ECE1778

Creative Applications for Mobile Devices

UNIVERSITY OF
TORONTO

Final Report: ParkinSense

Team Members:

Akshata Puranik	1006225540
Carolina Gorodetsky	1006660061
Christopher Lucasius	1000362662

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Introduction

Parkinson's disease is a common progressive neurodegenerative disorder causing debilitating motor fluctuating symptoms including tremor and slowness of motion (bradykinesia). Today, more than 100,000 people live with Parkinson's disease in Canada with 6500 new cases diagnosed each year[1].

What: The goal of ParkinSense is to continuously monitor and record tremors in patients with Parkinson's disease. ParkinSense also combines this objective information with the patient's medication intake diary and sends this information to their physician via email.

Why: Patients with Parkinson's disease have frequent fluctuations in their tremors which require constant adjustments in oral medications. Objective continuous information regarding these symptoms may help physicians to perform more precise changes in these patients' management, specifically in medication adjustments.

How: ParkinSense uses the phone's accelerometer to extract and analyze objective tremor information. ParkinSense combines this objective information with the medication diary that will be inputted by the patient according to their prescribed medications.

Functionality and Screenshots

ParkinSense has three main features: storing and displaying the patient's personal and medical information, tracking and saving the tremor data and dosage intake history, and providing these details to the patient's doctor for review. These features are divided into separate pages for increased user experience, and they are described in detail below.

- ***Launch Page*** – ParkinSense launches with this page (shown in Fig. 1) and transitions to the Login Page.
- ***Registration/Login*** – The registration page allows first-time users to create their accounts and subsequently access their profiles (Fig. 2). An existing user can view their profile by logging into their account from the Login page using their email and password (Fig. 3).
- ***Profile Information*** – After successful login/registration, a user reaches this page. It contains users' personal data and their physician's information as seen in Fig. 4. It also has a button that enables a user to review their summary report.
- ***Medication List*** – This allows users to view, delete (Fig. 5) and enter (Fig. 6) their prescribed medications, dosage amounts, and times recommended by their physician while simultaneously setting a daily alarm reminding the user to take their medication (Fig. 7). The log button seen in Figure 7 takes the user to the medical schedule.
- ***Medical Schedule*** – A user can log their medications in this section (Fig. 8). These logs are available for viewing and editing for seven days. The medications can be logged by clicking on them. However, only logs from past days can be altered in case a user forgets to enter them on time while future medications are not clickable. Red colour signifies a missed medication, green

[1] Statistics Canada, Canadian Community Health Survey (CCHS) 2000-2001, custom tabulation.

signifies a confirmed medication, grey means that a medication is upcoming today, and white represents a medication on a future day.

Figure 1: Launch Page

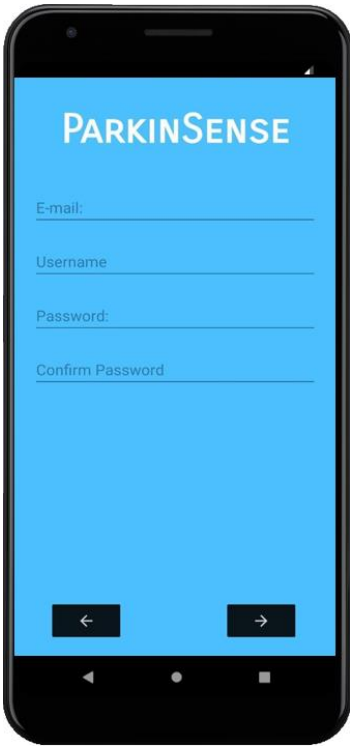

Figure 2: Registration

Figure 3: Login

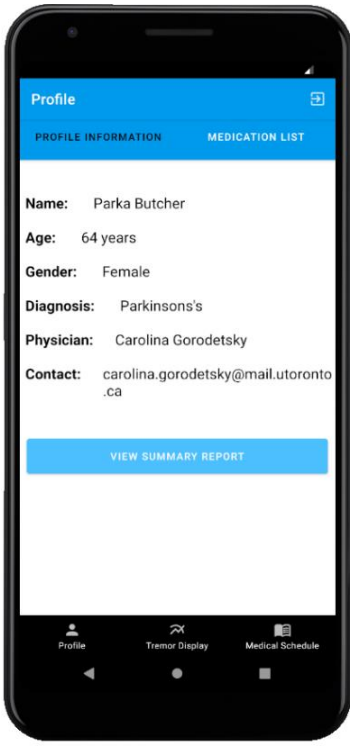

Figure 4: Profile Information

Figure 5: Medication List

Figure 6: Adding medication.

- ***Live tremor assessment*** – Located inside the tremor display section, this page allows users to see the objective information of their motor symptoms in real-time (Fig. 9).
- ***7-day history and 24-hour history*** – These pages show information for the last seven days (Fig. 10) and the last 24 hours (Fig. 11). Different colours are used in the graph to differentiate tremors (orange) from normal movements (blue). Amplitude average and range are also displayed with the above information.
- ***Review and Generate Summary report*** – By clicking on the "View Summary Report" button in the profile section, a user can generate and review their summary report before sending it to their physician. This page combines the medical logs with the tremor data on a day-to-day basis to give an insight into the effect of medication on tremors (Fig. 13) for the past seven days. Additionally, it takes a user's prescription details from the medication list as shown in Fig. 12 and forms a PDF ready to be emailed.
- ***Email Summary report*** – The "Email" button at the end of the Summary report enables a patient to email their weekly report to their physician (Fig. 14). After confirmation, the user's email, physician's email, email body, and subject along with the PDF is automatically populated in the e-mail draft for convenience.

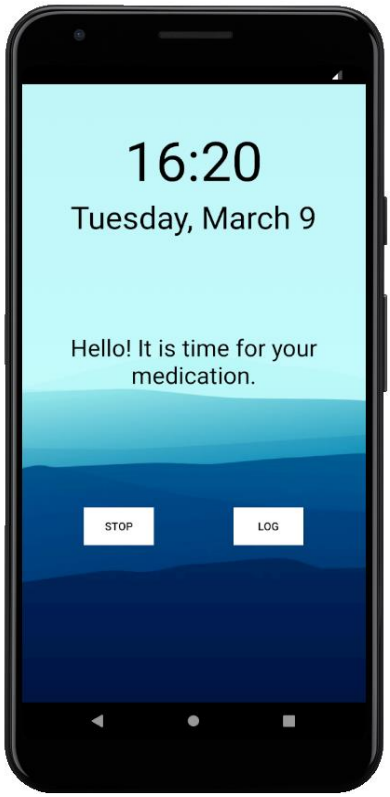

Figure 7: Notification Page

Figure 8: Medication Schedule

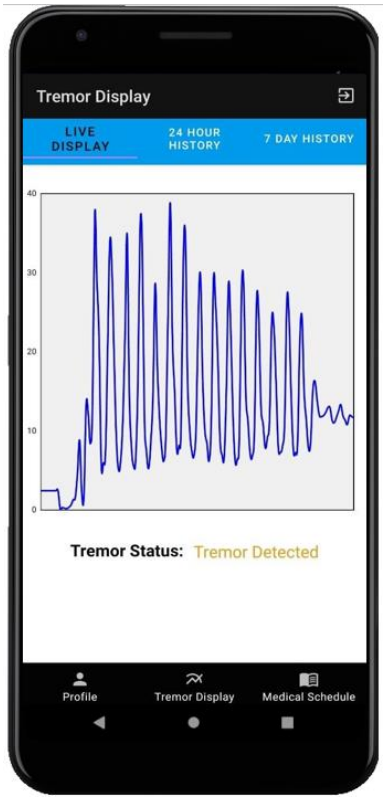

Figure 9: Live tremor assessment

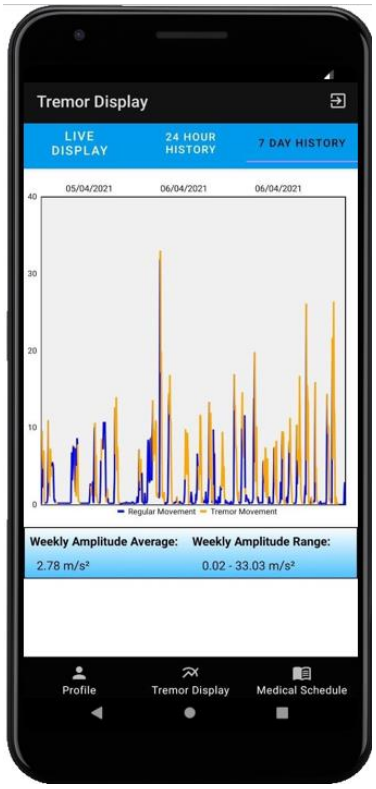

Figure 10: 7-day history

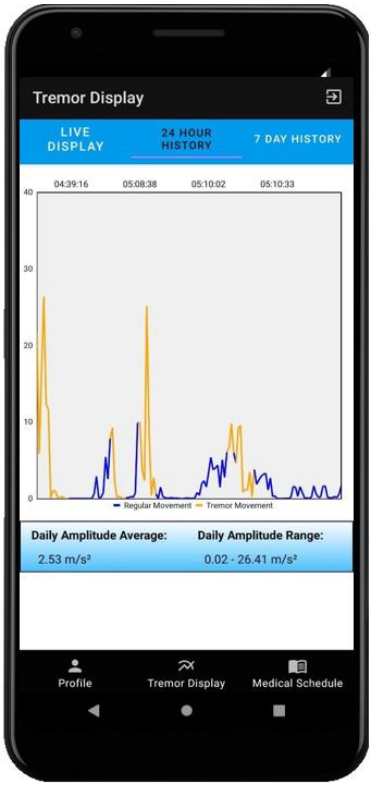

Figure 11: 24-hour history

Figure 12: Summary Report

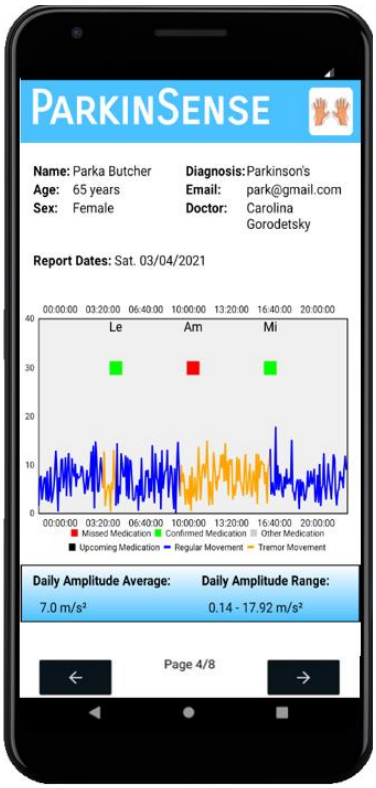

Figure 13: Summary report

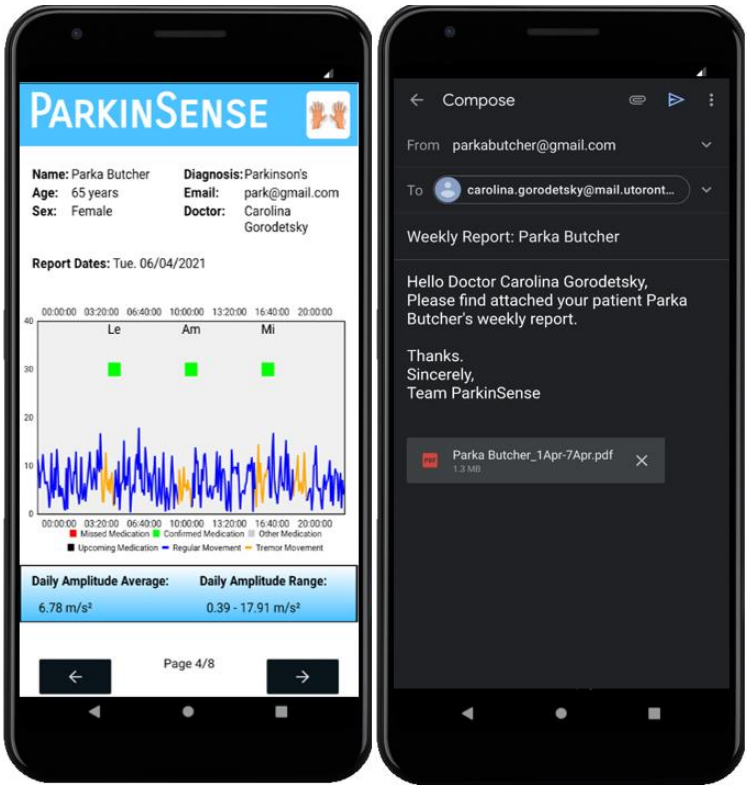

Figure 14: Email report

Overall Design

Fig. 15 shows the block diagram of the app's architecture. It also gives information about the data flow between different components of this app, which are described below.

User Input

This block allows the user to signup/login into ParkinSense and authenticates via Firebase Authentication using an e-mail address and password. After the user signs up, ParkinSense allows them to input their information in the ***Medication List*** page which is saved in the Medical Information Database.

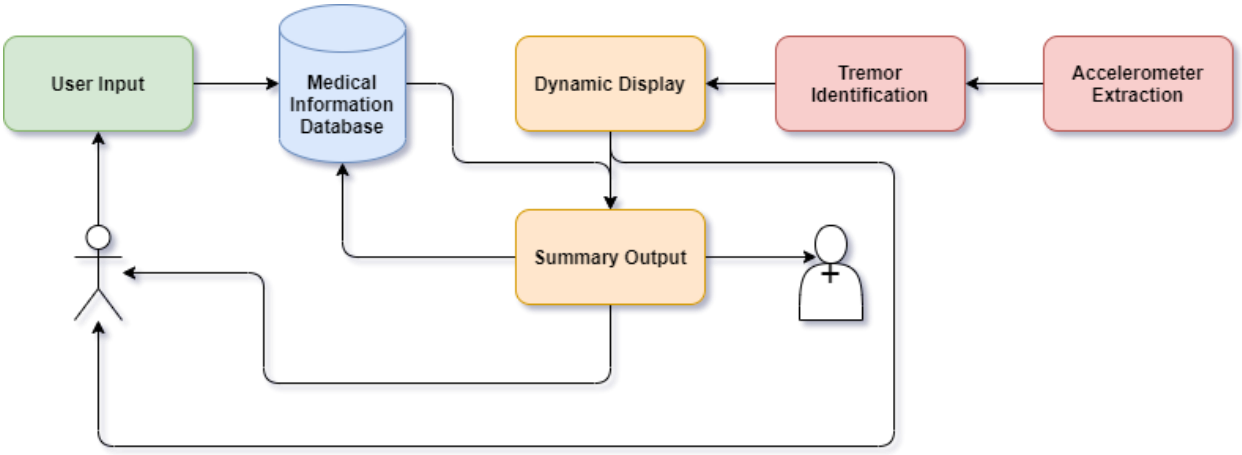

Figure 15: Block diagram giving an overview of the application and showing data flow within the app.

Medical Information Database

The Medical Information Database is hosted by the Firebase Firestore. This block stores all information in the ***Profile Information***, ***Medication List***, and ***Medical Schedule*** pages.

Accelerometer Extraction

This block extracts acceleration data (x, y, and z-direction) at a sampling rate of 50 Hz and uses local memory to keep track of them. It then outputs these signals to the Tremor Identification block and Dynamic Display blocks.

Tremor Identification

This block processes raw acceleration data and gives a score indicating how likely the data corresponds to a tremor. It continually processes a running window of short-term acceleration data from the Accelerometer Extraction block.

A tremor detection algorithm is run in the backend, continuously checking whether 5s of data contains evidence for a tremor. It uses the Fast Fourier Transform to transform the amplitudes in the time domain to the frequency domain. This is used to compute the power spectrum density, integrating the densities

from the 4-8 Hz range. This method is described in more detail in a manuscript that also used smartphone data to detect tremors[2]. If the power exceeds a given threshold (empirically found), it informs the Dynamic Display that tremor is detected.

Dynamic Display

The Dynamic Display block runs the ***Live tremor assessment*** and ***7-day history and 24-hour history*** pages. The first shows a maximum of 6s of data on the screen at any point in time. The Tremor Identification block is run in the backend, and whenever a tremor is detected, it displays a message saying a tremor is detected. All recorded data is written to a comma-separated value file that is stored locally on the phone. The second page reads this file to display either the past 24 h or seven days.

Summary Output

This block runs the ***Review and Generate Summary report*** and ***Email Summary report*** pages.

Reflection

We learned the following while working on this project:

1. Teamwork- we learned how to work within a team of people who have different backgrounds and their unique knowledge and experience. We found that it might be challenging working together due to various schedules and other commitments. We realized that setting a weekly/ bi-weekly meeting is beneficial as well as having a separate and well-defined responsibility for each team member.
2. Giving presentations and demonstrations- we learned that practice leads to perfection and observed that good demonstrations require multiple practice sessions. Also, due to the time restrictions on the presentations, we had to plan very carefully which functions we wanted to demonstrate. Furthermore, we learned that some aspects of the demonstrations can be unpredictable and even simple things can go wrong (e.g., our alarm failed to ring during our Spiral 2 presentation). We also learned that it is important to have a second person who is ready and can show the demo in case of technical issues.
3. User interface (UI)- none of our team members had any experience with UI design. Also, ParkinSense is designed for the older population (as Parkinson's disease usually affects people after the age of 60 years). We learned to concentrate on simple UI design while adjusting it for our target population with tremors.
4. Digital signal processing techniques- none of the team members had any experience with signal processing for tremors. We searched the literature to find the best algorithm and implemented it in our app.
5. Third-party libraries can be unpredictable- we used some third-party libraries for graph design and experienced difficulties working with its application programming interface. There were several bugs in the latest version (e.g., labels were not displayed the correct number of times) which hindered our progress. We learned that it is critical to allocate extra time when depending on external software.

[2] Zheng, X., Campos, A. V., Ordieres-Meré, J., Balseiro, J., Marcos, S. L., & Aladro, Y. (2017). Continuous monitoring of essential tremor using a portable system based on smartwatch. Frontiers in Neurology, 8(MAR), 96. https://doi.org/10.3389/fneur.2017.00096

Individual Contributions

Akshata Puranik

As a programmer of ParkinSense, Akshata was responsible for understanding and translating user requirements of the application, while working collaboratively with Carolina. She helped put together pieces of the UI design and code the interface in a way that would be easily accessible for the intended users (patients of old age) of the application. She worked on creating features that helped make the application extremely user-friendly. This included the launch & registration pages, setting up alarms and notifications, features like a clock for entering medication time and calendar for the date of birth as well as overall theming of the application.

She also worked on core building blocks of the application which included but was not limited to, saving and accessing tremor data to CSV file, creating summary sections, generating pdfs from multiple android activities and integrating with an email to be sent to the physician. Her role also involved preparing the application for demonstrations.

Carolina Gorodetsky

Carolina was the specialist for this project. She is a neurologist and movement disorder specialist who has experience treating patients with Parkinson's disease and understands the needs of this population. She was responsible for developing the concept of ParkinSense as well as conceptualizing its main functions. She also generated user-friendly interface ideas to design a patient-oriented app that provided clinically relevant and accessible information to the physician.

Carolina was responsible for literature review in order to find appropriate signal processing algorithms for tremor detection. Many previous studies were published on the usage of accelerometers for tracking tremors and using some of the previously published techniques made app creation much easier.

Carolina also tracked the app's development and provided real-time feedback during frequent team meetings. She also developed possible clinical scenarios for the different demonstrations and provided clinical interpretations for these scenarios. She was also responsible for guiding the design of a physician-oriented clinical report that is sent from ParkinSense to the physician.

Christopher Lucasius

Christopher wrote the backend in Firebase Firestore. He was responsible for logging in/signing up users and adding fields in the Medical Information Database. He set up the infrastructure of ParkinSense, including a bottom navigation bar to switch between the Profile, Tremor Display, and Medication Schedule. He also set up the infrastructure for tabs for all of these pages and wrote the backend for highlighting each medication in the medication schedule based on its status.

Christopher wrote the software for extracting accelerometer measurements and displaying them on a scrolling graph. He implemented a paper that used a Fast Fourier Transform to detect tremors. After some experimentation, he adjusted the threshold to make the tremor detection algorithm more suitable to actual tremors in the 4-8 Hz range. He extracted saved data and displayed it on the 24 h and seven-day history tabs. He coloured them based on whether the data corresponding to a tremor or not. For demonstration purposes, he generated simulated data.

Specialist Context

Carolina is a movement disorder neurologist who is working in Toronto Western Hospital and the Hospital for Sick Children. She treats patients with a variety of movement abnormalities including Parkinson's disease. During her clinical work, she encountered many patients who had difficulties objectively and chronologically monitoring their motor symptoms as they tend to change frequently throughout the day and with medication intake. Also, patients with Parkinson's disease are required to take frequent doses of different medications to control their symptoms (sometimes up to 24 pills per day). Patients find it very difficult to remain compliant with this amount of medication while correlating their medication intake with their motor symptoms in real-time. Acquiring this information is crucial for the treating physician as this can help with management adjustment. We designed ParkinSense to address these needs. ParkinSense can continuously and objectively monitor the tremors as well as combine this information with a patient's medication intake.

Due to the COVID-19 pandemic, many of the clinic encounters were transitioned to virtual care, making the patient-physician interaction even more challenging as well as further complicating the acquisition of objective tremor assessment. ParkinSense accounts for these challenges as all the information can be emailed to the physician easily prior to each clinic visit.

Carolina is also a second-year master's student at the Institute of Medical Science. Her thesis is on the usage of wearable devices (more specifically small accelerometers) for better characterization and severity stratification of dystonia within the pediatric population. Dystonia is a type of movement disorder causing sustained or repetitive muscle contractures. Some of the data analysis techniques that she used in her thesis were implemented in ParkinSense (i.e., the tremor detection algorithm). She is also hoping to use some of the data plotting and graphical representation techniques from ParkinSense in future work for her thesis.

Future Work

ParkinSense can have numerous additional features and capabilities:

1. Detection of other motor features of Parkinson's disease- currently ParkinSense is able to detect the tremor objectively and continuously within Parkinson's disease population. As mentioned in the introduction, patients with Parkinson's disease experience other bothersome motor features such as bradykinesia. In the future, we can add a continuous and objective detection of bradykinesia.
2. Usage of external accelerometers- in order to easily obtain continuous motor data, we can connect ParkinSense to external accelerometers (for example the accelerometers in smartwatches). This will allow the users to not need to continuously hold their phones.

3. Adding a function that allows the patient to directly communicate with their physician via the app- this function will allow for easier and more direct communication between the patients and healthcare providers.
4. Connecting ParkinSense to other technologies that are used for Parkinson's disease treatment- During the last decade, multiple technologies were developed to assist patients with Parkinson's disease, for example, deep brain stimulators (DBS). DBS is a surgically inserted device that includes two electrodes located in the patient's brain allowing for electrical stimulation of neuronal networks responsible for motor function. Connecting ParkinSense to DBS allows the acquisition of more precise information from these neuronal networks. This may further assist with treatment adjustment.

Consent to share

i. Video of final presentation – yes
ii. Report – yes
iii. Source code – no (We intend to launch ParkinSense on the Google PlayStore)