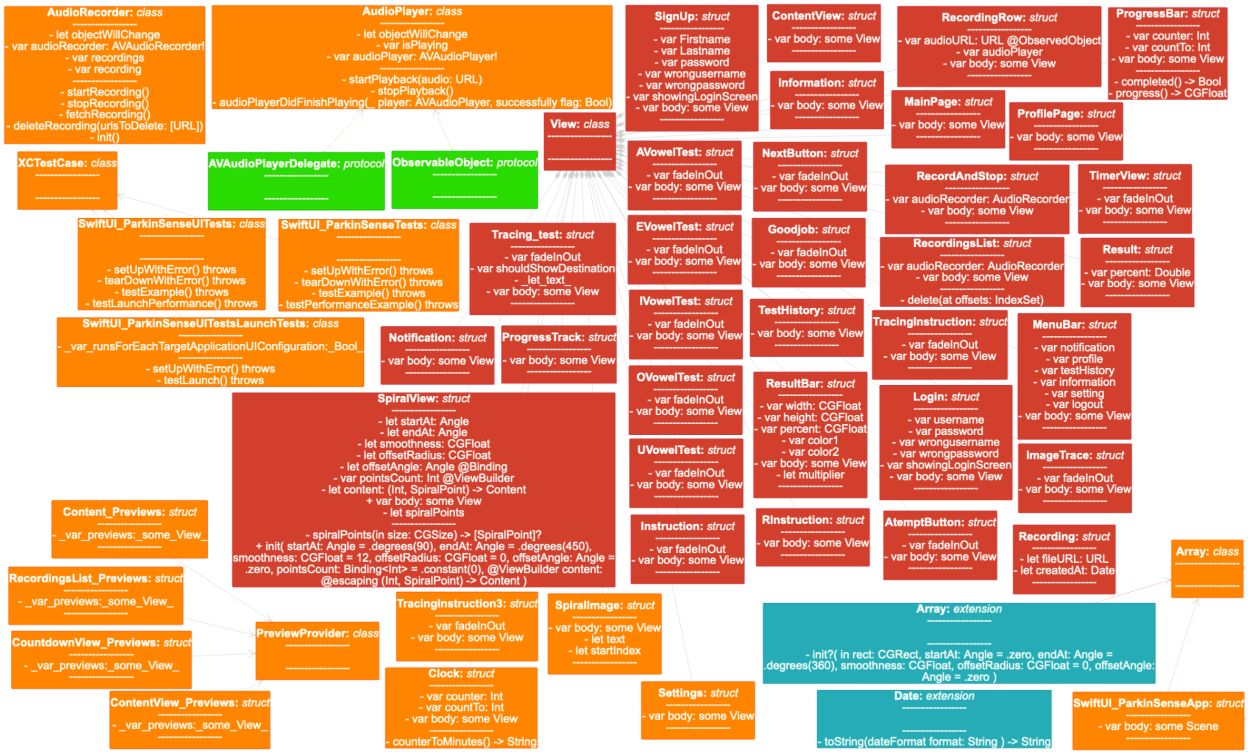
NF3: Data Programming Language

Python will be used to train and process the data that will be used for testing, since it has access to many well-established libraries for data processing and machine learning.

NF4: Software License

For this application, we intend to use the MIT License. For the sake of advancements in accessible early detection methods for Parkinson's disease, we grant permission to distribute and modify our source code as long as we are given credit.

Design Document



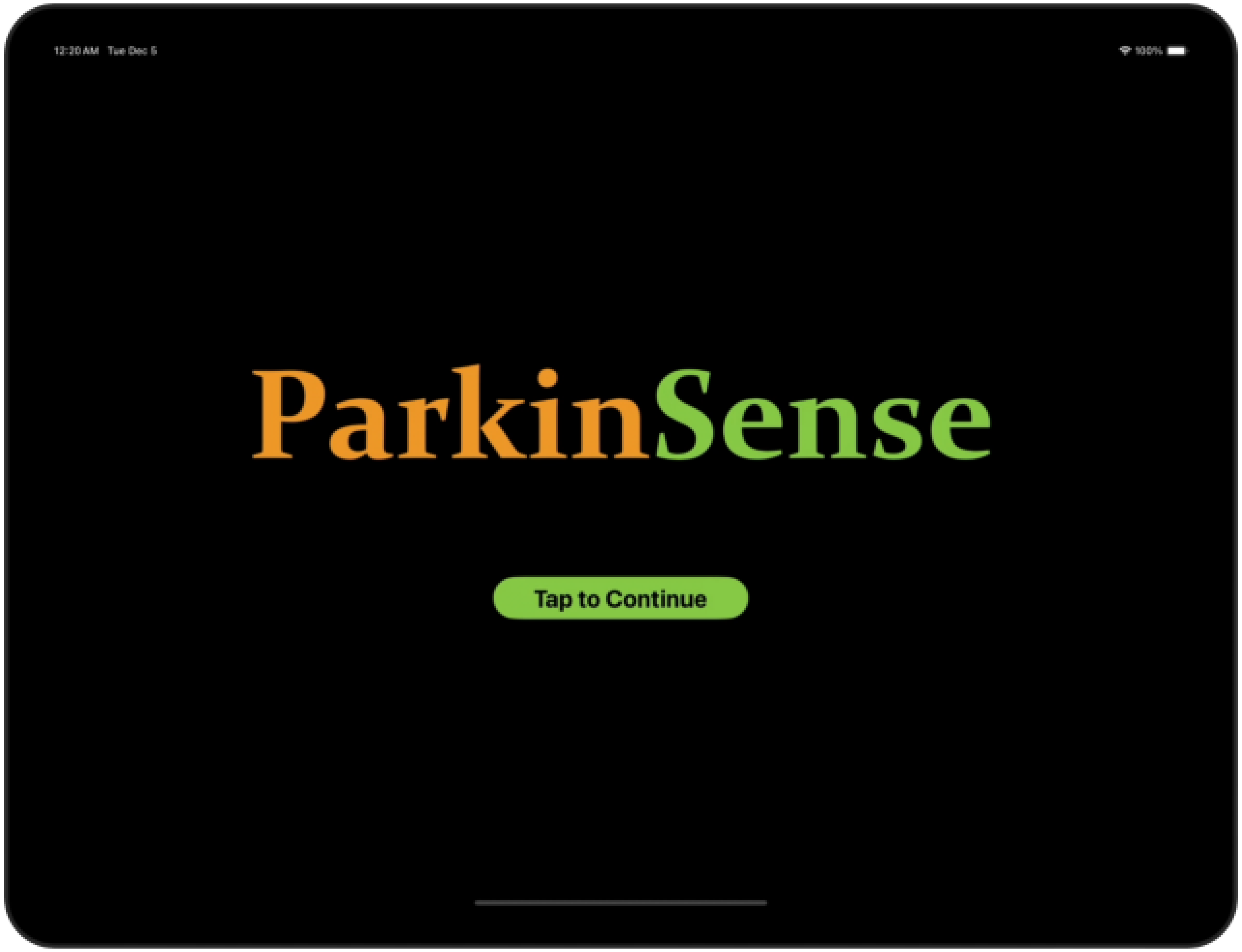
This UML Class Diagram was generated automatically using the [Swift Auto Diagram] open-source program. When the diagram was first generated, it did not have the details on the lines which indicate dependencies, composition, nor inheritance. As a result, those were manually added in. They may be hard to see as it is a large image and some of the elements overlap the lines. Finally, since the Swift language uses structs for almost everything, most of the elements in the diagram are structs, and therefore, *typically* do not have methods.

Elements highlighted in red on the UML class diagram represent pages that are accessible within the app. As an illustration, the *AVowelTest* page displays the symbol 'A,' produces a sound, and captures audio.

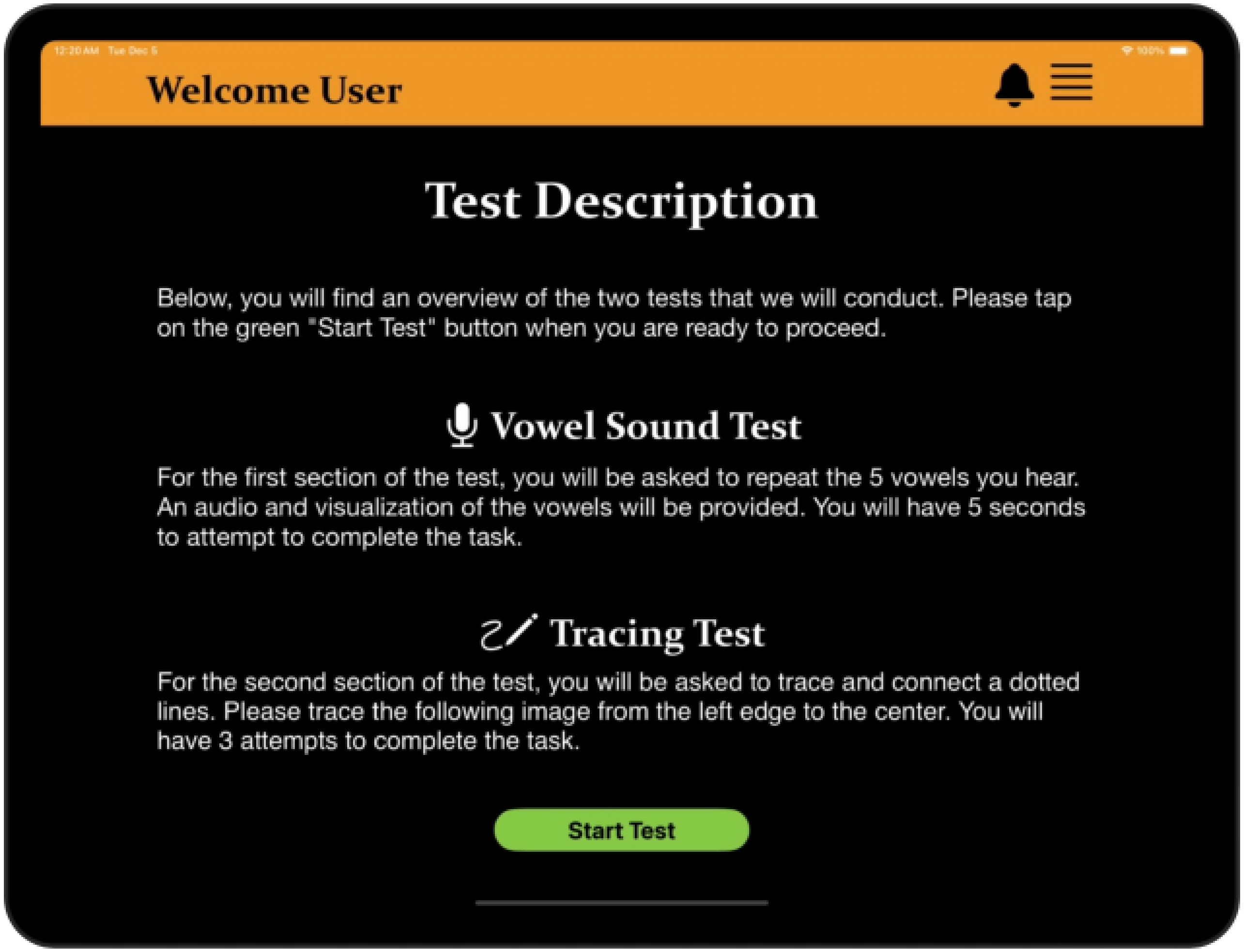
Items shaded in orange denote structs or classes that operate in conjunction with other Swift files but are not visible within the app interface. For instance, *AudioPlayer* and *AudioRecorder* are open-source projects developed by external contributors, enhancing the functionality of voice tests.

Green elements correspond to protocols, while aquamarine elements signify extensions on the diagram.

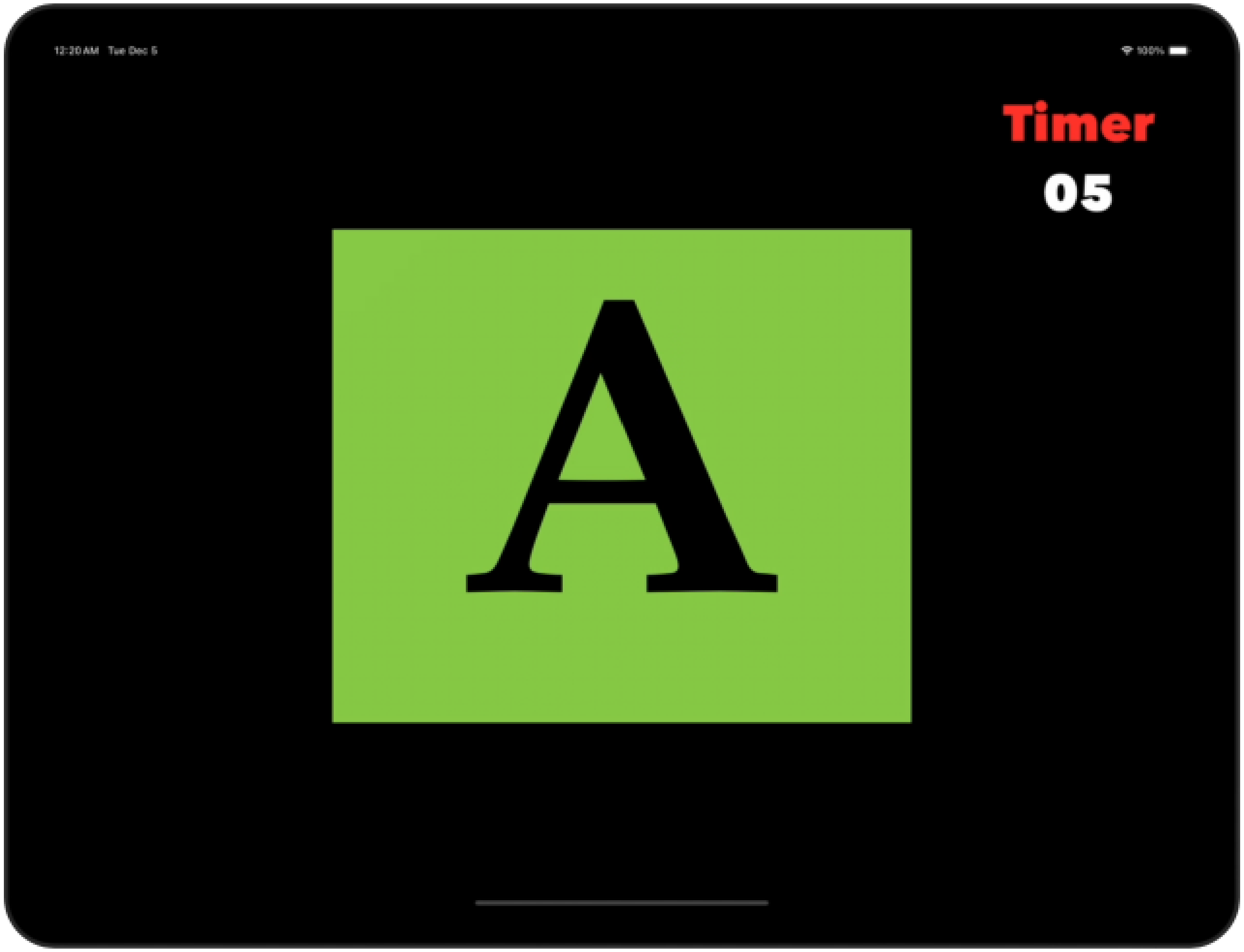
Prototype



This is the homescreen. It shows the app logo and asks the user to tap the button to start the testing process. Originally, there was supposed to be a login system to differentiate between profiles. This would have been done using Apple ID or Face ID, native to iOS.

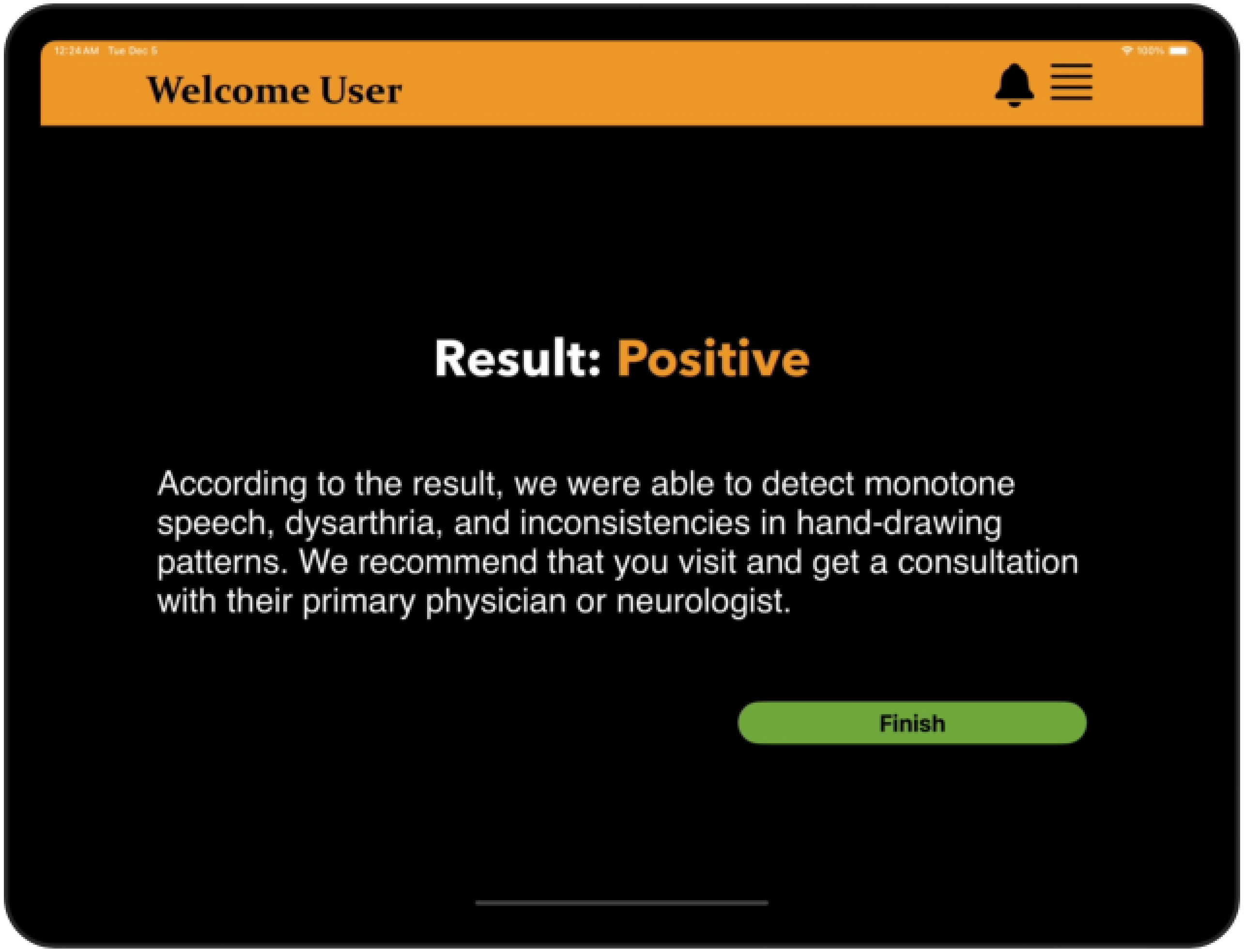


Descriptions of the tests so that the user knows what to expect.



The vowel test displays a vowel and plays the sound that the user is supposed to mimic. After the sound plays, a microphone icon lights up indicating that it is recording and the timer at the top right counts down. This is supposed to record the user's vowel sound. Then, these audios are extracted into MEL-spectrograms for the machine learning model to process. After 5 seconds, it moves onto the next vowel. There are 5 vowels in total.

The spiral test displays a dotted spiral for the user and they are supposed to trace the dots starting from the center. They have 3 attempts and afterwards, it will save the images for the machine learning model to process.



After the last spiral test, the machine learning model will compute the results and display either a positive or negative result. This diagnosis is not considered to be final due to medical standards, but it should be an indicator to seek professional help.

User Study

ParkinSense is aimed as an all-encompassing tool for Parkinson's Disease management, aiming to cater to a diverse user base. This user base is segmented into two principal groups: healthcare professionals, which include neurologists, primary care providers, specialized and administrative nurses, and end users, comprising patients and their caregivers. We expect that each category will offer distinct insights and varying perspectives on the app.

For the user study, we have outlined three key objectives in our questionnaire design:

1. **Validating Our Concept:** We seek to understand the potential criticisms and concerns healthcare professionals might have about ParkinSense. This early feedback is crucial to address or circumvent potential issues from the outset.
2. **Identifying Real-World Problems:** We aim to uncover specific challenges in professional practice and condition management that these professionals believe ParkinSense could address.
3. **Gauging Expectations:** Understanding what both healthcare professionals and end users expect from the app will help us align our development goals with their needs.

By focusing on these areas, we aim to tailor ParkinSense not only as a technological solution but as a practical aid in the management of Parkinson's Disease.

Interview Questions

Different interview questionnaires for different user groups, however, they are the same in terms of focusing on their expectations, concerns and suggestions toward the product.

Healthcare professionals:

Project name: ParkinSense - iPad app to help detect Parkinson's Disease

Project Goals:

- Enhance management of patient conditions.
- Alleviate the workload for healthcare professionals.

Project Descriptions:

- An iPad app that takes user's speech and handwritten patterns as inputs, then returns the estimated MDS-UPDRS rating
- Mechanism: machine learning model we train from publicly available data on the subject
- Academic background: recent surveys (Mei-2021, Amato-2023) are attached for your preference.

Queries on Current Methodologies:

- Our research suggests that MDS-UPDRS is a dominant methodology for PD diagnosis. What are your thoughts on this approach?
- In your opinion, what are the primary shortcomings of this method?

- How do you believe this approach could be refined?

Feedback on Our Proposed Solution:

- Do you find our stated goals and ideas both necessary and practical?
- What specific features do you think our solution should encompass?
- How do you envision the integration of our tool within case management?
- In which situations do you think our application would be exceptionally beneficial, or perhaps not at all effective?
- Are there specific factors that, in your view, would determine the success or failure of our application?

Additional Considerations:

- Could you share with us on any ethical or regulatory challenges we should be mindful of?
- We would be grateful for any additional feedback you might have concerning the feasibility of our initiative.

End users:

Project name: ParkinSense - iPad app to help detect Parkinson's Disease

Our Goals:

We want to make it simpler for you to manage Parkinson's Disease from the comfort of your home, quickly and easily.

Your Current Routine:

- How do you currently keep track of your (or patient's) health, especially when it comes to Parkinson's?
- What do you like or dislike about this current method?
- Do you have any ideas on how this routine could be made easier for you (and the patient)?

About Our Upcoming App:

- Do you think our app sounds like something you would find useful?
- What features would you love to see in our app?
- How would you see yourself using our app in your (or patient's) day-to-day life?
- Can you think of any situations where our app would be really helpful? Or perhaps not useful at all?
- What do you think would make our app a hit or a miss?

Extra Thoughts:

- If you have any more suggestions or comments, we'd love to hear them!

Demographics

Tag	Age	Gender	Education	Occupation	Access to healthcare	Time working with PD
Specialist nurse 1		Male	Ph.D	Registered Nurse		Not specifically on PD
Neurologist 1*		Male	Ph.D	Neurologist		3 years
General nurse 1		Female	Bachelor	Nursing Assistant		1 year
Patient 1	83	Female	K12	N/A	Good	4 years
Caregiver 1	55	Female	K12	Service	Good	4 years

*As off the date of 10/26: we are still waiting on their responses.

Results

User Tag	Concerns	Suggestions
Specialist nurse 1	Method transparency Scientific Validity Wide range of users: dementia, amputees and mute Complex cases: PD with co-existing conditions	Include gait-walking and tremors as inputs Should act as screening tool, rather than replacement of clinician
General nurse 1	Technical support: availability and quality	
Patient 1	Ease of use Remember to use	N/A
Caregiver 1	Ease of use	Reminder function

The user study has provided us with a range of insights that will be invaluable as we continue the development of ParkinSense.

Overall, the healthcare specialists have indicated a welcoming interest in our initiative, although they have substantial concerns. Their questions primarily focus on the machine learning algorithms and how effectively they can generalize the collected data across a broad population of patients. They are also skeptical about how external factors, such as background noise, might interfere with the voice recordings, thereby affecting the diagnostic capability. Another recurring concern is the specificity of the app: they questioned how the app would differentiate Parkinson's disease symptoms from those of other conditions such as .

In our interview with the specialist nurse, several key concerns were raised that touch on various dimensions of the ParkinSense app. The nurse emphasized the importance of methodological transparency, suggesting that users are more likely to trust the app if they understand how its algorithm functions. Questions were also raised about the scientific validity of our machine-learning techniques, indicating that we may need to bolster the app with additional research or endorsements from credible sources in neurodegenerative diseases. The nurse also pointed out the need for inclusivity, particularly for users who might have co-existing conditions like dementia, or physical limitations such as amputations or speech difficulties. Lastly, handling complex cases where Parkinson's Disease coexists with other conditions like dementia was a concern, emphasizing the need for the app to be adaptable to complicated medical profiles. They also suggested that we should include measuring gait-walking and tremor as input features as they are common PD's symptoms but hard to detect by clinicians.

Building on the specialist nurse's feedback, we find that many of their concerns align with the challenges and limitations we have encountered in academic literature. This serves as a validation of sorts, but also as a reminder of the challenges that lie ahead. First and foremost, we are significantly limited in our ability to obtain quality and adequate datasets. For example, we're currently grappling with issues related to the publicly available datasets we're using for model training. These datasets often lack critical information like demographic details and MDS-UPDRS ratings, providing only binary labels for Parkinson's Disease (PD) or healthy control (HC). Furthermore, there's a notable imbalance in the size of these datasets. While we have access to a sizable dataset of hand-drawn patterns, the available speech data is significantly limited in comparison. Another complication is the absence of datasets that combine both drawing and speech features from the same sample, making it difficult to construct an ideal ensemble learning model. As a result, we're forced to use a less-than-ideal approach, which involves assigning weights or biases to the outputs of individual models.

Expanding on the issue of input features, adding more variables like gait-walking and tremor detection, as suggested by the specialist nurse, is indeed an attractive idea. In general, machine learning models benefit from more diverse and relevant input features, which can lead to improved diagnostic capabilities. However, there are pragmatic constraints we need to consider. The focus on voice and handwriting in the initial stages of ParkinSense was deliberate; these are non-invasive metrics for which datasets are more readily available and easier to test in a controlled environment.

Furthermore, integrating these additional features presents its own set of challenges, especially when considering our current dataset limitations. As we've previously discussed, constructing an ideal ensemble model is difficult when datasets for different features are independent from each other. Nevertheless, incorporating more diverse and interconnected datasets should be at the top of our agenda for future development, following the conclusion of this senior design project.

On the other hand, the general nurses raised concerns about practical integration. They were keen to understand how the app and its hardware would fit into their existing administrative and patient-care processes. They questioned the reliability of the app and its hardware and were especially interested in the level of technical support that would be available.

On the side of the end users, willingness to adopt the technology exists, but there are reservations. The primary concern is around usability; they want to know that they'll be able to use the app without any hitches. Participants expressed the need for a user-friendly interface that would include features such as larger font sizes and more straightforward steps, particularly given that many users may have limited eyesight or not be tech-savvy.

Based on the invaluable feedback from healthcare specialists, general nurses, and end users, we are readjusting our action plan with a focus on incremental improvement. Our first major adjustment is to shift the intended usage scenario from at-home use by end users to implementation within selected healthcare facilities as a preliminary screening tool. This move aims to address multiple concerns: it minimizes user error, ensures a more controlled environment for data collection, and allows healthcare providers to better assess the tool's reliability and effectiveness. The centralization also allows us to provide better support to a smaller number of users.

Our second modification involves repositioning the app's output as a tool for gathering research data. Given the current limitations of our datasets and machine-learning models, it's too soon to present the app as having any diagnostic value, let alone as a standalone solution for diagnosing Parkinson's Disease. However, collecting more high-quality data in controlled clinical settings will enable us to fine-tune the app's algorithms and improve its diagnostic accuracy over time. This iterative process not only allows the product to reach the market sooner, avoiding endless development cycles, but also enables us to incorporate continuous user feedback and address ongoing concerns and suggestions.

Team Reporting

Meeting Report - Detecting Parkinson's Disease App

Date: 9-13 **Time:** 17:00 - 19:00 **Location:** Discord VoIP

Attendees:
- Tan Nguyen
- Alex Akoopie
- Francesca Cueto
- Emnet Alemayehu

Meeting Agenda:
1. Introduction and Research Overview
2. App Development Plan
3. Assignments and Responsibilities
4. GitHub

Meeting Summary:
The meeting prioritized respecting everyone's time and highlighted the importance of clear and efficient communication. We agreed that team members should reach out for assistance if they encounter challenges while working on their tasks.

1. Introduction and Research Overview:
During the presentation, Tan Nguyen outlined his research, which revolves around the utilization of a machine learning algorithm to identify Parkinson's disease by analyzing speech audio. Parkinson's disease is a neurodegenerative disorder that primarily impacts motor skills. Key highlights of the discussion included:
- The quality of audio does not significantly impact machine learning results.
- All audio data for the app will consist of vowel sounds.
- The potential impact of accents on audio quality was acknowledged.
- The app will have a feature to store history from past tests.
- It was determined that MFCC (Mel Frequency Cepstral Coefficients) is the most suitable feature for detecting Parkinson's disease in audio.

2. App Development Plan:
The app development process will involve several phases:
1. Machine learning (Python)
2. Prototype development (ProtoPie)
3. App building (Swift)
4. User interface and/or art

3. Assignments and Responsibilities:

During the meeting, Tan Nguyen took the initiative to create the GitHub repository for the project. Assignments and responsibilities for each phase of development were not explicitly outlined in the provided transcript but should be discussed and documented separately for clarity.

Conclusion:

The meeting served as an introduction to the project and research conducted by Tan Nguyen. It established the development plan for the Parkinson's disease detection app and emphasized effective communication and mutual respect among team members. Further discussions and assignments are needed to progress through the project's various phases.

Next Steps:

- Define specific roles and responsibilities for each team member.
- Develop a detailed project timeline.
- Initiate the machine learning phase using Python.
- Begin prototype development using ProtoPie.
- Start Swift app development.
- Design the user interface and/or artwork for the app.

Date: 9-18 **Time:** 17:00 - 18:20 **Location:** Discord VoIP

Attendees:
- Tan Nguyen
- Alex Akoopie
- Francesca Cueto
- Emnet Alemayehu

Meeting Agenda:
1. Project Updates
2. Discussion on Design Document
3. Questions for the Teacher

Meeting Summary:
The meeting centered on project progress updates and deliberations regarding the design document. Additionally, the team collaboratively generated a list of questions aimed at seeking clarification on different project aspects from the teacher.

1. Project Updates:
- Alex created the Gantt chart for the project.
- The design document was discussed section by section, from top to bottom.
- Tan created the abstract and encouraged everyone to suggest names for the app.
- Tan also completed the executive summary and abstract.
- Tan made progress on the motivation section but noted that there are no identical apps to use as references.
- Tan is still working on gathering journal articles.
- Fran created a requirements table for the app. Tan suggested ordering it by dependency, while Alex recommended ordering it by ease of implementation. Fran will also refine the descriptions.
- Fran initiated a non-functional requirements table, which is in the early stages.
- Fran produced a UML diagram for some of the requirements, utilizing gleek.io.
- Emnet developed a prototype, focusing on the login system and testing using ProtoPie. Feedback is required before submission.
- Alex recorded the previous meeting and generated a team tasks chart.

2. Discussion on Design Document:
During the meeting, the team addressed multiple sections of the design document, encompassing the abstract, executive summary, motivation, and requirements tables. Additionally, there was a discussion about Fran's UML diagrams and Emnet's prototype.

3. Questions for the Teacher:
The group compiled a list of questions to seek clarification from the teacher:
- Whether references should be included in the executive summary.
- Clarification on the required number of journal articles and their depth.
- Guidance on the number of UML diagrams required for the functional requirements table.
- Clarification on the date format in the functional requirements table.
- Guidance on software licensing considerations.
- Specific expectations regarding the team tasks chart.
- Clarification on individual commit requirements.

Conclusion:
The meeting emphasized the advancements achieved across different project facets, such as the design document, Gantt chart, and prototype. The team also worked on a list of questions to ensure alignment with the teacher's expectations.

Next Steps:
- Continue refining the design document and gather necessary references.
- Provide feedback on Emnet's prototype.
- Address the questions raised with the teacher for clarification.

Date: 10-2 **Time:** 17:00 - 17:30 **Location:** Discord VoIP

Attendees:
- Tan Nguyen
- Alex Akoopie
- Francesca Cueto
- Emnet Alemayehu

Meeting Summary:
This group meeting revolved around project updates and planning. Key points discussed include virtual environment setup, project responsibilities, and upcoming tasks.

Project Updates:
- Alex Akoopie successfully set up the virtual environment using Macincloud and Xcode. However, attempts to configure it remotely with his Windows machine using Visual Studio faced challenges.
- Alex experimented by writing the project title on the iPad simulator using Swift.

Backend Concerns:
- Emnet Alemayehu expressed concerns about the backend aspect of the project, particularly voice recordings. She suggested that Alex, Fran, and herself should focus on this aspect.
- It was clarified that Tan had already completed the model, so there's no need for concern in that area.
- Alex agreed to integrate the UI with the backend to ensure a smooth workflow.
- Emnet emphasized her preference for avoiding redundant work and stated that she would complete the UI by the end of the day.

Fran's Contributions:
- Francesca Cueto mentioned that she doesn't have any significant updates to share but highlighted her efforts in contacting a neurologist to enhance the project's credibility.
- She also mentioned her intention to contact the Parkinson's community for a live test with an actual patient.

Tan's Contributions:
- Tan Nguyen reported that he had uploaded the model and made changes to the README file.

Upcoming Tasks:
- The group discussed logistics for taking pictures for the project and appropriate attire.
- Emnet stated that she would begin working with Swift code the following week.
- Tan committed to sending emails to doctors as part of the project's next steps.

Conclusion:
The meeting served as an opportunity to update and coordinate the team's efforts, with a focus on project setup, backend responsibilities, and upcoming tasks.

Next Steps:
- Continue working on the designated tasks, with Emnet focusing on UI completion, Tan on communication with doctors, and Fran on networking with relevant professionals.
- Address any issues related to the virtual environment setup.
- Regularly communicate and update each other on project progress.

Date: 10-9 **Time:** 17:18 - 18:24 **Location:** Discord VoIP

Attendees:
- Tan Nguyen
- Alex Akoopie
- Francesca Cueto
- Emnet Alemayehu

Meeting Summary:
This group meeting primarily focused on addressing issues related to the virtual environment setup. The team also discussed various project-related tasks and responsibilities.

Virtual Environment Challenges:
- The majority of the meeting was dedicated to resolving errors in the virtual environment, specifically Macincloud. Several issues were encountered, including Xcode errors such as "active scheme does not build this file."
- Fran and Alex also faced preview problems due to Xcode's extended loading time. Efforts were made to rectify these issues. While some progress was made, Alex and Fran still needed to download the iOS base each time they started the simulator.

Project Tasks:
- Alex assigned a task to Fran, asking her to create a new branch to test the picture upload capability. The objective is to load an image into the app through RAM.
- Emnet took the lead in Swift code development. Her work so far encompasses a substantial portion of the functional requirements, including transitions and buttons. Key components include the vowel test, a login screen, settings, and a results page.
- Tan suggested a user-ready confirmation before the vowel test begins to enhance the user experience.

Model Conversion and Doctor's Questions:
- Alex developed a conversion model to transform a TensorFlow Keras model into a format suitable for Swift. However, he encountered some errors and required Tan's assistance to resolve these issues. Alex believed the problems might be related to his programming environment.
- Tan prepared a set of questions intended for an email to a doctor. The questions aimed to gather valuable insights for the project, including the popular methodologies for diagnosing Parkinson's disease and factors that could impact the app's effectiveness.

Conclusion:
The meeting primarily addressed challenges in the virtual environment setup and discussed the ongoing project tasks related to code development, model conversion, and communication with medical professionals.

Next Steps:

- Continue efforts to resolve virtual environment issues.
- Progress with the picture upload capability test.
- Emnet to further develop the Swift code with improvements based on the team's suggestions.
- Collaboration between Alex and Tan to fix model conversion errors.
- Finalize the list of questions for the doctor's email and initiate communication.

Date: 10-16 **Time:** 17:00 - 17:54 **Location:** Discord VoIP

Attendees:
- Tan Nguyen
- Alex Akoopie
- Francesca Cueto
- Emnet Alemayehu

Meeting Summary:
This meeting primarily addressed project updates and tasks as the deadline for Design Document 2 approaches.

Project Progress:
- Emnet Alemayehu made significant progress on the prototype, successfully getting the code for audio recording to function. She also initiated the spiral hand tracing test, though it currently lacks full functionality.
- Unfortunately, some of Emnet's work was unexpectedly deleted from the Git remote repository. After the meeting, Alex, Fran, and Emnet collaborated privately to rectify the issue by rebasing the entire repository.
- Fran Cueto responded to Alex's request by creating a separate branch for testing image upload functionality. She implemented a feature where a button allows users to upload an image from local storage, which then generates a random number as an output.
- Fran reached out to the Parkinson's support community but did not receive a response. Tan provided additional links related to Parkinson's disease communities, although Fran noted that she had already contacted most of them.

Upcoming Task:
- Alex Akoopie will focus on integrating Python with Swift. This integration is crucial as Tan requires Python to convert audio to an image using Python libraries.

- Tan to complete the user study summary and the group's plan adjustment (if any)

Conclusion:
The meeting highlighted the progress made by Emnet and Fran in terms of prototype development and image upload functionality. The team also discussed the challenge of deleted work from the repository and the upcoming deadline for Design Document 2.

Next Steps:
- Continue addressing any technical issues within the project repository.
- Collaborate to finalize the remaining aspects of the prototype.
- Coordinate efforts to meet the impending deadline for Design Document 2.
- Ensure Python-Swift integration for audio-to-image conversion.

Date: 10-16 **Time:** 17:00 - 17:54 **Location:** Discord VoIP

Attendees:
- Tan Nguyen
- Alex Akoopie
- Francesca Cueto
- Emnet Alemayehu

Meeting Summary:
The meeting was brief and focused on showcasing Emnet's project progress, discussing Fran's upcoming absence, and affirming that the project is on track.

Project Showcase:
- Emnet Alemayehu presented her project progress, demonstrating the login system, a vowel test, and a settings page. However, it was noted that the login system would not be used in the final product.
- Emnet ensured that the font sizes were adjusted to be easily readable, catering to elderly users.

Upcoming Absence:
- Francesca Cueto informed the group that she would be absent from Friday to Tuesday due to a vacation trip to Mexico. This information was shared to ensure awareness of her unavailability during that period.

Project Status:
- The team concluded that everything is proceeding according to the established plan, indicating that the project remains on track.

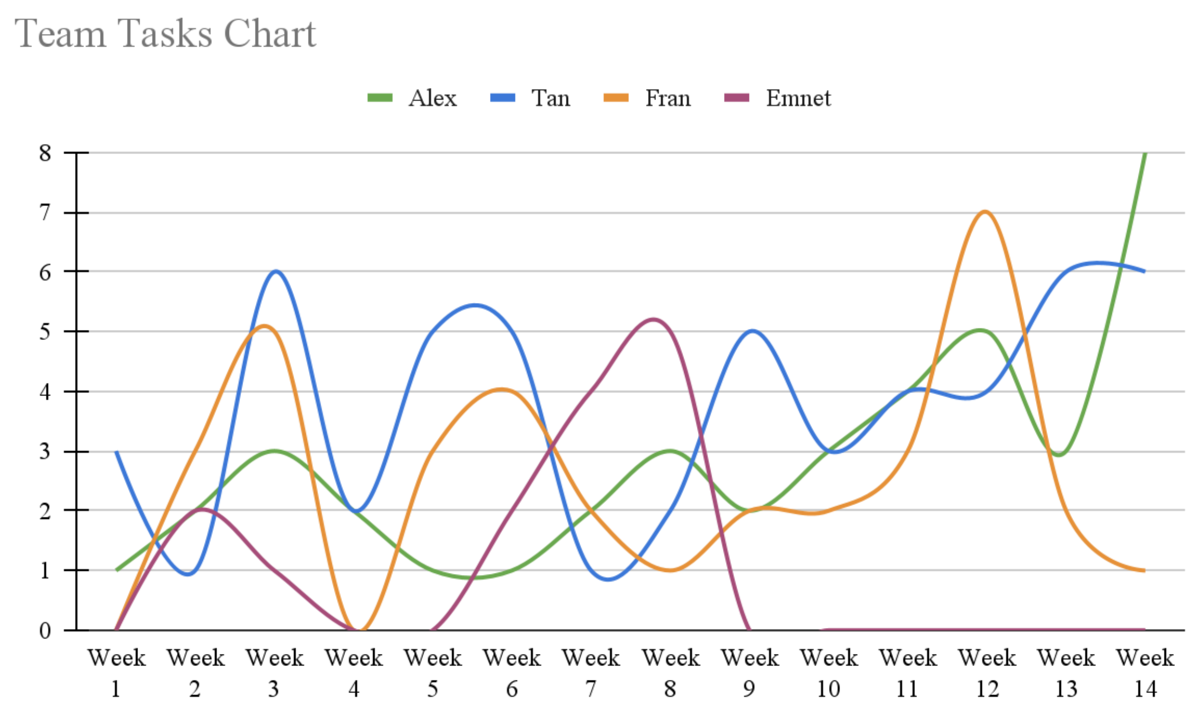
Conclusion:
The meeting primarily focused on showcasing project developments, addressing an upcoming absence, and affirming the project's progress. All team members were aware of Fran's temporary unavailability, and the project was confirmed to be proceeding as planned.

Next Steps:
- Continue with project tasks and responsibilities as outlined in the project plan.
- Accommodate Fran's absence during the specified period.

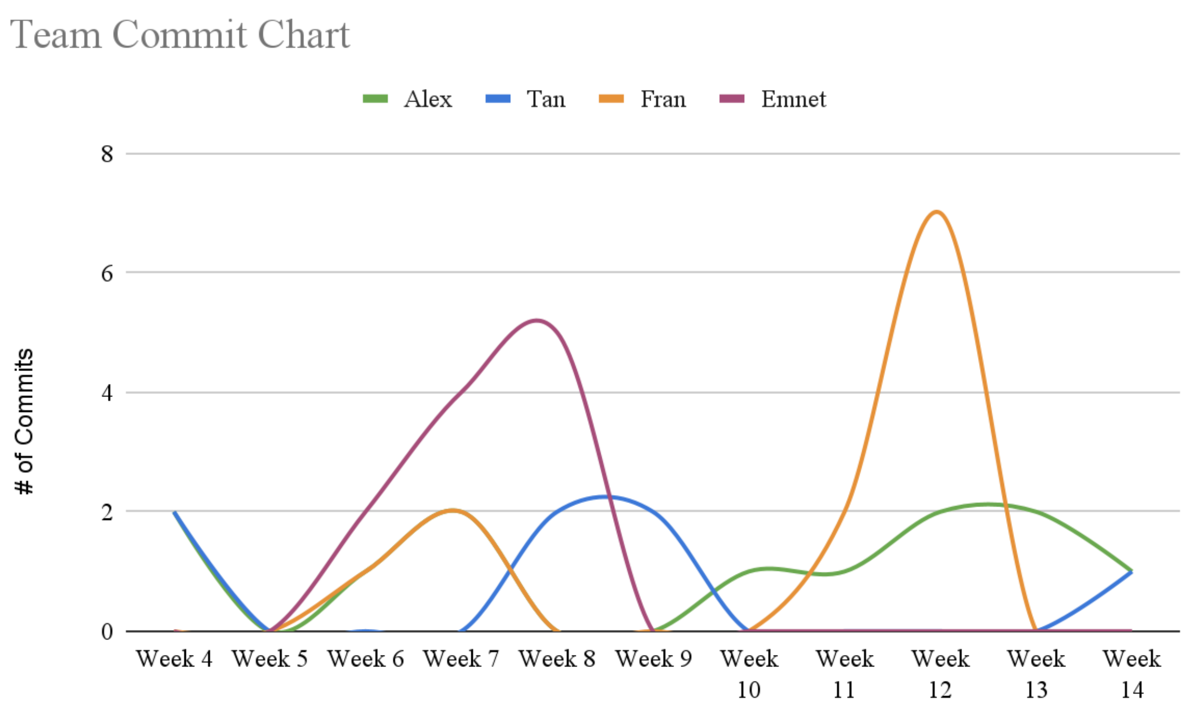
After Emnet's departure, there have not been any formal group meetings, only updates through the Discord group chat.

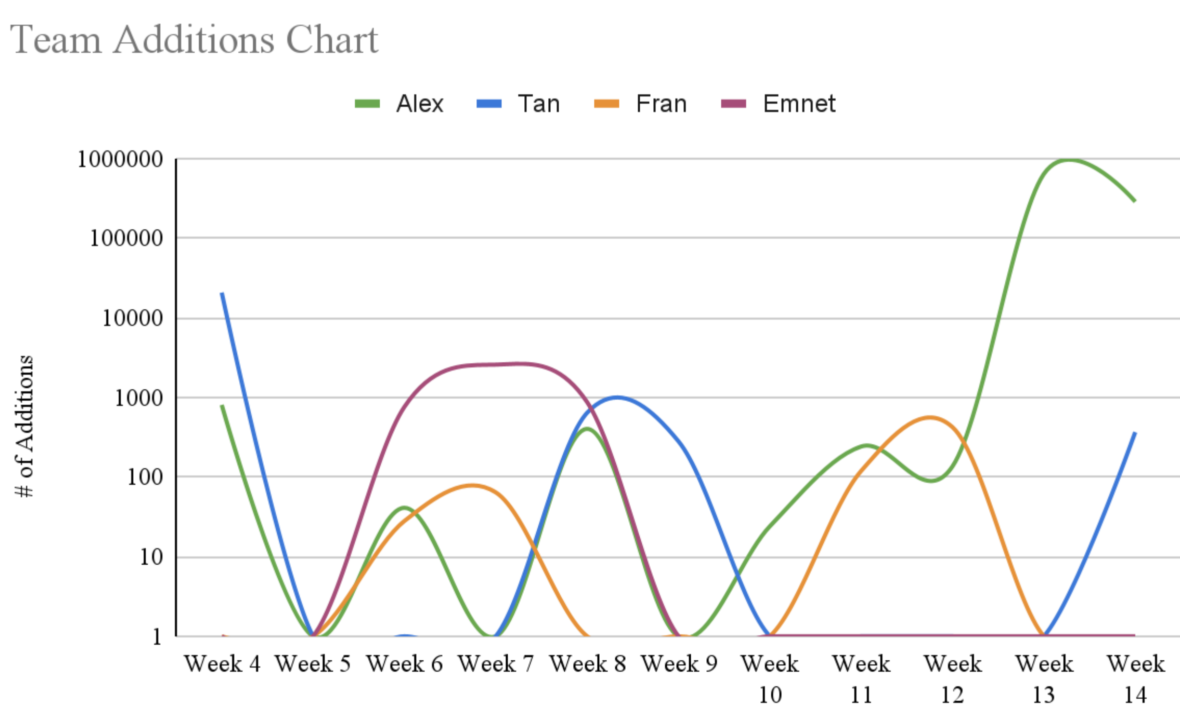
Team Tasks Chart

This is a chart of all "tasks" completed by members of the group over the time period working on this project. For our project, these tasks include commits to the repository, creating assets, contacting healthcare professionals, contacting Parkinson's disease support groups, scheduling proceedings with the coordinator, and experimental prototyping. The y-axis represents the sum of all those tasks for each team member.



Team Commit Chart





Success Report

Team Member	Doc 2	Obtains Grade	Doc 3	Obtains Grade	Total Commits	Passes CS 472
Alex A.	5	Yes	7	Yes	12	Yes
Emnet A.	11	Yes	0	No	11	No
Fran C.	3	Yes	9	Yes	12	Yes
Tan N.	4	Yes	3	Yes	7	Yes

Alex:

- Week 4:
  - Sep 27:
    - Commit 1: Added Swift workspace (complete)
    - Commit 2: Changed title (complete)
- Week 6:
  - Oct 9:
    - Commit 3: Added a conversion script (complete)
- Week 7:
  - Oct 17:
    - Commit 4: Lite model with corrected conversion script (complete)
- Week 8:
  - Oct 20:
    - Commit 5: Added PythonKit framework (not complete)
- Week 10:
  - Nov 4:
    - Commit 6: Created references (complete)
- Week 11:
  - Nov 13:
    - Commit 7: Modified extraction script: part 1 (complete)
- Week 12:
  - Nov 20:
    - Commit 8: Modified extraction script: part 2 (complete)
    - Commit 9: Modified extraction script: part 1 (complete)
- Week 13:
  - Dec 1:
    - Commit 10: Fixed a preview error that hindered our group since the first time we worked on the workspace (complete)
  - Dec 2:
    - Commit 11: Added Python integration (not complete)
- Week 14:
  - Dec 5:
    - Commit 12: Fixed delays and added new recordings, basically making it polished for the judges on competition day (complete)

Tan:

- Week 4:
    - Sep 27:
        - Commit 1: Added prediction models (complete)
        - Commit 2: Updated the README file (complete)
- Week 8:
    - Oct 21:
        - Commit 3: Uploaded ensembled model (complete)
        - Commit 4: Added ensembled CNN model (complete)
- Week 9:
    - Nov 8:
        - Commit 5: Updated CNN model (complete)
        - Commit 6: Created RNN model (complete)
- Week 14:
    - Dec 4:
        - Commit 7: Recreated RNN model for higher accuracy (complete)

Fran:

- Week 6:
  - Oct 8:
    - Commit 1: Created a text box and changed the text size (complete)
- Week 7:
  - Oct 17:
    - Commit 2: Added image upload feature (complete) (branch: feature-imageupload)
    - Commit 3: Properly linked the image upload file to the project (complete) (branch: feature-imageupload)
- Week 11:
  - Nov 15:
    - Commit 4: Got rid of deprecated code (complete)
    - Commit 5: Dynamic scaling and got rid of more deprecated code (complete)
- Week 12:
  - Nov 20:
    - Commit 6: UI Changes (complete)
  - Nov 22:
    - Commit 7: UI Changes and polishing, new fonts (complete)
    - Commit 8: Rearranged linked fonts (complete)
    - Commit 9: Rearranged linked fonts and other UI changes (complete)
    - Commit 10: Fixed a merge conflict (complete)
    - Commit 11: Relinked fonts again (complete)
    - Commit 12: Cleaned up code (complete)

Emnet:

- Week 6:
  - Oct 9:
    - Commit 1: Added logo to the frontpage (complete)
    - Commit 2: Added logo and continue button to the frontpage (complete)
- Week 7:
  - Oct 17:
    - Commit 3: Modified existing layout and added a timer (complete)
    - Commit 4: Deleted unnecessary assets (complete)
    - Commit 5: Added opensource spiral tracing test (not complete)
    - Commit 6: Added menu bar, information, notification, and testing history pages (not complete)
- Week 8:
  - Oct 23:
    - Commit 7: Temp authentication for login (complete)
    - Commit 8: Timer delay and modified recorder to automatic (complete)
    - Commit 9: Modified tests (complete)
    - Commit 10: Added app icon (complete)
  - Oct 24:
    - Commit 11: Added more details to settings and test history (complete)

Conclusion

In conclusion, ParkinSense aims to innovate Parkinson's disease detection by using machine learning to analyze voice and handwriting inputs. This method is aimed to contribute partially to the effort to overcome the limitations of existing diagnostic approaches and fill the gaps identified in current market offerings and academic research. We've considered insights from various studies, diverse data sources, modeling metrics, and emphasized a user-friendly interface, especially given our primary focus on senior citizens.

After initial user studies, including feedback from healthcare specialists and end-users, we've gained valuable insight that have led us to rethink our approach. Recognizing the limitations of our current datasets and algorithms, we are repositioning the app as a research tool to be used in clinical settings for data collection at least in its initial stages. This will allow us to refine its capabilities iteratively and better address the critical concerns raised about its scientific validity, inclusivity, and adaptability to complex cases.

As part of our renewed focus, we've revised our requirements documents to reflect the new features and functions that the app needs to incorporate, based on user feedback. This shift doesn't signal a scaling back of our ambitions, but rather a more informed and realistic pathway to achieving them.

We remain optimistic about ParkinSense and its potential to contribute to a better understanding of Parkinson's Disease and to improve the quality of life for those affected by it. While some things did not go according to plan, we hope that this app inspires us for things to come.

References

[1] M. Ricci, G. Di Lazzaro, A. Pisani, N. B. Mercuri, F. Giannini, and G. Saggio, "Assessment of motor impairments in early untreated Parkinson's disease patients: The Wearable Electronics Impact," *IEEE Journal of Biomedical and Health Informatics*, vol. 24, no. 1, pp. 120–130, Jan. 2020, doi: 10.1109/jbhi.2019.2903627.

[2] E. R. Dorsey and B. R. Bloem, "The Parkinson Pandemic—A call to action," *JAMA Neurology*, vol. 75, no. 1, p. 9, Jan. 2018, doi: 10.1001/jamaneurol.2017.3299.

[3] D. M. Huse, K. L. Schulman, L. Orsini, J. Castelli-Haley, S. K. Kennedy, and G. Lenhart, "Burden of illness in Parkinson's disease," *Movement Disorders*, vol. 20, no. 11, pp. 1449–1454, Jan. 2005, doi: 10.1002/mds.20609.

[4] I. Abeynayake, M. Klingler, and H. Roberts, "The financial burden of Parkinson's disease is greater for caregivers of people experiencing OFF periods," *Parkinsonism & Related Disorders*, vol. 79, p. e86, Oct. 2020, doi: 10.1016/j.parkreldis.2020.06.313.

[5] A. Schrag *et al.*, "The late stage of Parkinson's –results of a large multinational study on motor and non-motor complications," *Parkinsonism & Related Disorders*, vol. 75, pp. 91–96, Jun. 2020, doi: 10.1016/j.parkreldis.2020.05.016.

[6] M. L. Hacker *et al.*, "Deep brain stimulation in early-stage Parkinson disease," *Neurology*, vol. 95, no. 4, pp. e393–e401, Jun. 2020, doi: 10.1212/wnl.0000000000009946.

[7] J. Rusz, R. Cmejla, H. Ruzickova, and E. Růžička, "Quantitative acoustic measurements for characterization of speech and voice disorders in early untreated Parkinson's disease," *Journal of the Acoustical Society of America*, vol. 129, no. 1, pp. 350–367, Jan. 2011, doi: 10.1121/1.3514381.

[8] J. Opara, A. Małecki, E. Małecka, and T. Socha, "Motor assessment in Parkinson's disease" *Annals of Agricultural and Environmental Medicine*, vol. 24, no. 3, pp. 411–415, Sep. 2017, doi: 10.5604/12321966.1232774.

[9] G. J. Canter, "Speech Characteristics of Patients with Parkinson's Disease: I. Intensity, Pitch, and Duration," *Journal of Speech and Hearing Disorders*, vol. 28, no. 3, pp. 221–229, Jul. 1963, doi: 10.1044/jshd.2803.221.

[10] P. Drotar, J. Mekyska, I. Rektorová, L. Masárová, Z. Smekal, and M. Faundez-Zanuy, "Evaluation of handwriting kinematics and pressure for differential diagnosis of Parkinson's disease," *Artificial Intelligence in Medicine*, vol. 67, pp. 39–46, Feb. 2016, doi: 10.1016/j.artmed.2016.01.004.

[11] C. G. Goetz *et al.*, "Movement Disorder Society-sponsored revision of the Unified Parkinson's Disease Rating Scale (MDS-UPDRS): Scale presentation and clinimetric testing results," *Movement Disorders*, vol. 23, no. 15, pp. 2129–2170, Nov. 2008, doi: 10.1002/mds.22340.

[12] K. Kubota, J. Chen, and M. A. Little, "Machine learning for large-scale wearable sensor data in Parkinson's disease: Concepts, promises, pitfalls, and futures," *Movement Disorders*, vol. 31, no. 9, pp. 1314–1326, Aug. 2016, doi: 10.1002/mds.26693.

[13] "Assessment training programs" https://www.movementdisorders.org/MDS/MDS-Rating-Scales/Training-Programs.htm

[14] A. Regnault, B. Boroojerdi, J. Meunier, M. Bani, T. Morel, and S. Cano, "Does the MDS-UPDRS provide the precision to assess progression in early Parkinson's disease? Learnings from the Parkinson's progression marker initiative cohort," *Journal of Neurology*, vol. 266, no. 8, pp. 1927–1936, May 2019, doi: 10.1007/s00415-019-09348-3.

[15] L. J. W. Evers, J. H. Krijthe, M. J. Meinders, B. R. Bloem, and T. Heskes, "Measuring Parkinson's disease over time: The real‐world within‐subject reliability of the MDS‐UPDRS," *Movement Disorders*, vol. 34, no. 10, pp. 1480–1487, Jul. 2019, doi: 10.1002/mds.27790.

[16] M. Lu *et al.*, "Quantifying Parkinson's disease motor severity under uncertainty using MDS-UPDRS videos," *Medical Image Analysis*, vol. 73, p. 102179, Oct. 2021, doi: 10.1016/j.media.2021.102179.

[17] C. G. Goetz, G. T. Stebbins, and S. Luo, "Movement Disorder Society–Unified Parkinson's Disease Rating Scale Use in the COVID‐19 Era," *Movement Disorders*, vol. 35, no. 6, p. 911, May 2020, doi: 10.1002/mds.28094.

[18] "Parkinson's disease detection using smartphone recorded phonemes in real world conditions," *IEEE Journals & Magazine* | *IEEE Xplore*, 2022. https://ieeexplore.ieee.org/document/9887934

[19] P. Moreta-De-Esteban, P. Martín-Casas, R. M. Ortiz-Gutiérrez, S. Straudi, and R. Cano-De-La-Cuerda, "Mobile Applications for Resting Tremor Assessment in Parkinson's Disease: A Systematic review," *Journal of Clinical Medicine*, vol. 12, no. 6, p. 2334, Mar. 2023, doi: 10.3390/jcm12062334.

[20] J. Mei, C. Desrosiers, and J. Frasnelli, "Machine Learning for the Diagnosis of Parkinson's Disease: A Review of Literature," *Frontiers in Aging Neuroscience*, vol. 13, May 2021, doi: 10.3389/fnagi.2021.633752.

[21] F. Amato, G. Saggio, V. Cesarini, G. Olmo, and G. Costantini, "Machine learning- and statistical-based voice analysis of Parkinson's disease patients: A survey," *Expert Systems With Applications*, vol. 219, p. 119651, Jun. 2023, doi: 10.1016/j.eswa.2023.119651.

[22] A. Talitckii *et al.*, "Comparative study of wearable sensors, video, and handwriting to detect Parkinson's disease," *IEEE Transactions on Instrumentation and Measurement*, vol. 71, pp. 1–10, Jan. 2022, doi: 10.1109/tim.2022.3176898.

[23] S. S. Gornale, S. Kumar, R. Siddalingappa, and P. S. Hiremath, "Survey on Handwritten Signature Biometric Data Analysis for Assessment of Neurological Disorder using Machine Learning Techniques," *Transactions on Machine Learning and Artificial Intelligence*, vol. 10, no. 2, pp. 27–60, Apr. 2022, doi: 10.14738/tmlai.102.12210.

[24] R. Kale and M. Menken, "Who should look after people with Parkinson's disease?," *BMJ*, vol. 328, no. 7431, pp. 62–63, Jan. 2004, doi: 10.1136/bmj.328.7431.62.