A Mobile-based Tremor Detector Application for Patients with Parkinson's Disease

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***Abstract*—Parkinson's disease affects millions of people worldwide and its frequency is steadily increasing. No cure is currently available for Parkinson's disease patients, and most medications only treat the symptoms. This treatment depends on the quantification of Parkinson's symptoms, such as hand tremors. The most commonly used method to measure human tremors is a severity scale, which lacks accuracy because it is based on the subjectivity of neurologist review. Furthermore, the use of severity scales prevents the extraction of information from tremor activity, such as speed, amplitude, and frequency. Therefore, a mobile application was developed to measure the hand tremor level of Parkinson's patients using a mobile phone-based accelerometer. Agile method was used to develop this application, and Android Studio and Android Software Development Kit were utilized. The application runs on an Android smartphone. This application allows patients to identify their tremor activity and subsequently seek relevant medical advice. In addition, a neurologist can monitor tremor activity of patients by analyzing the records generated from this application.**

Keywords*—Agile; mhealth; mobile application; Parkinson; tremor detector

I. Introduction

The increasing number of patients with Parkinson's disease has resulted in the prevalence of many symptoms, such as tremors, stiffness, bradykinesia (slowness of movement), foot cramps, and postural alteration [1]. Procedures for monitoring tremor of patients are quite challenging because they require patients to undergo tests, and neurologists must obtain a detailed history of patient's symptoms prior to their analysis [2]. However, the clinical observation of experts is time-consuming and may not necessarily be accurate because the test environment may impose pressure on the patient. Insufficient methods to identify and assess tremors over a long duration require patients to manually complete their tremor evolution for days. Owing to the unavailability of tools to accurately detect tremors, determining whether the stage and cause of patient's tremor are worsening or are side effects from medication intake is impossible.

In response to the aforementioned problems, several quantitative methods were developed by previous researchers. These methods include electromagnetic detector device [3], mechanical linkage devices for fingertips [4], electromyography [5], wearable sensors [6], miniature gyroscopes [7], digitizer tablets [8], tremor pens [9], and accelerators [10]. However, in addition to their high cost, the usage of these devices is challenging because they require technical expertise to manipulate the hardware and analyze the results [2].

Therefore, a mobile application for detecting tremors for patients with Parkinson's disease was developed at an affordable cost and can be downloaded onto a user's smartphone. Patients can also continuously monitor their health state.

II. Theoretical Background

A. Measuring Parkinson Tremor

Experts on Parkinson's disease do not have sufficient resources to monitor symptoms, such as tremors, in patients of Parkinson's disease [11]. In most cases, inconsistent clinical visits resulted in insufficient and inaccurate information on patient health state for neurologists to plan for the most effective treatment. Some methods can be used to test human tremor [12]; the most commonly used method is the severity scale. This method requires a patient to draw multiple patterns, such as spirals, circles, and alphabets (Fig. 1).

The drawing is classified by neurologists based on a numerical scale, normally from 0 (no visible tremors) to 5 (strong disabling tremors). The drawings of patients are later compared with drawings and their classification from previous clinical cases. Thus, this method depends on visual comparison and expert subjectivity. Moreover, other important tremor attributes, such as frequency, amplitude, and speed, cannot be captured from this classification.

Therefore, clinical evaluation cannot provide the most accurate answer on the disease evolution because the abnormalities of individual patients are disregarded and the dependency on expert subjectivity is considered in the evaluation and classification of each patient.

B. Previous Applications

Several related systems were critically analyzed, and their strengths and limitations were used as a guideline to develop the tremor detector app for Parkinson's disease patients. Table I illustrates the comparison of system features and functions between previous systems and the proposed app in relation to Parkinson's disease patients. All system interfaces are simple and neat, except for the smartphone app, which was found to be confusing for first-time users. Most systems are also complex. The smartphone app displayed all data on the same screen, resulting in a crowded page display. Lift Pulse is

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confusing, and this situation is compounded by the absence of a user manual. A user must examine the app function while tremor data are not clearly displayed. Sensors and smartwatch apps require challenging hardware for users because the sensor must be accurately positioned, and this alignment is time-consuming. By contrast, ParkNosis and the proposed app are easy to use and equipped with a user manual for reference purposes.

Some functions were also compared among the six systems. The common function across all systems is the tremor test. Most systems display detailed results for tremor activity, such as amplitude, frequency, and acceleration. By contrast, Lift Pulse and ParkNosis do not display detailed results. In terms of the graph display, only the smartphone app for tremor detector does not have this feature. Three functions, namely, calculating tremor values, providing recommendations for tremor activity, and generating tremor activity report of users (including patient details and tremor activity record), were added to the proposed app.

In terms of record submission, the smartwatch app and ParkNosis use the database while the smartphone app sends data by email. The proposed app enables users to send their reports to family members and store them in the app's database. Lift Pulse and the sensor app do not provide this function. The smartphone app and Lift Pulse do not provide a user manual, causing difficulty to some users in understanding their systems.

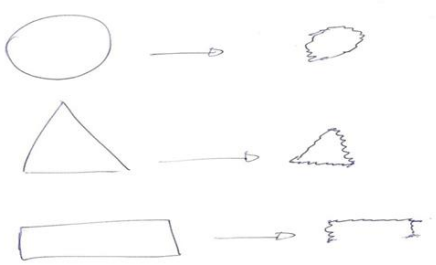

Fig. 1. Example of Patterns Drawn by a Patient with Parkinson's Disease [12].

TABLE. I. COMPARISON BETWEEN PREVIOUS SYSTEMS AND DEVELOPED APP

Features/ Functions	**Previous systems**					**Developed app**
	Smartphone app for tremor detector [13]	***Lift Pulse [14]***	***Sensor-based evaluator for tremor activity [15]***	***Quantifier for tremor activity using smart watch [16]***	***ParkNosis [17]***	***Tremor detector app***
User interface	Confusing for first-time user	Simple and neat	No user interface because this is a hardware	Simple	Simple and neat	Simple and neat
Complexity	Complicated – all data for tremor, accelerator, and user are displayed on the same interface	Confusing – no user manual, and tremor data are not clearly displayed	Complicated hardware use; sensor must be accurately positioned and set up is time consuming	Easy to use smartphone app but complicated hardware use	Easy to use; user manual is provided	Easy to use; user manual is provided
Tremor test	Main function	Main function	Main function	Main function	Sub function	Main function
Display of detailed results for tremor activity (amplitude, frequency, and acceleration values)?	Yes	No	Yes	Yes	normal and abnormal values only	Yes
Results display form	No visual display	Graph	Graph	Graph	Graph	Graph
Generate report for tremor activity?	No	No	No	No	No	Yes
User manual?	No	No	No	Yes	Yes	Yes

III. Method

The application was developed using the Agile method due to its iterative, incremental approach to enable early system. Delivery and real-time communication and teamwork [18], ensuring the fulfillment of user requirement. Joint application development (JAD) was also used to encourage user involvement through system design and development workshops [19], yielding to short development duration. The app development involved a number of phases. In the first phase, a JAD workshop was conducted between a subject matter expert with the app developer (author PXY) to determine app requirements, design, and analysis. In the second phase, user evaluation, including app scope and development risk, was conducted. The third phase involved app development based on user requirements, followed by app demonstration involving testing (user and user acceptance) and verification. These processes were iterated when users were not satisfied with the app. Appropriate and logical algorithms were used in developing the app.

A. Architecture

The tremor detector app for Parkinson's disease patients was developed in a two-tier client-server architecture. A database server is used to store data via the Internet while the mobile app performs the core functions and displays the related data.

B. Coding

The app modules were developed in phases using Java and Android Studio framework. The coding was completed in five months. Each function was tested to ensure its expected function and the absence of errors.

C. Testing

The app was tested based on functional and non-functional aspects. Black box testing was also conducted by utilizing a use case test technique. Moreover, an overall system testing was conducted to ensure that the app fulfills user requirements and is free from critical problems. Therefore, unit and user acceptance testing were respectively performed at the system and acceptance testing level. The test levels are appropriate for black box testing. In addition, the app used analytical and design testing techniques based on a requirement specification document.

User acceptance testing was conducted with three individuals: SME, an information technology student, and a science student. The SME confirmed that the app was appropriately developed based on user requirements. The two other subjects verified the functionality of all app functions. The black box testing involved a testing plan, testing procedure, and test log. All testing statuses for the app indicated "pass".

IV. Tremor Detector App for Patients with Parkinson's

The app used an accelerometer, a detector for testing patient tremor. The accelerator has been tested, evaluated, and proven to be potentially beneficial in treating Parkinson's disease [10].

Furthermore, neurologists can obtain readings on frequency, amplitude, and speed from the tremor activity of a patient generated from this app. They no longer need to use the severity scale, which is time-consuming and inefficient, because they do not need to ask patients to draw multiple patterns that require additional time for analysis and compare them with previous cases. Instead, neurologists can obtain patient readings and monitor tremor levels by simply using this app.

A. User Type

The app was designed for three types of user: Parkinson's disease patients, neurologists, and regular users. The modules for Parkinson's disease patients are account registration, tremor test, report submission, and test record history. Functions for regular users are limited to tremor test only, while the neurologist user module includes account registration and patient tremor activity record for analysis. Fig. 2 and 3 show the flowcharts of modules

B. Interface Design

1) Registration: In order to register for the app, users must fill in detailed information and verify them via their email account for security (Fig. 4).

2) Tremor test: Users can start the test by pressing the "start" button, and they must hold their mobile phone for one minute to obtain the test results, as shown in Fig. 5. For existing registered users, a report containing patient information and tremor activity results would be generated. Reports would not be generated for guest users. Fig. 6 illustrates interfaces for starting tremor activity testing, and Fig. 7 shows tremor activity results of a user. Fig. 6 presents a report generated based on registered user information and their tremor activity results.

3) Report submission: After taking the tremor activity test, registered users can submit their reports to their family members via email by pressing the "submit report" button (Fig. 8).

The tremor detector app for Parkinson's disease patients is beneficial for monitoring tremor evolution. Patients can use the app to discover their health state while neurologists monitor their patient condition by examining their record. The app functions were tested to ensure accurate functionality and the absence of errors. The app has numerous benefits and limitations.

The app is accessible, user-friendly, and features essential Parkinson's disease diagnoses. Owing to its mobility, the app can be assessed anytime and anywhere. The interface of the app considered aesthetic aspects by using and coordinating appropriate colors, graphics, and element positions. The app functions are easy to use and learn. The app also stores patient information and generates reports and graphs for reference and monitoring.

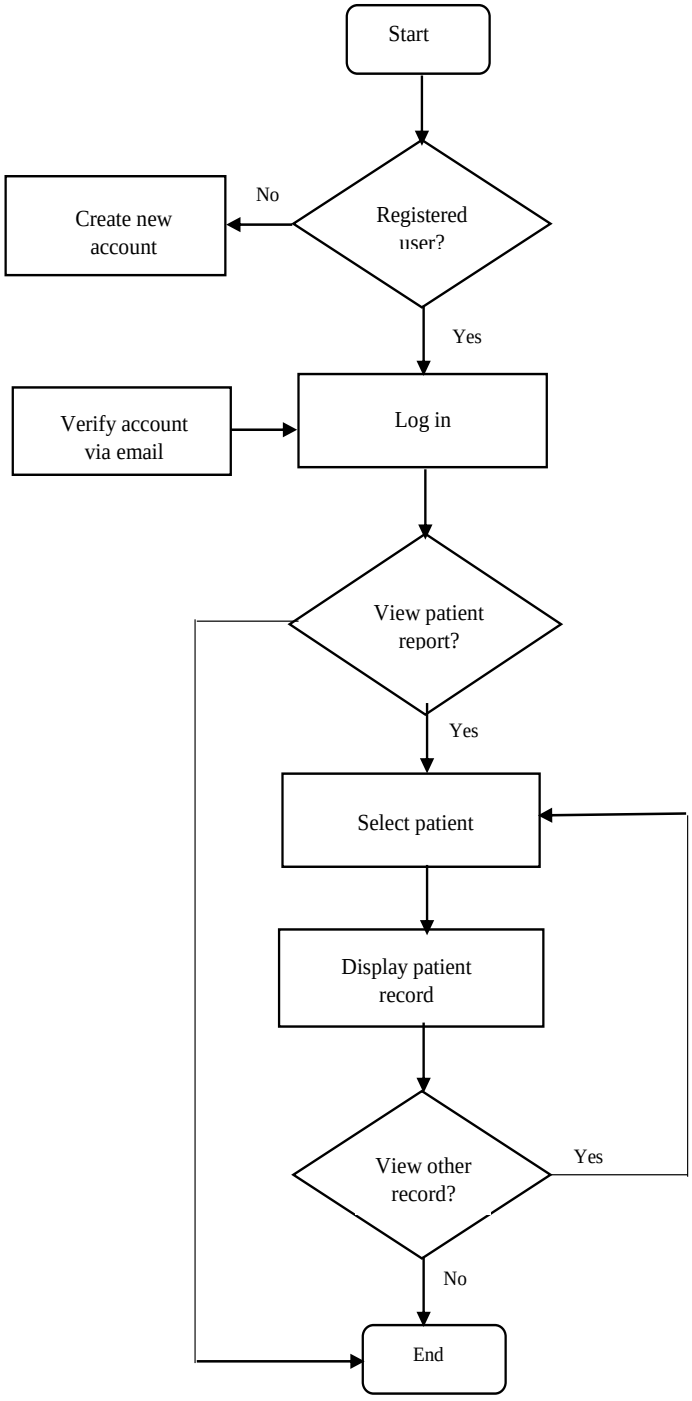

Fig. 2. Flowchart for Parkinson's Disease Patient.

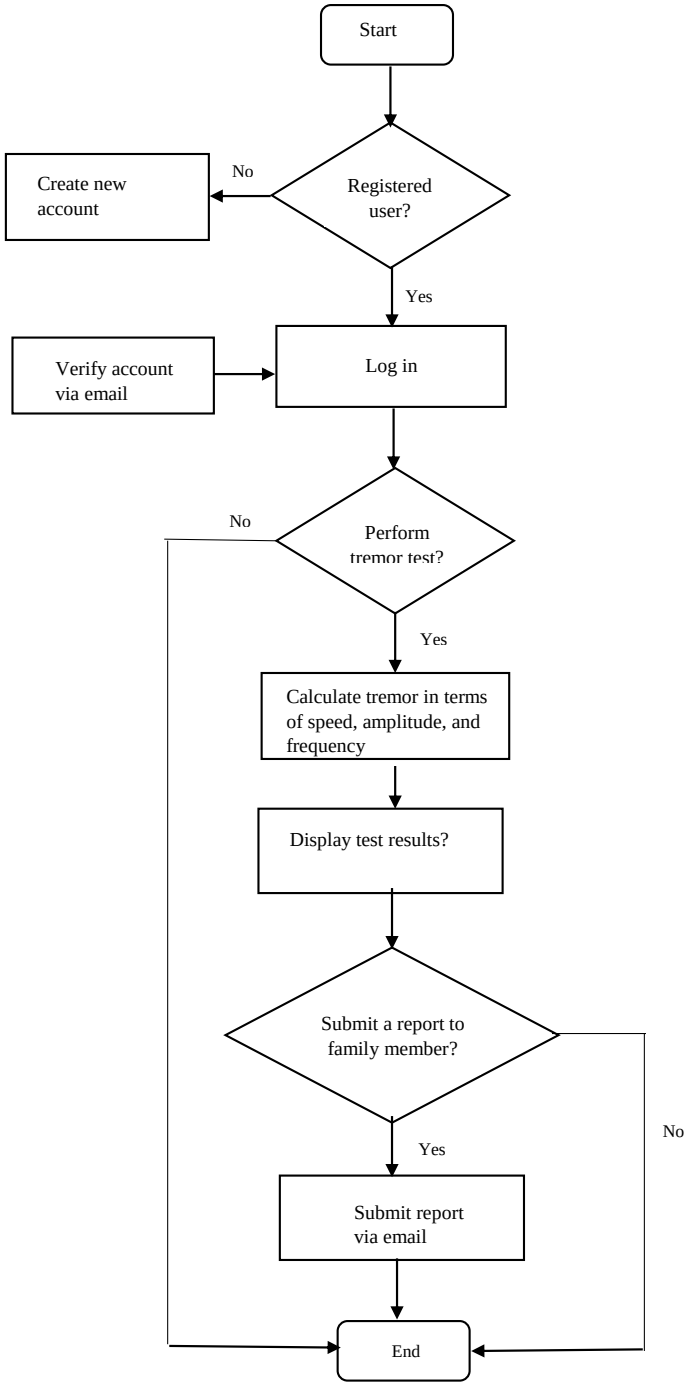

Fig. 3. Flowchart for Parkinson's Disease Neurologist.

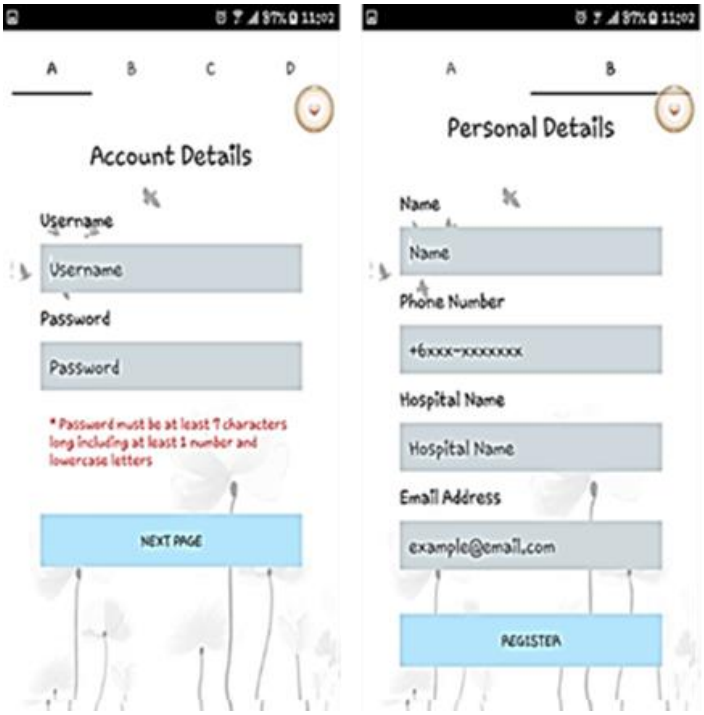

Fig. 4. Account Registration Interface for Parkinson's Disease Patient.

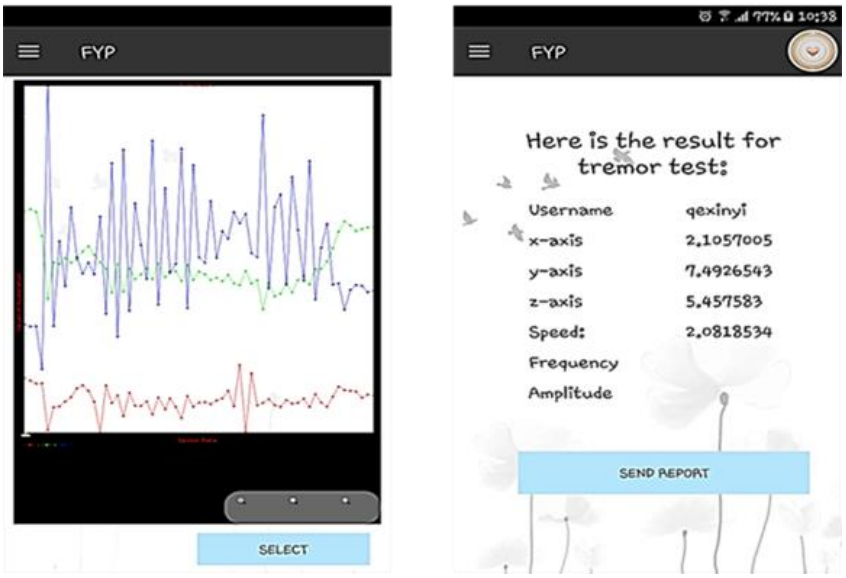

Fig. 5. Interface for Performing a Tremor Activity Test.

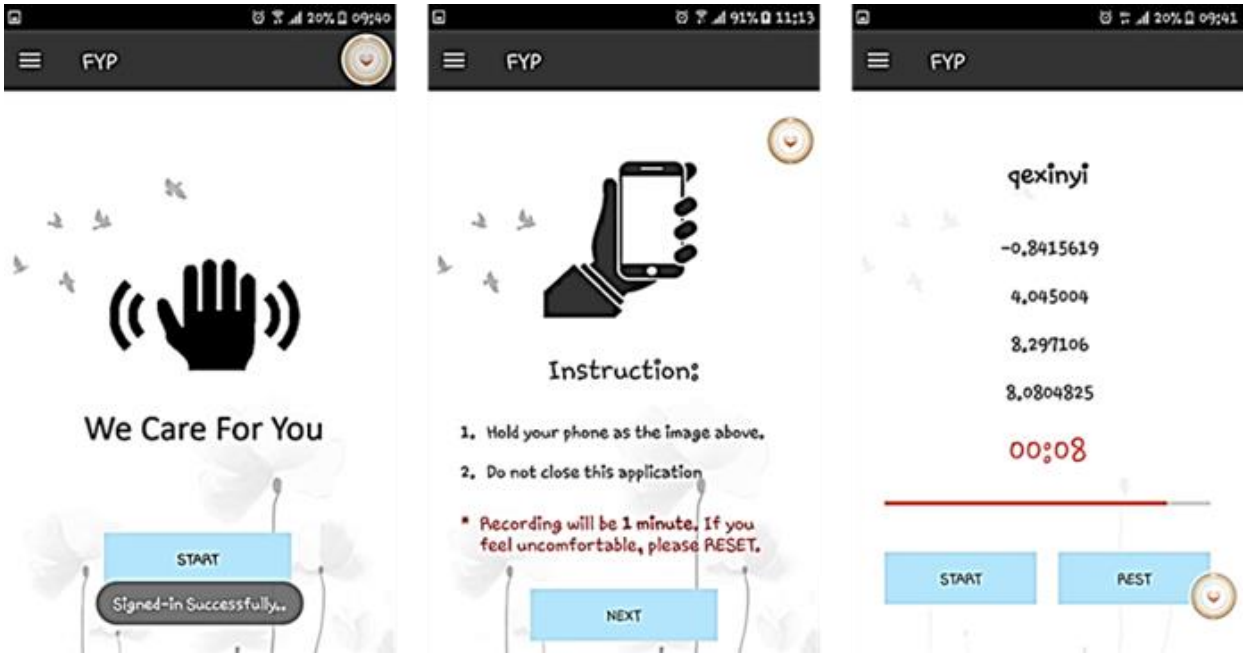

Fig. 6. Tremor Activity Results of users.

Fig. 7. Report Generated based on Information of a Registered user and her Tremor Activity Results.

Fig. 8. Interface for Submitting Tremor Activity Report for Parkinson's Disease Patient.

V. Conclusion

Overall, the tremor detector app for Parkinson's disease patients has successfully achieved its intended objectives. The app may be potentially beneficial to Parkinson's disease patients and neurologists in effectively managing the disease. Instead of manual, subjective analysis of patient drawings, the app enables neurologists to conveniently analyze patient tremor records in graph form. Tremor frequency, amplitude, and x, y, and z axes can be recorded in a report generated by the app during patient tremor test. Moreover, patients can monitor their health state and subsequently seek further medical assistance by comparing their current and previous record history.

However, the app has a number of limitations including restricted platform, communication language, and comparison ability. The app can only be run on Android-based mobile phones. Although patients can generate their tremor test results and respective graphs, they are unable to compare the latest test results with the previous ones on the same graph. This condition may cause difficulty for patients because they have to view their records in a separate graph. In addition, the app does not provide a function to directly translate its interface into another language by a "change language" function. The app language is assigned based on the smartphone installed language, and it only supports three languages, namely, Malay, English, and Chinese.

The app can be improved in the following ways: i) using other platforms apart from Android, such as IOS or Window operating systems; ii) enabling users to compare multiple data, such as those from x, y, and z axes with previous records on the same graph, to evaluate their health state and further discuss their situations with neurologists; and iii) utilizing multiple communication languages through a translation function to support the language preference of users.

Acknowledgments

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