

Smartphone-Based Self-Diagnosis of Parkinson's Disease

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Smart City REU/RET Smartphone Self-Diagnosis of Parkinson's Disease

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Abstract

Parkinson's Disease (PD) is a brain disorder that leads to shaking, body stiffness, and difficulty with walking, balance, and coordination. The main goal of this project was to develop a smartphone-based easy-to-use self-diagnostic tool to detect early stages of PD. A cross-platform mobile app development environment (Microsoft Visual Studio) was used to develop a smartphone app that runs on Android and iOS devices. The app uses the smartphone's built-in gyroscope and accelerometer sensors to acquire data about a patient's hand tremors and other disease biomarkers. Signal processing algorithms such as filtering and time/frequency domain analysis of the acquired signals were implemented for a possible diagnosis of PD.

***Index Terms*— Parkinson's Disease, signal processing, -GSapp development**

Introduction

There are over one million people in the United States that are living with PD which is expected to rise to 1.2 million by 2030, with 60,000 Americans diagnosed with PD each year. More than 10 million people worldwide are living with PD [1]. There is a lack of awareness among the public about PD, its hallmark symptoms, and demographic predominance. The PD in a patient is usually discovered at a later stage when the symptoms are visible. However, disease management becomes challenging when it is discovered in later stages. The goal of this project is to exploit the ubiquitous technology of smartphones to detect early onset of PD and direct such users to the doctor for more comprehensive diagnosis and disease management. In addition, we aim to create awareness about the disease among the more vulnerable population.

Parkinson's Disease is believed to be because of a combination of genetic and environmental factors. The stages of PD are categorized mainly as juvenile (ages below 21yrs), early onset (21-50yrs), and late onset (ages greater than 60yrs). Up to about 50% of juvenile cases have been seen in people with a family history of the disease which is associated with a mutation of the parkin gene [2]. The degeneration of the neurons in the midbrain known as the "substantia nigra" results in PD. These neurons finally extend to the cortex which controls all the movements of a person and any disruption in these connections could result in disorders in movement. These disorders in movements are called tremors. Tremors are symptoms of many diseases. Hence, it is important to properly identify a tremor as Parkinson's tremor before any further diagnosis is made. The tremors associated with PD are most likely a result of degeneration of neurons in the "substantia nigra" and usually occur when the person is at rest and have frequencies in the range from 4-6Hz [3].

There are a few existing smartphone apps to detect occurrence of PD such as Parkinson's Check in Slovenia, as well as a host of other apps. However, these apps have limitations such as smartphone capabilities being universal in giving an accurate analysis [4]. Moreover, most of these apps rely on a

single test which may not be accurate enough to give a proper pre-screening, causing confirmation bias. It has been suggested that more than one test should be administered for more accurate and precise pre-diagnosis and suggestion to seek further assistance at a medical facility. With a view to overcome these limitations, we have incorporated a questionnaire and two tests in our app which will provide a more vivid diagnosis before suggesting the user to seek medical assistance.

Methods

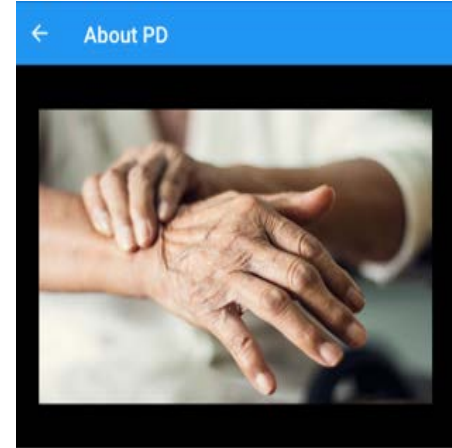
A smartphone application was designed for PD awareness and self-diagnosis. The app was created in Microsoft Visual Studio using C# (C-sharp) for the back-end and Xamarin for the User Interface.

The 'About' page in the app provides information on PD and the various symptoms to help users who might not be acquainted with the disease to also understand the disease enough to be able to provide better care for people living with the disease. PD is not a very well-known condition and is easily misjudged to be just another sign of old age especially in the late onset phase. Disorders such as Essential Tremors, multiple-system atrophy, and Dementia with Lewy Bodies disease (DLB) are sometimes difficult to distinguish from PD and can sometimes make diagnosing PD more difficult unless through trained personnel. A better understanding of the disease

by the general public is important for early diagnosis of the disease. Figure 1 shows a snapshot of the 'About PD' page.

This app uses information across multiple fronts to improve the probability of making the right inferences based on the data collected from users. Data is collected in four main areas through: i) demographic questionnaire, ii) symptoms, iii) tremor test, and iv) spiral test

Demographic Questionnaire: It has also been observed that PD patients satisfy certain specific demographic criteria namely - age, family history, sex and race. People over the age of 60 are more likely to exhibit symptoms of PD in comparison to the younger age groups. Those people having a familial history of PD have an increased risk of Parkinson's. Men are more likely to have PD than women [5]. Moreover, it is observed that PD is more prevalent in white men than their black and Asian counterparts, with PD being 50% less prevalent among black and Asian men than in white men. Among all the races, most of the PD patients are Native Americans due to lack of awareness among the other races. All these pointers were taken into consideration while designing the demographic questionnaire. The demographic



About Parkinson's Disease

Parkinson's Disease is a disorder of the central nervous system that affects movement. Those who suffer with Parkinson's Disease may experience tremors, slowed movement (also known as bradykinesia), rigid muscles, impaired posture and balance (blinking, smiling, etc.), and changes in speech and writing patterns.

Figure 1: About Page with general information about Parkinson's.

Figure 2: Demographic Questionnaire - Information about age group, sex, race, and family history is gathered to supplement symptoms information to better understand the user.

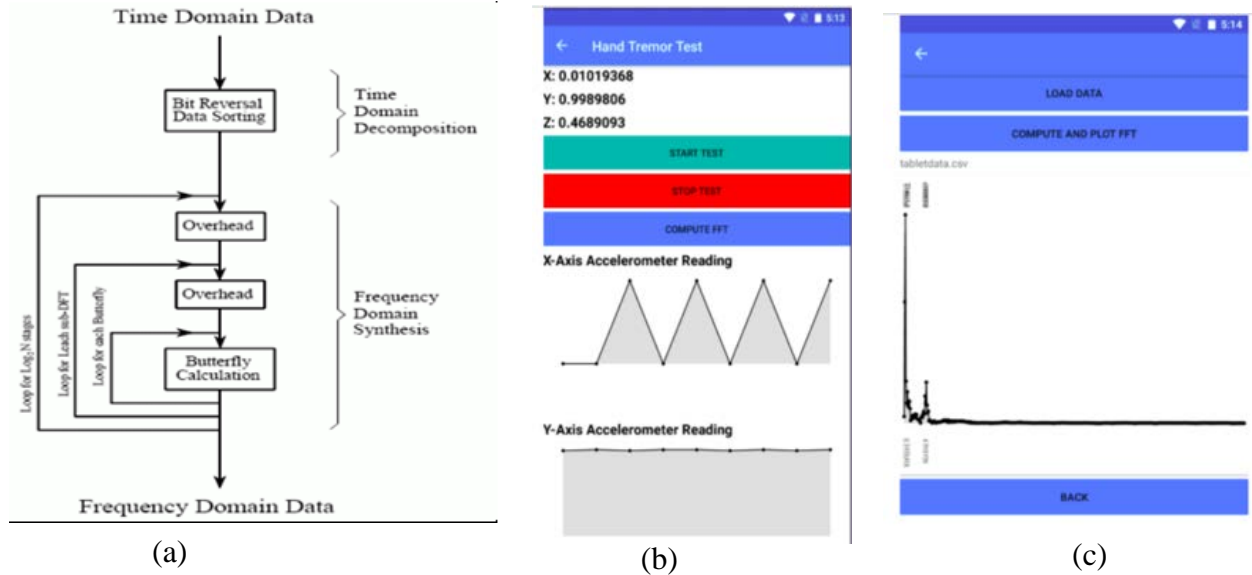


Figure 3: (a) Flowchart of FFT Algorithm. (b) Hand Tremors Test page where the hand tremors are recorded and relevant messages are displayed to the user. (c) Plot of the Fourier transform of sample data of X-axis accelerometer reading of PD patient recorded from the wrist [4].

questionnaire page (Figure 2) seeks to gain information on individuals taking the test with a priori knowledge on the statistical prevalence of the disease across various races, sexes, and ages.

Symptoms: Every disease and disorder come with certain markers that are used to detect their presence in people being affected. Most of these markers cut prevail in a large proportion of individuals affected while some are rare for the conditions. The symptoms associated with PD may differ from one patient to another. However, some of the frequently noticed symptoms include – Bradykinesia (slowness of movement), stiffness of muscles, changes in writing and speech, loss of smell (anosmia), and sleep disorders [5]. These signs and symptoms are included in the symptoms questionnaire where the user selects the symptoms he/she experiences. The user is asked to select from a list of symptoms, some of which are related to PD and others which are not. The response to this questionnaire and responses from the demographic questionnaire page are combined using weighted averages and compared to a threshold to determine the likelihood of the user being affected by PD. Although this step gives a better view of the user's state, further testing is required for people who are determined to have scores equal to or greater than the threshold. These people are prompted to take the tremor and spiral tests to get more data and make more informed inferences.

Tremor Test: The Tremor Test is composed of two sections: The first which makes use of the inbuilt accelerometer Application Programming Interface (API) from Xamarin.Essentials which tests the user for Parkinson's tremors. This API records the accelerometer readings (hand tremors) along the X, Y and the Z axes. The Compute FFT button computes the frequency spectrum corresponding to these recorded tremors using FFT (Fast Fourier Transform) algorithm as shown in Figure 3(a). The app displays an alert to the user depending upon the nature of the frequencies. If the frequencies of the tremors fall between the expected frequency range of the Parkinson's tremors (4-6Hz) the app displays an alert that the user exhibits symptoms consistent with PD and could proceed with other tests from the app for a better diagnosis. Otherwise, it displays a message that the user's symptoms are not consistent with PD, but he could continue with other available tests to rule out possible causes of the

symptoms (Figure 3(b)). In the second section, the app allows the user to load in a file which could have the accelerometer readings (hand tremor readings) of patients suffering from PD when the Load Data button is clicked and when the user clicks on Compute and Plot FFT it computes the FFT for the imported data (Figure 3(c)) and displays a alert message that the patient exhibits symptoms of PD and should consult a doctor for further diagnosis when the frequencies fall into the desired range and vice versa.

Spiral Test: Changes in the writing forms are identified as another potential symptom of PD. As a result of the Parkinson's tremors, the user may experience difficulty in writing which is what we aim to record in the spiral test. The Spiral test consists of a Archimedes Spiral which the user is expected to trace to analyze his/her writing behavior (Figure 4). After the user traces the spiral with his finger to the best of his ability, when he clicks on the Process Results button. The app then computes a suggestion for the user depending upon the nature of the spiral traced. If the user traces the spiral in a zigzag manner owing to the characteristic Parkinson's tremors, the app displays a message that the user exhibits signs consistent with PD. Whereas, in a scenario where the trace is smooth and no disturbances in writing are observed the app displays a pop up alert saying that the user does not exhibit signs consistent with PD.

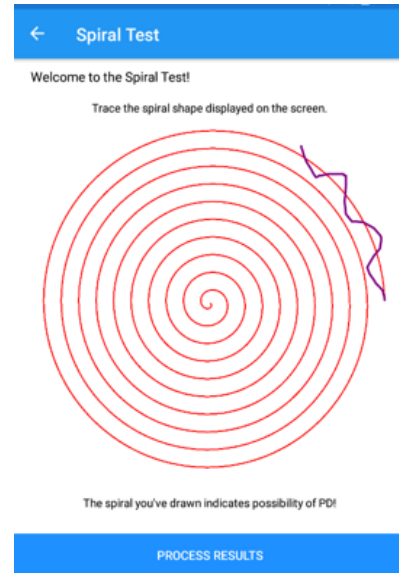


Figure 4: A Spiral Test that can help detect potential changes in an individual's writing ability.

Engineering Standards and Constraints: This work demonstrates the important use the avalanche of smartphones can be put to by employing sensors to help in introducing biomedical solutions that are easily accessible to a large part of the global population. However, before we plan to release a potential smartphone app in real life, it needs to be compliant with basic standards. For example, for health-related phone apps, some of the applicable standards could be:

- ISO TC215> ISO/TR 17522:2015 Provisions for health applications on mobile/smart devices
- FDA Playbook on Medical Device Cybersecurity
- Health Insurance Portability and Accountability Act (HIPAA) guidelines on Health Information Technology
- HL7 Consumer Mobile Health Application Functional Framework (cMHAFF)

We believe that it would be best to make the app free for purchase because we created the app to raise awareness for Parkinson's Disease. Also, in order to make sure that the app can continue being developed it would be best to make it open-source because more developers can bring new ideas for improvement.

Summary and Conclusions

In this paper, we were able to successfully propose the design of an Android/iOS App prototype that can help detect early signs of Parkinson's Disease with the help of questionnaires and relevant tests. The app is useful for self-assessment by vulnerable population through the easily-accessible smartphones and as such has wide usability especially in the regions where healthcare access is limited. The app can be further improved by adding more diagnostic tests, such as a speech test, based on latest research. The app warrants careful validation based on real PD patients' data collected from hospitals and senior homes.

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