Parkinson Analyzer: Unlocking Insights with the app Newlan

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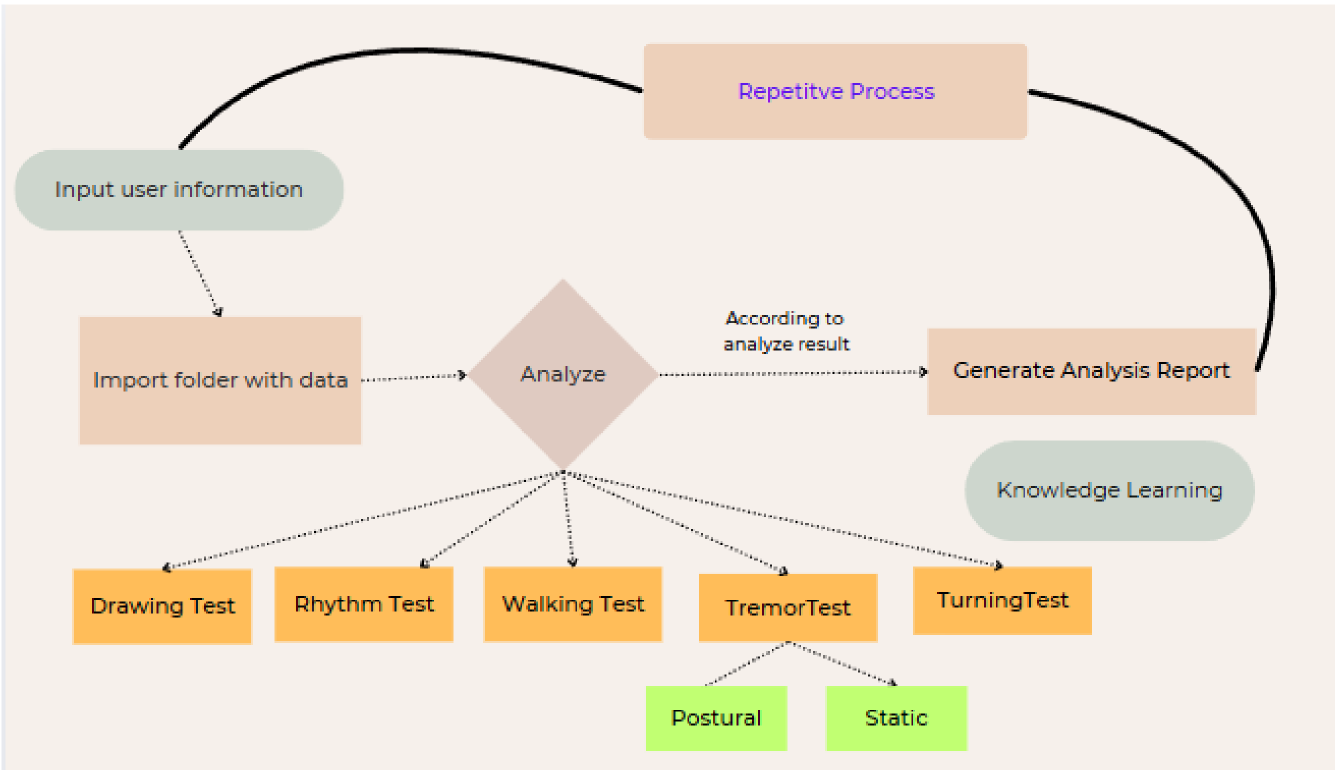

Figure 1: Basic Workflow of the Parkinson Analyzer App

Abstract

In our laboratory, we have developed an application called "Newlan," specifically designed for individuals with Parkinson's Disease. This application allows patients to complete questionnaires and perform tests related to their disease symptoms, thereby providing them with valuable data regarding their physical condition for reference. Although Newlan has successfully collected substantial data from both patients and healthy individuals, it lacks an integrated data analysis feature. To address this limitation, we have created a companion application, the Parkinson Analyzer, which is dedicated to analyzing the data collected by Newlan. This paper provides an overview of the Parkinson Analyzer application, detailing its user interface design, core functionalities, system integrations, testing procedures, and potential directions for future development.

Keywords

Parkinson's Disease, Data Analysis, Computer App, System Building, Report Generation

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1 Introduction

Parkinson's Disease (PD) is a progressive neurological disorder characterized by unintended or uncontrollable movements such as shaking, stiffness, and difficulties with balance and coordination.[1] Symptoms typically develop gradually and worsen over time, affecting both motor and non-motor functions.[2] As the disease progresses, individuals may face challenges with walking, talking, and mental health, including sleep disturbances, depression, memory issues, and fatigue.[3]

The global burden of Parkinson's Disease is alarming. In the United States, nearly one million individuals are living with the condition, with projections suggesting this figure will rise to 1.2 million by 2030. Each year, approximately 90,000 new cases are diagnosed in the U.S.[4] Internationally, China has the highest recorded incidence and prevalence among G-20 countries, with 5.077 million patients by 2021.[5]

PD symptoms are broadly categorized into motor and non-motor symptoms. Motor symptoms, such as difficulty walking, tremors, and muscle stiffness, are relatively easier to observe and quantify. Non-motor symptoms, however, encompass cognitive and psychological challenges, making them harder to diagnose and monitor.[3] Despite advancements, diagnosing Parkinson's Disease remains complex due to the absence of standardized neurological tests.[6] Variability in individual symptoms and the lack of tools to interpret intricate neurological signals, such as brainwaves, further complicate the diagnostic process.[7] Current methods often rely on costly and intricate neurological examinations, which are inaccessible to many patients.

In response to these challenges, practical solutions have focused on assessing motor symptoms, as they provide measurable indicators of a patient's condition. Metrics such as muscle control, body tremors, and speech accuracy can be quantified through tests like click counts or movement precision, offering valuable insights into disease progression.[8] Yet, our limited understanding of brain signals and their meanings poses a significant barrier to finding a comprehensive cure for PD.[9]

To bridge gaps in PD management, our laboratory developed a mobile application called Newlan, designed to provide patients with accessible tools for symptom assessment. Newlan enables users to complete questionnaires and perform tests evaluating muscle control, tremors, and speech. By collecting data remotely, it reduces the need for frequent hospital visits and creates a valuable repository of patient information. Users input basic information, including their diagnosis duration, medication regimen, and other relevant details, enabling personalized insights into their condition.

However, while Newlan excels at data collection, the absence of an analytical platform for interpreting this information limits its impact. To address this, we initiated the development of Parkinson Analyzer, an app designed to process and analyze data collected via Newlan. Parkinson Analyzer provides users with actionable insights into their symptoms and progression, bridging the critical gap between data collection and meaningful interpretation. Together, Newlan and Parkinson Analyzer represent an integrated solution to empower PD patients and support healthcare professionals with better tools for monitoring and managing the disease.

1.1 Design and Development

In contrast to the initial design proposal, the data analysis and report generation functionalities were developed as a separate, standalone application rather than being integrated into the existing "Newlan" app. This decision was driven by two primary considerations: anticipated user behavior and the constraints of the current development environment.

Rationale for a Standalone Application

From a user perspective, a standalone application offers enhanced flexibility in analyzing and comparing multiple data sets. For instance:

- Patients can track changes in their condition over time by comparing their own data sets.
- Doctors or researchers can analyze data from multiple patients simultaneously or evaluate different data sets from the same patient to facilitate more accurate diagnoses or refine app functionalities.

The separation of analysis capabilities from the Newlan app also avoids potential disruptions caused by the app's ongoing development. Newlan is actively maintained and modified by multiple contributors within the lab, leading to challenges such as:

- Frequent updates to development tools (e.g., Android Studio and Flutter).
- Variations in virtual environment configurations across collaborators.
- Coordination difficulties stemming from the lack of a dedicated project manager and the varying schedules of team members in an academic setting.

Development and Platform Choice

To address these challenges and ensure a focused development process, the Parkinson Analyzer app was developed as a desktop application using Python. While the current version is compatible with Windows only due to device constraints, the codebase is designed for cross-platform flexibility and can be compiled for macOS in the future. This approach ensures scalability and adaptability for diverse user needs.

Target Audience and Functionality

The Parkinson Analyzer app is designed to support individuals associated with Parkinson's Disease, including patients and medical professionals:

- For Patients:
  The app serves as a self-check tool, enabling patients to analyze their data, gain insights into their health, and identify areas requiring attention. This empowers them to take proactive measures to manage their condition.
- For Doctors:
  The app provides comprehensive analyses of patient data, offering valuable insights into their conditions. This aids in making informed diagnoses and devising effective treatment plans.

The Parkinson Analyzer app primarily relies on data collected via the Newlan app. While this data may not meet professional-grade standards, it serves as a valuable reference for both patients and doctors.

It is essential to emphasize that the Parkinson Analyzer is a supplementary tool designed to support the management of Parkinson's Disease. If the analysis highlights poor performance in specific areas, patients are strongly encouraged to seek professional medical evaluation and treatment. The app is not intended as a replacement for professional medical advice but as a complementary resource to enhance understanding and management of the condition.

1.2 Structure and Functionality

The Parkinson Analyzer is a desktop-based application designed, developed, and tested within the Windows environment. Comprising over 5,000 lines of code, the app is structured around four primary components, each contributing to its comprehensive functionality:

(1) Menu Bar
The menu bar provides access to essential functions and features. Notably, it includes a help section, offering information about the application and basic details about its designer, ensuring user accessibility and transparency.

(2) User Information Section
This section allows users to input basic patient details, which are incorporated into the generated reports. This feature ensures that analyses are personalized and relevant to the patient's unique profile.

(3) Graph Section
Serving as the analytical core of the app, the graph section includes modular analysis buttons and tabs for displaying basic analysis graphs or raw data visualizations. Users can generate reports, clear graphs, and interact with data, making this section central to the app's functionality.

(4) Knowledge Learning Section
This section features a combo box where users can select from various learning options. Based on the selection, the app opens corresponding web pages, providing resources and information to enhance understanding of Parkinson's disease.

Operational Framework

The Parkinson Analyzer operates on a straightforward principle: in the absence of a definitive criterion for assessing Parkinson's Disease (PD) severity, it compares patient data against a "normal performance" baseline established from data collected from healthy individuals.[10] This comparative approach offers nuanced insights into a patient's condition.

To establish the normal performance range, data from healthy individuals were collected and processed for five motor-symptom-related tests incorporated into the app, which are the Drawing Test, Rhythm Test, Walking Test, Tremor Test (covering both postural and static tremors), and Turning Test. Each test is designed to assess specific aspects of motor function.[11] By comparing a patient's results to this baseline, the app determines whether their performance falls within the normal range or deviates slightly, moderately, or significantly.

Enhancements and Future Directions

The current version of the Parkinson Analyzer has been rigorously tested within various Windows-based environments by colleagues to ensure compatibility and functionality. Feedback from these tests highlighted areas for improvement, one of which involves integrating artificial intelligence (AI) to enhance the app's analytical capabilities.

The incorporation of AI could enable the generation of more comprehensive and varied analyses in the reports, providing deeper insights into the motor symptoms of Parkinson's Disease patients.[12] This enhancement would significantly augment the app's utility, making it an even more valuable tool for patients and medical professionals alike.

2 Data Processing

To process the data and prepare it for analysis, the app's primary function, the method of quartile division was employed. This technique was applied to the data template, which represents information from healthy individuals, to facilitate a structured and comparative analysis.

The quartile division method is a statistical technique that involves partitioning a set of observations into four distinct intervals, based on their values and their relative position within the entire dataset. Quartiles are organized into lower quartiles, median quartiles, and upper quartiles.[13] These intervals are known as quartiles and are categorized as the lower quartile (0% - 25%), the median quartile (25% - 50%), the upper quartile (50% - 75%), and the top quartile (75% - 100%). Although there are several related concepts in statistics, they are not pertinent to the data analysis process employed in this application and will therefore not be discussed further.

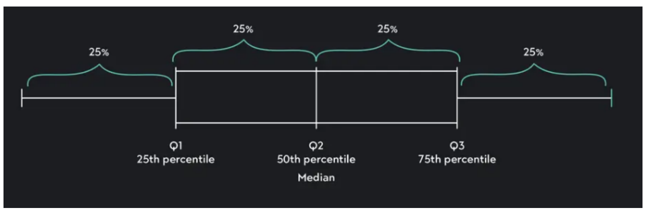


Figure 2: Schematic Diagram of Quartile Division

Quartile division is employed during the data treatment and processing phase for several key reasons. First, quartiles are valuable tools for summarizing the spread and skewness of data[14]. By dividing the dataset into four distinct segments using quartile boundaries, the dispersion of the data can be easily measured. Additionally, quartiles offer a means of assessing the robustness of the data. In particular, quartile deviation serves as a robust measure of dispersion, as it is relatively unaffected by extreme values or outliers within the dataset. This makes it especially useful for datasets containing extreme values or exhibiting skewness[15]. Furthermore, quartile division is applied to identify outliers and assess the abnormality of patient data, particularly when treated variables fall outside the "normal range."

Computational Simplicity of Quartile Division

The second rationale for employing quartile division in data processing is its computational simplicity. Dividing a dataset into four parts requires identifying five key points:

- Minimum value: The first data point in the sorted dataset.
- Maximum value: The last data point in the sorted dataset.
- Quartile points (Q1, Q2, Q3): Values dividing the data into equal intervals.

Quartile points are determined using the formula:

$$Q_r = l_1 + \frac{r(\frac{N}{4}) - c}{f}(l_2 - l_1)$$

Where:

- Q_r = Quartile value (e.g., Q1, Q2, Q3)
- l_1 = Lower class boundary of the quartile interval
- l_2 = Upper class boundary of the quartile interval
- r = Quartile rank (e.g., 1 for Q1, 2 for Q2)
- N = Total number of data points
- c = Cumulative frequency before the quartile interval
- f = Frequency of the quartile interval

This formula provides precise positions of quartiles in the dataset, whether as specific data points or averages of adjacent points. For example:

- First Quartile (Q1): Could correspond to the 6th value in the sequence or the mean of the 6th and 7th values.
- Median (Q2): Divides the dataset into two equal halves.

Quartile calculations are applied exclusively to the template data (collected from healthy individuals) to define reference ranges. For individual patient data, quartile division is unnecessary as the analysis focuses solely on evaluating the preprocessed data.

Data Structure and Preprocessing

The third rationale arises from the nature of the data being analyzed. Upon review, it is evident that datasets can vary significantly:

(1) Single Data Point Files: For tests like drawing strokes, the dataset contains one value per patient. In such cases, quartile division is applied only to aggregate healthy individual data for reference.

(2) Larger Datasets: Tests with multiple data points (e.g., motion tracking) require preprocessing steps like averaging values or calculating differences between consecutive data points.

These preprocessing methods streamline analysis by focusing on test performance characteristics rather than individual data points. This is crucial given that data is often collected at high frequencies (e.g., intervals of 10 milliseconds), producing multiple data points per second.

Given the variability of motor control among healthy individuals, establishing a range of acceptable performance is more practical than comparing each data point. Preprocessing simplifies the analysis while ensuring meaningful comparisons.

The relatively small sample size of healthy individuals (<100) limits the ability to establish a normal distribution model.[16] However, the symmetric design of the tests ensures that quartile-based methods remain valid for defining acceptable ranges.

3 Components and Design

The design of the application was entirely accomplished using the Eric Integrated Development Environment, a comprehensive platform for Python coding and design. Leveraging the PyQt5 package and associated Python libraries, the User Interface was constructed utilizing Qt Designer, an application included within Eric's suite of tools specifically for UI design. Qt Designer facilitates the creation of .ui files, which can subsequently be converted into .py files within the Eric IDE.

The decision to utilize Qt Designer as the primary tool for UI development in the Parkinson Analyzer application was driven by several compelling factors. Firstly, Qt Designer provides an intuitive, visual approach to designing interfaces, which significantly accelerates the development process. The drag-and-drop functionality for adding components, combined with the ability to customize their properties directly within the tool, eliminates the need for extensive manual coding of the UI. Its seamless integration with the PyQt5 package ensures efficient conversion of design files into Python code, streamlining the workflow and aligning the design and coding phases effectively.

The design process in Qt Designer is further characterized by an intuitive interface, as illustrated in the accompanying diagram. The left toolbar contains a variety of components that can be effortlessly dragged and dropped into the design window to establish the corresponding UI elements. Each component's attributes, such as enablement status, size, font, and alignment, can be meticulously examined and modified in the right feature bar.

Additionally, Qt Designer's robust feature set—such as its signal-slot editor for connecting UI elements to functionality and its filter section for managing component layers—offers the flexibility and precision needed for complex UI design. These tools were particularly advantageous in ensuring the usability and visual clarity of the Parkinson Analyzer application's interface, which caters to both patients and medical professionals. By leveraging Qt Designer, the development process benefited from a streamlined workflow, enhanced productivity, and the creation of a professional-grade UI tailored to the needs of the target audience.

3.1 Main Window Structure

(1) Menu bar

The menu bar of the application presently comprises two functionalities, namely "Help" and "Import User Info," both of which are categorized under the "Basic Info" tab. The "Help" function serves to display a window containing designer information, providing users with assistance and guidance on using the application. On the other hand, the "Import User Info" function facilitates the input of content from a TXT file into the user information section, allowing for the efficient importation of user data.

(2) User information

The User Information section is encapsulated within a group box specifically tailored for gathering essential patient details. This section allows users to input fundamental data such as name, age, address, and medication usage. Additionally, there are fields available for capturing supplementary details like patient ID and the duration of Parkinson's Disease. However, as the primary purpose of this application is to convert patient test results into reports, some of this additional information may not be crucial for inclusion or might be presented elsewhere. Recognizing that patients may not always disclose extensive personal details, the application focuses on collecting only the basic information necessary to establish their identity, which is deemed sufficient for the intended purpose. The group box is equipped with multiple tags and line edit fields, enabling users to enter their information. For users of the Newlan app who may be testing for potential Parkinson's Disease symptoms rather than being confirmed patients, the group box is appropriately labeled 'User Information' instead of 'Patient Information.' The details collected include the user's name, age, address, and medication usage. Users have the flexibility to leave any of these fields blank if they choose not to disclose certain information, and such omissions will be reflected in the generated PDF report.

Recognizing the need for flexibility in the medication usage field, users can input up to three medications in separate fields. If they are taking fewer, the remaining fields can simply be left blank. Alternatively, users may list all their medications in a single field, separated by commas, for convenience. The generated report will display this information exactly as entered when the 'Generate Report' button is clicked.

To enhance the functionality, the section also includes a 'Select Photo' feature. Clicking this button opens a dialog window where the user can choose a patient photo to include in the final PDF report. This feature is separate from the 'Import User Info' function available in the menu bar, which allows users to import data from a corresponding .txt file to streamline the process further. The combination of manual and automated options ensures that the application caters to a wide range of user preferences and scenarios.

(3) Analysis parts

The Analysis Section of the application consists of several components to present analysis results derived from the collected data.

The first component is the Data Import Layout, which includes an ‘Import Folder’ button and a tag that displays the address of the selected folder. This feature allows users to import a folder containing multiple .csv files from the patient’s tests, as well as an optional .txt file with additional details.

The second component is the Analysis Section, featuring five buttons for analyzing drawing, rhythm, walking, tremor, and turning tests. Below these buttons, a tab widget contains five corresponding tabs, each dedicated to displaying the results of a specific test analysis. Each tab includes a graphic view canvas where visual representations of the results are displayed. Users can navigate through the tabs by selecting the entries in the widget’s upper row, enabling them to view the outcomes of different tests. Only the relevant canvases are updated based on the selected tests, ensuring clarity in the presentation of results.

For the walking, tremor, and turning tests, the tabs are further divided into Raw Data and Treated Data sub-tabs. The Raw Data sub-tab displays the cleaned data curves, while the Treated Data sub-tab highlights specific features extracted from the data. Additionally, the tremor test tab includes an extra row to separate and display the results of the postural tremor and static tremor tests.

This structured layout simplifies the analysis process by organizing results according to test type and data characteristics, making it easier for users to interpret the findings effectively.

(4) Knowledge learning

A distinct section is dedicated to knowledge learning, clearly separated from the previous section by a dividing line. Within this section, a combo box allows users to select a specific topic for further exploration. By clicking the ’Start Learning’ button, the application opens the corresponding web page, offering valuable information on the selected subject. The combo box presents a total of seven options, covering various aspects of Parkinson’s Disease, including its causes and symptoms. This feature serves as an excellent resource for users seeking to deepen their understanding of the condition.

(5) Signal-slot functions

Signal-slot functions are fundamental components of Qt Designer that enable seamless communication between different elements of an application. These mechanisms allow signals,

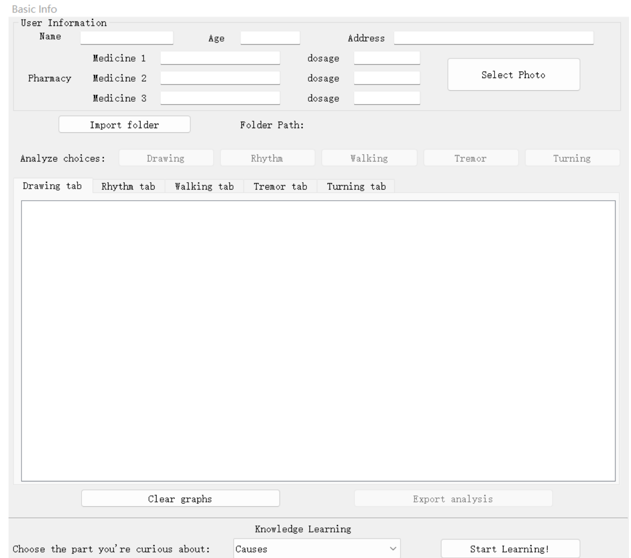


Figure 3: Main window structure for all four subparts

representing specific events or triggers, to initiate corresponding actions in designated slots. This facilitates dynamic interactions and adaptive state changes within the user interface. In this application, signal-slot functions ensure synchronization and responsiveness across various components, dynamically reflecting user inputs and other relevant events to enhance usability and coherence.

One major use of signal-slot functions is updating the content of components within the main window. For instance, when the Import button is clicked, the tag within the same widget is updated to display the address of the selected folder. While this functionality could be achieved by directly editing the .py file, signal-slot functions ensure that actions are contextually valid and compatible with the edited window. For example, executing an action like "close the main window" through a button click is valid, whereas trying to close the window via changes to a line edit field is not.

Signal-slot mechanisms also handle other critical functionalities. For instance, the ‘Import User Info’ menu bar action inputs content into appropriate fields, and clicking analysis buttons updates corresponding graphic view boxes with results. These interactions are processed seamlessly through signal-slot functions, ensuring a responsive and cohesive user interface.

The second key use of signal-slot functions involves modifying the availability or enabled state of application components.

For instance, when the application first opens, buttons for analysis, clearing, and exporting are disabled because no data is available for processing. Once a valid folder is imported using the Import button, these buttons are enabled. If the selected folder is invalid, the buttons remain disabled. This behavior is controlled by custom code that verifies the folder's validity and adjusts the button states accordingly.
By dynamically controlling the availability of components and ensuring that only valid actions can be performed, signal-slot functions prevent errors and provide a more intuitive, user-friendly interface. This approach enhances both functionality and user experience by maintaining an adaptive and responsive system.

3.2 Functions

Numerous functions were developed to complete this application. For clarity and ease of understanding, these functions will be introduced in the order of the user interface design, following the sequence in which they appear and interact within the interface. It is important to note that all functions are structure-based, meaning they are triggered exclusively by interacting with the designated components within the user interface, such as buttons, menus, or other interactive elements in the main window. This structure-based approach ensures that each function is directly tied to a specific UI element, making the application intuitive and easy to navigate for users, as all actions are triggered by clear, purposeful interactions with the interface components.

(1) Menu Bar

The menu bar of the application currently includes two functions. The first is the 'Help' action, which, when selected, displays an information box containing basic details about the Parkinson Analyzer app, along with the developer's contact information, including phone number and email address. The information box is straightforward, featuring an "OK" button to close it after the user has reviewed the content. It also includes a standard close button in the upper-right corner, as is typical for Qt's information box widget. The 'Help' action provides valuable assistance to users, offering quick access to essential information and contact details for reaching the developer with questions or feedback.
The second function in the menu bar is "Import User Info." This feature allows users to select a TXT file from a folder containing patient information. The TXT file follows a specific template, where the content after the equal sign is editable. Users can modify the existing file or create a new one based on the template and save it to a desired location.
Once the TXT file is selected, the system automatically extracts the information and populates the corresponding fields in the "User Information" section, reducing the need for manual entry and minimizing the risk of errors.
If the user clicks "Cancel" when prompted to select a TXT file, a warning window appears, informing them that no file was chosen. This warning window follows a consistent design template used throughout the application whenever files or folders are selected. The template can be adapted to show different messages depending on the context, but its design and functionality remain consistent.

(2) Import Action

File Preparation

The general process for importing test results involves handling multiple .csv files, each containing data from different tests. These files are typically stored in a designated directory and named according to patient-specific information. To ensure proper analysis, the files should be renamed to reflect the corresponding test type, such as "Walking Test," so the application can easily identify each file's content.
Once the files are renamed, they should be placed into a single folder, which is then renamed to include the patient's details. This organized structure is essential for the analysis process, as it allows the Parkinson Analyzer app to easily locate and access the relevant files associated with each patient.
By following these steps, the files are systematically organized and named, streamlining data processing and analysis. This structured approach reduces the risk of errors and confusion, as all necessary files for a specific patient are contained in one clearly labeled folder. Furthermore, it improves data management by making it easier to locate, update, and track patient information throughout the analysis process.

Import Process and Data Validation

The import action within the application consists of two key stages, both designed to ensure thorough fault-checking and accurate data handling.
First, when the "Import" button is activated, the system triggers a file selection dialog, prompting the user to select a folder containing the required patient test result .csv files. Once the appropriate folder is selected, the system proceeds

to update a label next to the "Import" button. This label displays the selected folder's file path, confirming that the correct data repository has been chosen for the analysis. This two-step process helps ensure that the data import is accurate and systematic, minimizing the potential for user error.

After a folder is selected, the application invokes the data preparation function to begin the analysis process. However, if the folder is empty or if the user closes the file selection dialog without choosing a folder (by clicking the "X" button), the system will display an informational dialog box to notify the user that no folder has been selected. In such cases, the import function is terminated.

Additionally, the system manages the state of various buttons based on the import process's progress. Several buttons are initially disabled (grayed out) until a valid folder containing data files is selected. If the selected folder is empty or no folder is chosen, the buttons remain disabled. The application automatically reverts these buttons to the disabled state if the folder is invalid, preventing users from proceeding with analysis or other actions until a valid dataset is imported.

As shown in previous figures, the "Analyze" button and the two corresponding buttons below the analysis area remain disabled until a valid folder is selected and the label is updated with the folder's path. Once this update occurs, the buttons become enabled, allowing the user to proceed with the analysis. This design ensures a clear, intuitive user experience, guiding users through the import and analysis steps within the Parkinson Analyzer application.

Data Preparation for Analysis

The data preparation function within the application plays a critical role in organizing and processing the collected data for analysis. Several variables are predefined in the main function to accommodate the data from the five tests in the Parkinson Analyzer app. The purpose of this function is to extract relevant data from the selected folder's CSV files and populate initially empty lists with this data for further processing.

For the drawing and rhythm tests, which measure hand movements and muscle control, data collection is straightforward. The data is inserted directly into the corresponding lists, with minimal processing such as rounding.

For the other three tests, which utilize the phone's locating device (such as a level meter), the data is more complex. Each test produces nine types of data, which requires additional processing, including calculating averages, minimums, or maximums. The treated data is rounded to a consistent standard to maintain uniformity.

It is important to note that the rounding level varies across tests. This is intentional, as it accounts for the data from healthy individuals, ensuring that the rounding level for each test aligns with the standard data collected from healthy subjects. This ensures accurate, consistent processing, enabling meaningful comparisons between patient and healthy subject results during analysis.

(3) Five Test Analysis

In the Parkinson Analyzer application, the analysis of each test is based on the quartile division method, which provides a standardized approach for comparing a patient's data to the reference data from healthy individuals. All the healthy individuals' data is processed using quartile division to establish a clear reference framework. The primary difference from the previous approach is that most of the data is treated by calculating the average value, which provides a reliable baseline for comparison. However, for the coordination-related data collected during the last three tests—walking, tremor, and turning—the processing method differs. Instead of taking the average, the data from these tests is treated by calculating the gap between each collected value. The maximum gap within each test's data is then used to establish the reference for comparison, as it provides a more accurate representation of the coordination ability and movement variability.

For visualizing the comparison, the application now displays five bars and one line in the chart. Each of the five bars represents a specific range based on the quartile divisions of the reference data from healthy individuals. The bars are as follows:

(a) Below 0% — Representing values lower than the lowest quartile (the first bar).
(b) 0%-25% — Representing values in the first quartile.
(c) 25%-50% — Representing values in the second quartile.
(d) 50%-75% — Representing values in the third quartile.
(e) 75%-100% — Representing values in the top quartile.

In addition to the bars, there is one line on the chart representing the patient's current value for that particular test. The line indicates where the patient's data falls within these quartile ranges. If the patient's value intersects with any of the bars, it shows the exact range the patient's data belongs to. For example, if the patient's line intersects with the bar representing the 25%-50% range, this indicates that the patient's data falls within that specific quartile of the reference data.

However, if the patient's data exceeds the highest quartile (i.e., the patient's line does not intersect with any bar), it indicates that the patient's result is beyond the 100% range of the healthy population's data. This scenario highlights the fact that the patient's performance is greater than what is typically observed in healthy individuals for the particular test, which could signal an anomaly or improvement.

- **Drawing Test**

  The drawing test within the Parkinson Analyzer app is specifically designed to assess the patient's fine motor skills and hand muscle control by tracking the number of touches (or "strokes") the patient makes on the phone screen while performing a drawing task, such as drawing part of a clock. Each touch on the screen represents a single stroke, and the total number of strokes is used as the primary variable to evaluate the patient's ability to control hand movements with precision.

  To gather this data, the 'Newlan' application monitors the start and end times of each drawing stroke, which is registered as a touch event on the screen. The application ensures data accuracy by filtering out any invalid records, such as instances where the start and end times are identical, which might occur due to test initialization errors or other unexpected events.

  Once the valid stroke data is collected, it is compared against the quartile division of strike numbers from healthy individuals. This comparison allows for the classification of the patient's performance into one of six possible tags, which correspond to various performance ranges defined by the quartile divisions of healthy individuals. These tags include below baseline, within the baseline to the 25th percentile, and so on up to above the top line.

  The comparison results are visually represented in a chart within the application's canvas. Since the drawing test focuses on a single variable—the number of strokes—the chart occupies a smaller portion of the canvas, and a horizontal scroll bar is not required unless multiple charts are displayed. In such cases, the scroll bar allows for easy navigation between different charts.

- **Rhythm Test**

  The rhythm test within the Parkinson Analyzer app is designed to assess the patient's ability to accurately click and maintain a consistent rhythm in response to a target that alternates between two positions on the screen. The target turns red to indicate the correct position, challenging the patient to predict and react to the alternating pattern. This test provides important insights into the patient's body control, coordination, and ability to respond to dynamic stimuli.

  Two key variables are collected during the rhythm test: the number of correct clicks within the one-minute test duration and the average distance (in pixels) of each click from the center of the targeted circle. The number of correct clicks is determined by counting the valid click records, similar to the method used in the drawing test. The average pixel distance is calculated by measuring the distance between each click point and the center of the target circle, then averaging these values.

  These two variables give a comprehensive view of the patient's performance in the rhythm test. The correct click count reflects their ability to respond promptly and accurately to the alternating target, while the average pixel distance reveals how precisely they can click on the target. Together, they offer valuable insights into both the patient's rhythm and their ability to control fine motor movements.

  The results of the rhythm test are visualized in two separate charts, displayed within the same canvas. One chart represents the correct click count, while the other shows the average pixel distance. To facilitate easy navigation and detailed examination, both charts include sliding bars for horizontal and vertical movement, allowing users to explore the results more thoroughly.

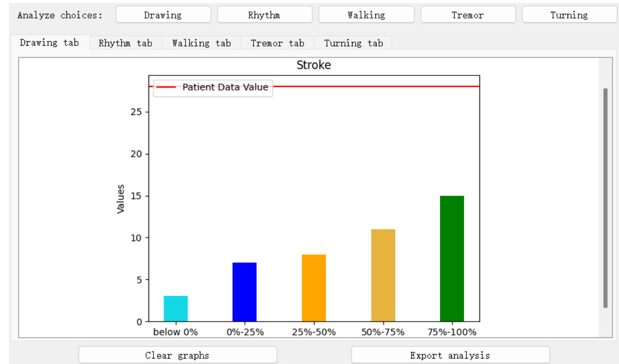


Figure 4: Example chart of quartile bars and patient data(line)

- **Walking Test**

  In the walking test, the patient's body control and coordination are assessed using the phone's built-in measuring device. Patients are instructed to walk for 45 seconds, turning around if they encounter any obstacles. Data is continuously collected whenever the phone detects a change in movement, allowing for the accumulation of detailed walking data for subsequent analysis.

The walking test collects a total of nine data points: acceleration, gyroscope, and magnetic data. Each type of data includes variables in the X, Y, and Z directions, resulting in a total of nine distinct variables. The magnetic data serves as an indicator of the patient's current coordination. For the acceleration and gyroscope data, averages are calculated to assess the patient's acceleration and body stability. For the magnetic data, a list of gaps is generated by subtracting the previous value from the current value, providing a more precise measure of the patient's movement.

Starting from the walking test, all subsequent tests in the Parkinson Analyzer app use these same nine variables—acceleration, gyroscope, and magnetic data—collected across the X, Y, and Z directions. This consistency across tests ensures that the data is comparable and allows for a more thorough and cohesive evaluation of the patient's coordination and movement.

The walking test results are presented in three raw data charts, one for each of the categories: acceleration, gyroscope, and magnetic data. Each chart displays the X, Y, and Z components, providing a clear representation of the raw data. In the treated data tab, the processed data is displayed across nine separate charts, corresponding to the nine variables. These charts allow for a detailed comparison of the patient's processed data with the reference data from healthy individuals, providing deeper insights into the patient's performance.

To enhance the user experience, the raw and processed data are placed on separate tabs, allowing users to easily switch between canvases and view both the raw data and the treated analysis. This structured approach ensures that patients can easily navigate the data and gain a comprehensive understanding of their performance.

- **Tremor Test**

The tremor test within the Parkinson Analyzer app consists of two main types: the postural tremor test and the static tremor test. In the postural tremor test, the patient is asked to maintain a position with their arm outstretched or holding the phone straight for several seconds. In the static tremor test, the patient sits in a chair with their arm holding the phone resting on the armrests. Both tests are designed to assess the patient's ability to maintain stability, focusing on the control of arm and wrist movements during the tests.

Similar to the walking test, nine variables of data are collected for both tremor tests, which include acceleration, gyroscope, and magnetic data, collected in the X, Y, and Z directions. These variables are essential for evaluating the patient's ability to control arm movements and detect tremors in different postures. This consistent approach to data collection ensures comparability between the tests.

However, unlike the walking test where data is collected continuously, the postural and static tremor tests are analyzed separately. Data for these tests are collected in two distinct CSV files, resulting in separate analysis for each test. To streamline the analysis process, both tests share the same "Tremor Test Analyze" button in the app. When the user clicks this button, both the postural and static tremor tests are analyzed sequentially.

To ensure the analysis runs smoothly, the app checks whether the respective files for the postural or static tremor tests exist before proceeding with the analysis. This precaution ensures that if only one test has been performed, and only one file is available, the analysis process will continue without errors, maintaining the app's stability.

Similar to the walking test, the results for both tremor tests are displayed on separate canvases—one for raw data and one for treated data—ensuring clear and organized presentation. Additionally, an extra tab bar was introduced to differentiate between the postural and static tremor tests. As a result, there are four tabs in total for the tremor tests: two for raw data (one for each test) and two for treated data (one for each test).

The structure of each canvas mirrors the setup in the walking test, with distinct displays for raw and treated data. This ensures that the analysis of both tremor tests can be easily accessed and reviewed, while maintaining clear distinctions between the postural and static tremor test data. This organization promotes a user-friendly experience and allows for efficient navigation of the test results.

- **Turning Test**

The turning test within the Parkinson Analyzer app evaluates the patient's ability to maintain body stability while performing turning movements. Unlike the walking test, which requires continuous walking, the turning test asks the patient to perform a turn and maintain stability for a brief period, repeating the process until the test concludes. This test challenges the patient's ability to manage balance while transitioning between movement and stillness, providing valuable insights into their coordination and stability.

Similar to the walking test, nine distinct types of data are collected during the turning test. These data points are crucial for assessing the patient's performance in maintaining stability during turning movements and while holding a stable posture. The data collected includes acceleration, gyroscope, and magnetic measurements, which are used to evaluate the patient's ability to control bodily movements during both dynamic (turning) and static (standing) conditions. By comparing this data to that of healthy individuals, the app provides critical insights into the patient's ability to manage balance and stability.

For the analysis, the app provides separate canvases for raw and treated data, with scroll bars available for users to review the patient's performance. The Y-axis scale is dynamically adjusted to suit the data being displayed. For example, when analyzing data from the turning test, the values may be more concentrated compared to those in the walking test. Since variables such as acceleration and coordination changes tend to be higher in the walking test, the chart scales each dataset accordingly, ensuring that the results from both tests are displayed in an organized and legible manner.

For example, the coordination gap in the treated data for the walking test might range from 2 to 28, while in the turning test, the range could be from 2 to 13. By adjusting the scale appropriately and incorporating a scroll bar, the data from both tests can be displayed without being crowded or overly dispersed. This approach ensures that each test's results are presented clearly, allowing for accurate comparisons and facilitating a user-friendly experience. The consistent application of this technique across all tests ensures that the visualization of the data remains both accurate and intuitive.

(4) Knowledge Learning

The knowledge learning section within the Parkinson Analyzer app serves a crucial function: allowing users to select the topic they wish to learn more about regarding Parkinson's disease. By selecting an option from the dropdown menu and clicking the "Start Learning" button, users are directed to a corresponding webpage that offers detailed information on the chosen subject.

This section operates independently from the Parkinson analysis functionality, offering users a resource to further their understanding of Parkinson's disease. After reviewing their test results or identifying areas where they may have underperformed, users can easily access educational content to gain more knowledge about the disease and its impact.

The section includes a user-friendly interface with the following components:

- A label guiding the user to select the aspect of Parkinson's disease they wish to explore.
- A combo box (dropdown menu) offering seven different topics: Causes, Symptoms, Diagnosis, Early Signs, Risk Factors, Prevention, and Treatments.
- A "Start Learning" button, which when clicked, redirects the user to the relevant webpage based on the selected topic.

Once the user activates the "Start Learning" button, the app evaluates the selected topic and opens the corresponding webpage. This design ensures seamless navigation and makes it easy for users to access educational resources that are most pertinent to their needs.

In some cases, topics within the dropdown menu may link to specific sections of the same website. The URLs for each option are structured to direct users to the appropriate part of the webpage, ensuring that the content they view is aligned with their chosen topic. This approach not only enhances the relevance of the educational material but also ensures that the information is easily accessible, contributing to a more engaging and informative user experience.

3.3 Export Analysis

The analysis export function is a crucial feature of the Parkinson Analyzer app, enabling users to generate and manage detailed reports based on the data and tags previously processed in the app (though the underlying analysis process is not displayed in detail). Once the analysis is complete, the app allows users to generate a PDF file, which is based on a pre-designed template, summarizing the results of the tests. This function has now been enhanced to allow users greater flexibility: they can either create a new PDF file to save the report or overwrite an existing PDF file with updated content, all while adhering to the preset template.

The exported PDF file is divided into three primary sections:

(1) User Information - Includes personal and demographic details of the patient.
(2) Test Analysis - Displays the analysis results for each test, along with relevant data and observations.

(3) Comprehensive Analysis - Summarizes the overall findings and provides an integrated view of the patient's performance across all tests.

The PDF is formatted using a structured template that ensures clarity and consistency. Each page of the document contains the following components:

- Page Header: Every page features a header, which includes a brief introduction or title for the PDF. This is followed by a horizontal line that separates the header from the main content on the page.
- Section Captions: Each section of the document is clearly labeled with captions to help the user navigate the information.

To maintain consistency and readability, the header is formatted with a smaller font size, distinguishing it from the rest of the content in the document. The use of different font sizes and styles throughout the PDF is intentional, helping to clearly differentiate between the sections, making the document visually appealing and easy to follow.

The export function ensures that the content is structured and formatted according to the preset template, providing users with a professional and comprehensive report of their test results. This added functionality for file management (creating or overwriting PDFs) makes it even more versatile, allowing users to conveniently update and save their reports without the need for manual intervention.

- **User Information**

  The "User Information" section is a fundamental component of the app, presenting the collected data in a format that mirrors the input structure used in the app window. This section displays the information within rectangular boxes, each delineating a distinct piece of data for clarity and organization.

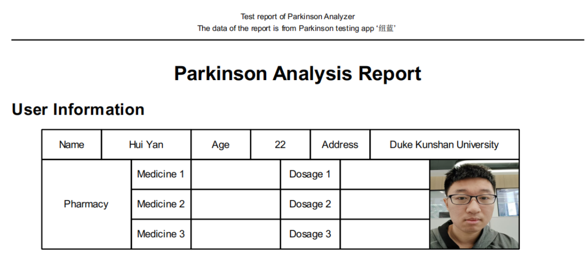
  The layout is structured as follows:

  (1) First Row: This row showcases the user's essential details, including their name, age, and address, each enclosed in its rectangular box.

  (2) Second Row: Occupying a larger space, this row is divided into three columns. The first column displays the user's selected pharmacy, while the second and third columns are dedicated to the three prescribed medicines and their corresponding dosages, respectively. The content in these columns directly reflects the input provided in the app window or imported from the TXT file using the "import user info" function, unless any modifications are made subsequently.

  (3) User Picture: To the right of the second row, there is a designated area for the user's photo. The image is resized to fit perfectly within the rectangular box provided.

  All the aforementioned information boxes are neatly encapsulated within their respective rectangles, which are further enclosed by a larger rectangle, clearly indicating that this section is devoted to the user's collected information. This design ensures clarity and ease of navigation for the user, allowing them to quickly access and review their personal and medical details within the app.



Test report of Parkinson Analyzer
The data of the report is from Parkinson testing app '纽蓝'

Parkinson Analysis Report

User Information

Name	Hui Yan	Age	22	Address	Duke Kunshan University
Pharmacy	Medicine 1		Dosage 1		
	Medicine 2		Dosage 2		
	Medicine 3		Dosage 3		

Figure 5: User Information Template(with author's info as example)

- **Test Analysis**

  The Test Analysis section in the PDF summarizes the results of the five tests previously conducted within the Parkinson Analyzer app, providing an evaluation of whether the collected treated data falls within the normal range established from the data of healthy individuals. The focus of this section is primarily on the comparison of the treated data against the standard range, particularly examining cases where the data exceeds the upper boundary of this range, as defined by the quartile-based analysis of healthy people's data.

  The rationale for emphasizing the upper boundary is rooted in the nature of the measurements, especially those related to "stability." For example, in tests involving magnetic coordination, the raw data is processed by calculating the gap between consecutive data points. This gap represents the extent of movement, with larger gaps indicating more significant shifts in position—often signaling instability. When the treated data exceeds the upper boundary, it suggests that the patient is displaying larger movements, which may reflect poor body control, particularly in tests requiring the patient to maintain stability. Larger gaps in the treated data are thus indicative of instability, a potential symptom of Parkinson's disease. Smaller gaps, conversely, signify better body control and stability, which is a more favorable outcome.

Therefore, only treated data that surpasses the top line of the standard range (based on healthy individuals' data) is flagged as a potential issue, signaling possible instability or difficulty in maintaining balance during the tests. This targeted approach is particularly useful in identifying areas where the patient's body control may be compromised, which is essential for monitoring Parkinson's disease progression.

The Test Analysis section also takes into account the possibility that a patient may not have completed all of the tests. In cases where a test has been omitted, the app ensures that the analysis for that specific test is left blank. The analysis for tests that were conducted is clearly presented, ensuring that the report reflects only the relevant information.

To maintain a professional, neat, and organized layout, the Test Analysis section reserves placeholder space where tests were not completed. This ensures that the analysis for each test remains in its designated spot, preserving the document's structure and appearance even in the absence of some test results. This thoughtful approach ensures the consistency and integrity of the PDF template, keeping the layout aligned and easy to read, regardless of the number of tests completed.

(1) Drawing test

In the Drawing Test, the primary focus is on the patient's strike number, which represents the number of touches the patient made while attempting to complete the drawing task. The raw data for this variable is used to directly compare the strike count with the standard quartile data, offering a simple yet insightful measure of the patient's hand control and coordination.

The analysis begins by introducing the purpose of the test, which is to evaluate the patient's ability to control hand movements accurately. Following the introduction, the treated variable, strike number, is presented, showing the patient's performance. This treated data is then compared against the standard quartile range for healthy individuals, which was previously established using data from this population.

Since the drawing test involves only a single variable, the strike number, the analysis focuses on comparing this value to the predefined quartile ranges. The comparison helps to determine whether the patient's strike number falls within the normal range, indicating proper hand coordination, or whether it exceeds the established boundaries, signaling potential abnormalities in movement or stability.

Based on this comparison, a conclusion is drawn, providing a detailed evaluation of the patient's hand stability and coordination. A higher strike number than the standard could indicate issues with hand control, which are key indicators of tremors or instability, both of which are common symptoms in Parkinson's disease. Conversely, a lower strike number within the normal range would suggest that the patient's hand coordination is intact.

By concentrating on the strike number, the analysis offers valuable insight into the patient's ability to perform fine motor tasks, which is essential for understanding their level of hand tremor and overall hand stability. This focused evaluation allows for a clear, specific assessment of the patient's performance in the drawing task, making it an important diagnostic tool in the overall Parkinson's disease assessment.

(2) Rhythm test

The rhythm test primarily assesses finger muscle control and hand stability by analyzing the rhythm count and the pixel-to-center distance as the treated variables.

In this test, the rhythm count and pixel-to-center are the key variables used for assessment. It's important to note that the significant digits of these variables may vary, reflecting the nature of the treated data. During data processing, different variables might display their exact values and measurement methods differently. For instance, some variables might be integers, while others could be 3-digit or 4-digit numbers. Additionally, a comparison of the quartile has been included to provide further insight into the data distribution.

The analysis of the rhythm test begins with a brief introduction, followed by a straightforward evaluation of the variables. The focus is on judging the variables and drawing conclusions about their corresponding situations. If the variable values fall within the normal range, no specific conclusion is given, but rather a line of encouragement to maintain the current situation. For most cases, as long as the variable values do not exceed the top line of the corresponding range for healthy people, it is considered satisfactory.

(3) Walking test

In the Walking Test section of the PDF report, the analysis covers the nine variables collected during the test, which are represented through raw data charts. These charts include measurements from acceleration, gyroscopic, and magnetic data, each corresponding to a different aspect of the walking test. To provide a comprehensive presentation, the raw data charts from the app's canvas are directly incorporated into the report, allowing the user to view the entire dataset without the limitations of the app's scrollable interface.

While the app employs a scroll bar to navigate through the canvas, which represents the visible area of the raw data, the PDF report captures the entire content of the canvas and includes it fully, eliminating the need for scrolling. This ensures that all data points are visible and accessible, providing a complete and uninterrupted view of the raw data.

The analysis of the walking test begins with an overview of key variables: the average acceleration, gyroscope data, and the maximum gap in coordination across the X, Y, and Z axes. Each of these variables is treated individually, and a brief judgment is made based on how the values compare to the typical range for healthy individuals.

Acceleration

- X-axis acceleration represents the patient's basic movement speed. Elevated or reduced values in this axis may suggest abnormalities in walking speed, potentially indicating mobility issues.
- Y-axis acceleration reflects lateral movement, and Z-axis acceleration measures vertical movement. These two axes help assess the patient's balance and stability during the walking test, with deviations from normal values possibly indicating instability or difficulty maintaining equilibrium.

Gyroscope Data

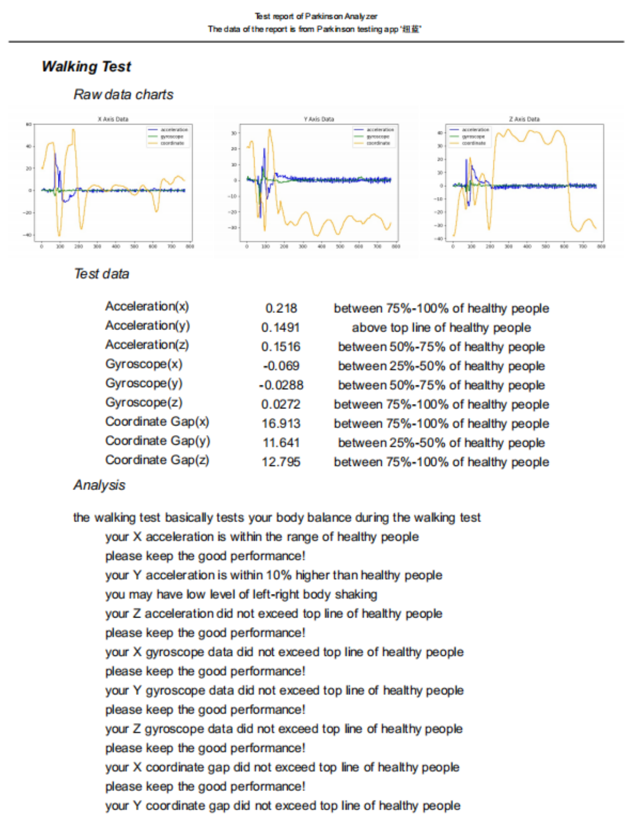
The gyroscope data measures the degree of deviation from the standard position, providing insight into the patient's ability to maintain balance and control in different directions. High gyroscope readings across any axis (X, Y, or Z) could suggest a lack of body control and potential instability during movement.

Coordination Gaps

The maximum gap in coordination for the X, Y, and Z axes measures the largest deviation in movement between consecutive data points. A large gap indicates erratic, rapid movements, which can suggest instability or difficulty in maintaining smooth motion. In contrast, a smaller gap implies better control and stability in movement.

For each variable, the analysis includes a comparison to the typical range observed in healthy individuals. A conclusion is drawn based on whether the patient's data falls within this normal range or suggests potential issues. If any of the treated data points exceed the standard range, it may indicate concerns regarding the patient's mobility or stability.

The results of this detailed analysis are presented clearly in the PDF report, with each variable's performance evaluated separately. The conclusions offer insights into the patient's overall mobility, stability, and coordination, helping to assess their control over body movements and their balance during the walking test. This approach ensures that the walking test data is thoroughly examined, with clear, actionable insights that can help in understanding the patient's physical health and movement capabilities.



Test report of Parkinson Analyzer

The data of the report is from Parkinson testing app "[illegible]"

Walking Test

Raw data charts

Test data

Acceleration(x)	0.218	between 75%-100% of healthy people
Acceleration(y)	0.1491	above top line of healthy people
Acceleration(z)	0.1516	between 50%-75% of healthy people
Gyroscope(x)	-0.069	between 25%-50% of healthy people
Gyroscope(y)	-0.0288	between 50%-75% of healthy people
Gyroscope(z)	0.0272	between 75%-100% of healthy people
Coordinate Gap(x)	16.913	between 75%-100% of healthy people
Coordinate Gap(y)	11.641	between 25%-50% of healthy people
Coordinate Gap(z)	12.795	between 75%-100% of healthy people

Analysis

the walking test basically tests your body balance during the walking test
your X acceleration is within the range of healthy people
please keep the good performance!
your Y acceleration is within 10% higher than healthy people
you may have low level of left-right body shaking
your Z acceleration did not exceed top line of healthy people
please keep the good performance!
your X gyroscope data did not exceed top line of healthy people
please keep the good performance!
your Y gyroscope data did not exceed top line of healthy people
please keep the good performance!
your Z gyroscope data did not exceed top line of healthy people
please keep the good performance!
your X coordinate gap did not exceed top line of healthy people
please keep the good performance!
your Y coordinate gap did not exceed top line of healthy people

Figure 6: template of test analysis with several variables

(4) Tremor test

In the Static Tremor and Postural Tremor tests sections of the PDF report, a consistent template is applied for both tests, similar to the one used for the Walking Test. The raw data charts from each test are included alongside nine processed variables, which are presented with rounded-up values and brief descriptions of the line placements.

Both tests involve a total of 18 variables (nine for each test), with separate analyses conducted for each. The X acceleration is specifically assessed for both tests, focusing on whether its value is excessively high or low. For the remaining variables, a standardized analysis template is employed, where values that do not exceed a predetermined upper threshold are considered within the normal range, indicating satisfactory performance.

X Acceleration Analysis

In both tremor tests, if the X acceleration value is found to be either too high or too low, a further categorization is performed based on the deviation's percentage from the normal range. The categories include:

- Within 10%: Minor deviation
- Between 10%-20%: Moderate deviation
- Between 20%-50%: Significant deviation
- Exceeding 50%: Severe deviation

This classification system helps to identify the severity of motor impairments, providing a clearer understanding of the patient's condition. It is crucial for assessing the extent of motor impairments and disease progression, particularly in the context of Parkinson's disease research.

Other Variables

For all other variables, the analysis begins with a brief introduction, followed by a comparison of the data to the expected ranges for healthy individuals. A concise conclusion is drawn for each variable, based on whether the measured values fall within the normal range or indicate potential concerns. This approach ensures that the results are consistently and systematically presented across both tests.

Test-Specific Focus

While the overall analysis structure remains consistent across both tests, the focus of each test varies based on the type of tremor being assessed:

- In the Postural Tremor Test, the patient is asked to maintain a straight-arm posture for a duration, allowing for an assessment of arm muscle control and overall stability during the test.
- In the Static Tremor Test, the patient sits with their elbow on the chair's armrest, providing a measurement of wrist control and stability.

Although both tests are relatively short (lasting approximately 45 seconds), they are designed to evaluate the patient's stability, which becomes increasingly challenging for individuals with Parkinson's disease. As a result, greater variability in the data is often observed, reflecting the difficulty in maintaining stability. These variations will be evident in the treated data and analyzed accordingly to highlight potential concerns with the patient's motor control.

This systematic approach to analysis ensures that the data from both tremor tests is thoroughly evaluated, offering valuable insights into the patient's ability to control their arm and wrist muscles, as well as their overall stability during dynamic movements. The consistent methodology and clear presentation in the PDF report help maintain a coherent and professional evaluation of each test result.

(5) Turning test

The turning test is similar to the walking test template, but it focuses specifically on assessing the patient's ability to maintain body stability during rotational movements.

In the turning test, a significant portion of the test is dedicated to the patient turning their body in a specified direction for given time intervals. This aspect allows for a detailed evaluation of the patient's competence in controlling their body stability when performing rotation actions. Unlike the walking test, which may assess stability during straight-line movement, the turning test specifically targets the challenges associated with rotational movements.

The template for presenting the turning test data follows the same structure as the walking test. Initially, the raw data charts are displayed. The test data consists of nine variables, with their rounded values presented accordingly. Notably, during the Python coding process for PDF printing, an interesting phenomenon occurs: while the first six variables are rounded to four decimal places, the last three are rounded to three decimal places. In certain cases, if a rounded value ends in "0," the printer intelligently omits the zero in the final printed result, as it does not affect the precision of the value. It is important to emphasize that this rounding adjustment is solely a visual modification in the PDF and does not impact the underlying analysis.

The analysis is conducted following the same template as the walking test. Each variable is examined to determine if it exceeds the established thresholds. Specifically, if any variable surpasses the top line or if the X acceleration falls outside the designated range (either above the top line or below the bottom line), a distinct conclusion is drawn regarding the patient's body stability during rotational movements. This focused analysis enables an accurate assessment of any impairments or deficiencies in the patient's ability to maintain stability while turning, which is critical for understanding their overall motor function and potential neurological or musculoskeletal issues.

In the overall design of the PDF, the decision to exclude a page footer was carefully evaluated and justified based on several important considerations.

Reasons for Excluding a Footer

(1) Layout and Spacing Disruptions:
   - Incorporating a footer would have disrupted the carefully planned layout and spacing of the content. A footer would require changes to font sizes, styles (such as bold or italic), and the positioning of all elements on each page. This would necessitate a meticulous review and adjustment of the entire content to ensure everything fits properly without compromising readability.
   - Since the PDF printing process relies on precise coordinates for text placement, adding a footer would have introduced the risk of overwriting and rearranging content on the page. Each subsequent page would need to be modified in a similar manner, making this process labor-intensive and inefficient.

(2) Redundancy of Footer Information:
   - The inclusion of a footer is unnecessary because most PDF viewing applications, such as WPS or web browsers, already display page numbers and the total page count. Thus, repeating this information in the footer would be redundant.
   - Furthermore, the app provides access to the designer's information through the "Help" button, eliminating the need to display this detail in the footer.

- **Comprehensive Analysis**

The comprehensive analysis, as expected, will present an overall evaluation of all five tests by utilizing the relevant variables from each test to conduct a thorough analysis.

In conducting the comprehensive analysis, the results from each of the five tests will be integrated. For each analysis section, the most pertinent variables will be selected, and a detailed examination will be performed based on the data from these chosen variables. This approach allows for a holistic evaluation of performance across all tests, enabling the identification of trends, patterns, or areas of concern that may arise.

(1) Precise Movements

The precise analysis of movement is crucial for assessing a patient's ability to control specific body parts. However, since the data is recorded via a phone, which captures an overall view of the tests rather than focusing on isolated movements (such as lower leg control), the analysis shifts to more accessible indicators of movement. These indicators allow for a broader understanding of the patient's motor abilities, even when finer details are not directly measurable with current technology.

Focusing on hand gestures and muscle control provides valuable insights into the patient's fine motor skills and coordination. Hand movements, especially finger control, involve intricate coordination between muscles and nerves. Analyzing these movements offers a clearer picture of the patient's motor control, serving as a reliable indicator of neurological function and potential impairments.

Focusing on hand gestures simplifies the analysis, as fewer muscles are involved compared to larger body parts like arms or legs. This allows for a more straightforward assessment of the patient's motor control capabilities.

To evaluate hand control accuracy, the strike data from the drawing test is analyzed. This data sheds light on the patient's ability to control hand movements and strike targets with precision. Additionally, the rhythm test assesses the patient's ability to consistently locate and click the same target point by evaluating the pixel count. In this test, the center of the circle remains stationary if the phone is correctly positioned. By analyzing this count, the system gauges the patient's precision and ability to maintain stability during repeated actions. This variable is a critical measure of the patient's motor coordination and fine motor skills over time.

For a comprehensive analysis, each variable is labeled according to the test it originates from, particularly for the last three tests involving X, Y, and Z data. This method ensures clear differentiation between variables, allowing for accurate evaluation of performance in each area.

After analyzing the data's placement within quartile divisions, conclusions are drawn about the patient's relative performance. This includes evaluating hand control accuracy, consistency in target location, and overall precision in movement, providing a well-rounded assessment of motor control abilities.

Finally, by synthesizing the analysis of selected variables, an overall conclusion is drawn regarding the patient's performance in movement control. This conclusion summarizes strengths and weaknesses in fine motor skills and coordination, offering valuable insights that can guide clinical decisions and treatment planning.

(2) Hand Movement

The reason for introducing the hand movement analysis separately from the precise movement analysis is that hand movement analysis focuses on the overall performance of hand control, whereas precise movement analysis is concerned with the detailed muscle control involved in finger movements.

In hand movement analysis, the entire range of motion of the hand is assessed to evaluate its overall ability to control movement. This differs from precise movement analysis, which emphasizes fine motor control of the fingers and the intricate muscle activity involved in finger movements. By distinguishing these two aspects, a more comprehensive understanding of hand function and performance can be achieved.

To assess hand movement, the count from the rhythm test is analyzed. This test involves frequent screen taps, and inconsistencies in tap placement may indicate instability or shaking of the hand. By measuring these movements, the stability and control of the hand during the task can be quantified.

Additionally, the static tremor test provides nine key variables that capture aspects of hand performance, including wrist movement. These variables offer valuable insights into hand function, helping to identify any abnormalities or deficiencies in hand control. Together, these data points provide a comprehensive picture of the patient's hand motor abilities.

It is important to note that there may be similarities between the comprehensive analysis and the test analysis, as the tests within the "Newlan" app were designed to evaluate the performance of specific body parts. As a result, some variables may be utilized in both analyses, potentially overlapping or being identical.

However, there are key distinctions between the two types of analysis. The comprehensive analysis not only offers detailed information on the specific application of each variable but also considers broader body control aspects. Unlike the test analysis, which focuses more on Parkinson's Disease features, the comprehensive analysis evaluates the relative performance of different body parts.

Therefore, sections of the comprehensive analysis integrate variables from multiple tests, allowing for a more holistic evaluation of body function and control. This approach goes beyond isolated assessments, offering a deeper understanding of how different body parts interact and contribute to overall performance. By combining data from various tests, the analysis uncovers patterns and relationships between different aspects of motor function that might otherwise remain undetected.

(3) Arm Movement

Arm movement analysis is conducted using data from the postural tremor test, as it provides a broader range of values compared to the static tremor test. The postural tremor test evaluates arm stability while holding the phone in a dynamic environment, allowing for greater differentiation among quartile divisions. This dynamic assessment is particularly effective at detecting subtle variations in arm movement, making it a more suitable method for evaluating arm stability and control.

In the comprehensive analysis, the nine variables collected from the postural tremor test are used to assess arm movement across three directions: forward-backward, left-right, and up-down. By examining data from these three axes, a more detailed and multidimensional understanding of arm stability is achieved. This multi-directional approach ensures that the assessment is thorough, capturing variations in movement that might otherwise be overlooked if only one direction were considered.

To assess whether arm movement falls within an acceptable range, the nine variables from the postural tremor test are compared against the corresponding data quartiles for healthy individuals. If none of the variables exceed the top line of the quartile, the arm movement is deemed to be within the acceptable range, and a conclusion of good performance is provided. This method follows the same reasoning applied in the hand movement analysis, ensuring consistency across tests.

It is also important to note that, since the patient is instructed to remain still during both the postural and static tremor tests, instances where the X acceleration is lower than the bottom line of the quartile are not considered. In these cases, the arm is regarded as having "very stable control" because no intentional movement or gestures are being performed, which aligns with the expected behavior during a static test. This consideration helps refine the analysis by accounting for the test conditions and the patient's expected behavior during the assessment.

(4) Leg Movement

For leg movement analysis, the focus is placed exclusively on the acceleration data, which is compared between the walking and turning tests. This approach is based on the fact that acceleration data offers the most direct insight into leg movement control.

The rationale for using only acceleration data lies in the fact that it is predominantly influenced by leg movements, whereas gyroscope and gap data reflect broader body motion and balance, rather than the specific movement of the legs. Acceleration data directly measures changes in velocity during movement, making it the most relevant variable for assessing leg movement. While gyroscope and gap data are valuable for broader assessments of body control and stability, they have a lesser role in analyzing leg-specific motion. This focused approach ensures a clearer and more precise evaluation of leg movement performance.

To conduct a thorough leg movement analysis, the acceleration data from both the walking and turning tests are utilized, providing six variables in total (X, Y, and Z components for each test). This allows for a direct comparison between the patient's performance in straight walking and turning ability, two crucial aspects of leg control.

By comparing the same variable across the two tests (e.g., X acceleration), discrepancies can be identified, pointing to specific areas of concern. For example, if the patient performs well in X acceleration during the walking test but shows difficulties in the turning test, it may indicate issues with knee function. Turning requires more complex coordination and joint movement, particularly in the knees, and any discrepancies in performance signal a need for further evaluation of the patient's knee health and mobility. This targeted analysis is essential for identifying weaknesses in leg control, which can guide further examinations or interventions.

(5) Body Balance

In the analysis of body balance, 12 variables from both the walking and turning tests are utilized, offering a comprehensive understanding of body control.

Before applying the standard template for comprehensive analysis, the combination of these 12 variables provides valuable insights into the patient's performance. By comparing the same types of variables between the two tests, consistency can be assessed, and any significant differences can be identified. Additionally, evaluating the six variables from each test individually allows for a more focused analysis of performance in each specific test, further enhancing the understanding of the patient's overall body balance.

This focused approach helps identify areas where balance control may need improvement, informing further evaluation or intervention. By combining the data from both tests, a more well-rounded understanding of the patient's body balance and stability across different types of movement is achieved.

A particularly insightful combination arises from analyzing gyroscope data and gap data. While both reflect overall body balance control, they offer distinct perspectives. Gyroscope data provides a more detailed view by directly showing the deviation of the phone, which corresponds to the deviation of the entire body. Since people typically keep their arms straight while holding something while walking, any significant difference in gyroscope data compared to the patient's "normal value" suggests issues with body stability. This difference is transmitted through the arm to the hand and recorded by the phone.

In contrast, gap data represents the combination of several body movements and can be seen as an "overall performance" indicator. Unlike gyroscope data, which is typically compared to the last data point or group, gap data is collected across multiple data groups within a second and reflects the overall deviation in the X, Y, and Z directions. While gyroscope data highlights the "tendency of movement," gap data provides a snapshot of the "overall performance of movement."

4 Fault-Checking

Fault-checking is a critical component in ensuring that the app functions smoothly and delivers accurate results without errors or unexpected behavior. The goal of fault-checking is to identify and resolve potential issues that may cause the app to malfunction, disrupt operations, or provide inaccurate results. This process involves verifying the app's logic, functionality, and data flow to ensure that each part operates as expected.

First, when the application involves opening files or folders, it is important to consider how the app should respond when users cancel the file or folder selection process. Normally, users are expected to open a file or folder and proceed with subsequent actions within the app. However, the responsibility for selecting the correct file and ensuring the file format is suitable falls on the user, not the app.

When users open files or folders, the operating system typically presents a dialog window for file or folder selection or cancellation. If the user cancels the selection, the process is aborted, and the app needs to handle this appropriately. For instance, if the user selects the 'import user info' function but cancels the file selection dialog, the app should refrain from performing any import-related actions, as no file was selected. In this case, no further action is needed from the app's perspective.

However, if canceling a file or folder selection affects other parts of the application, such as enabling or disabling buttons, the app must manage these changes manually. For example, if clicking an import button enables other buttons for further actions, canceling the import process should disable those buttons again. Since button enabling is typically handled during the UI design phase, the app should include code to manually disable the buttons when the import process is canceled.

The second scenario involves situations where only a subset of the five tests is available for analysis. This may occur if the patient experiences emergencies, has other commitments, or simply chooses not to take certain tests. As a result, the data files may contain only three or four test types instead of the full set of five.

When certain test data are missing, the system verifies the availability of each test type. If specific data are absent, an informational box is displayed to notify the user. As each test analysis operates independently, missing data from one test will not affect the analysis of other tests. In the test results, missing test data are marked as "not taken," and any judgment or conclusions relying on the missing data are adjusted to reflect the incomplete dataset, ensuring the analysis remains accurate and relevant.

The third scenario involves the PDF generation component of the app, specifically the substitution forms used for printing. The code for this feature is divided into two parts, separated by a conditional "if" statement, ensuring that the app continues to function smoothly even if conditions differ from those used in previous functions.

For example, in the test result section, if a patient did not take a particular test or did not click the analyze button for that test, the corresponding analysis content will be left blank. However, the titles for the relevant sections will still be displayed, indicating that the section is intended for a specific test, even though no analysis was performed.

Similarly, in the comprehensive analysis section, if a test was not analyzed (either because the patient did not take the test or did not click the analyze button), a substitute message will appear, such as "You didn't analyze the drawing test" or "No strike data for the drawing test was collected for analysis."

These conditional checks and substitute messages ensure that the app can continue to generate results, even if the user only utilizes a portion of the available functions, without displaying errors. By incorporating these safeguards, the app maintains usability and provides clear feedback to the user, even when not all tests were taken or analyzed.

5 Test and Trials

5.1 Test Types

For the software, accessibility has been tested in the following aspects:

(1) The reliability of the button enabling and disabling functionality is crucial to ensuring a seamless flow of actions within the software. In the application design, button-enabling functions are strategically implemented to guide users through the correct sequence of tasks. For example, the data analysis function becomes available only after the user selects a valid folder containing the necessary data and correctly formatted CSV files.
During testing, it was confirmed that buttons are enabled only after a valid folder is selected. If the user clicks "cancel" during the folder selection process, the corresponding buttons remain disabled. This behavior ensures that only valid actions can be taken at each stage. If an empty or invalid folder is selected, the system correctly disables the relevant buttons, maintaining the integrity of the application's workflow and preventing users from proceeding with incomplete or incorrect inputs. This functionality plays a key role in the overall reliability and usability of the software.

(2) The bar and line drawing features of the analysis functions, along with the graph clearing mechanism, are integral to ensuring accurate and up-to-date visualization of test results. When the correct folder is selected, the application analyzes

each test, assuming the CSV files are correctly located and the necessary lists and variables are in place for analysis.

During testing, it was confirmed that clicking the "analyze" buttons successfully displayed the corresponding results on the relevant canvases. Additionally, when switching to a different folder and re-clicking the "analyze" button, the canvas is updated to reflect the new results from the selected folder's data. This behavior was verified after the activation of the "clear graph" button, ensuring that previous data was removed from the canvas before new results were displayed.

The functionality of the "clear graph" button was thoroughly tested to ensure it effectively removed all graphs from the canvas, even when sliding bars or other graphical elements were present. It was observed that as new data was analyzed, the sliding bars were appropriately adjusted to the canvas size, maintaining accurate visualization of updated results without any graphical discrepancies or layout issues. This testing confirmed that the canvas and related components functioned as intended, providing a smooth and accurate display of analytical results.

Through extensive testing of the line drawing and graph clearing features, it has been confirmed that the application can handle multiple data sets and provide accurate, real-time visual representations of test results. The ability to clear graphs and update canvases with new data is essential for maintaining the application's usability and ensuring that users can confidently analyze and interpret the results of various tests.

(3) The export button in the application is designed to streamline the generation of PDF reports. During testing, the process was thoroughly evaluated to ensure that, when the data is accurate, the corresponding sections in the PDF analysis are generated smoothly upon clicking the "export" button. Any issues identified during the initial testing phase were addressed by making necessary code corrections, ensuring that the exported PDF consistently reflected the correct data and formatted results. This functionality was confirmed to work seamlessly, providing users with accurate and well-organized reports based on the analyzed data.

Due to the extensive number of lines of code involved, multiple trials may be required to fully verify that the judgment codes align with the corresponding data quartiles and variable names. This comprehensive testing is essential to ensure that the export process is reliable and that the resulting PDF analysis accurately reflects the data being analyzed.

(4) The import button in the application is designed to efficiently handle data when the app is used continuously. For typical use cases, such as when a patient uses the app, they simply need to select the folder containing their collected data, perform the analysis, and generate a PDF report if needed.

However, for testers and professionals, such as doctors reviewing results for multiple patients, the app must be capable of handling data from different patient folders seamlessly. It is crucial to ensure that the data preprocessing step is smooth and that previously used data does not influence subsequent analyses or report generation.

To address this, a reset variable function was implemented. This function is triggered each time the import button is clicked, ensuring that all relevant variables are reset to their initial state whenever a new folder is imported. After the reset, the data processing step assigns the appropriate values from the selected folder's data to the variables. This ensures that subsequent functions operate correctly, and that the analysis reflects only the data from the newly imported folder. This mechanism maintains consistency and accuracy throughout the data analysis process.

This approach is effective because, after resetting the variables, their initial values mirror those when the folder is first imported. This ensures that later functions are not influenced by previous data, preserving the integrity and accuracy of the analysis. By incorporating this reset mechanism, the app can efficiently handle multiple patient data sets, meeting the needs of both patients and professionals.

This process also underscores the significance of code reusability in software development. Code reusability involves leveraging pre-existing code in new applications, ideally making it adaptable for new projects. However, it is essential to ensure that reused code is appropriate and well-suited to the requirements of the new software [17]. In the context of this app, the reset variable function facilitates handling multiple data imports by resetting relevant variables each time the folder path changes. Since all analysis and report generation depend on the import action, this function meets the app's needs without unnecessary complexity.

5.2 Test Results

Several individuals were invited to test the functionality and performance of the Parkinson Analyzer app by providing them with the executable file (EXE) and the associated patient data files. To assess the continuity and reliability of the app, each participant received two folders containing patient data. This methodology enabled the testers to compare the differences between datasets after generating the corresponding analysis reports, ensuring that the app's data analysis and report generation functions were operating as intended. The patient data used for testing included records from patients 1, 2, 5, 8, and 17, which were randomly selected from a total of 56 available patient datasets.

Based on the feedback received from the testers, several key aspects were identified:

(1) Slow open speed

While the app operates smoothly when using the buttons to execute the designed functions, there is a slight delay of approximately 3 seconds when opening the app and displaying the main window. Although this delay is brief, it may feel longer when contrasted with the rapid response times typically expected from modern computing systems. A single-thread design was implemented for tasks such as data analysis and PDF generation, as these tasks were not anticipated to require multi-threading. Despite this, the app generally completes execution within 1 second, except for the tremor test, which experiences a 1-2 second delay due to the analysis of two data files. The startup delay is primarily attributed to the loading of Python libraries and components related to image creation and PDF generation, which are relatively large. This performance issue is something that will be addressed in future updates to enhance the overall speed and responsiveness of the application.

(2) Plain User Interface

In the development process of the app, the primary focus was placed on designing its core functionalities and ensuring the seamless connectivity and interoperability of the various components. For the user interface (UI) design, Qt Designer was employed, leveraging its integration with the Python library to provide the essential elements needed for constructing the app's interface. Given the emphasis on functionality, considerable time was not devoted to enhancing the visual aspects of the UI. As a result, the design remains simple, effectively displaying the app's functions without extensive visual embellishments.

In comparison to websites featuring dynamic backgrounds and sophisticated artistic designs, the app's interface may appear relatively minimalist and less visually striking. However, it successfully presents the essential features and functionalities. Should the opportunity arise to collaborate with professionals specializing in UI design, further refinement of the interface could be pursued, aiming to enhance its aesthetic appeal and user engagement while maintaining the app's core functionalities.

(3) Satisfying Function Processing

The performance of the app's functions has proven to be highly satisfactory. Extensive code reviews were conducted to ensure that all functions operated correctly and efficiently. Throughout the development process, significant attention was given to anticipating a wide variety of user scenarios, and fault-checking mechanisms were incorporated to ensure the accuracy of results and smooth operation during execution.

In comparison to other applications, websites, and software available, the reaction speed of this app is competitive, with performance that is either on par with or exceeds that of many others in the same category. Overall, the app's performance is considered to be highly effective in meeting user needs, and I am confident that it provides a reliable and efficient solution.

(4) Restriction of Executable Environment

One of the testers reported attempting to access the Parkinson Analyzer app on both Windows and macOS systems. However, it was necessary to inform the tester that the app is currently only compatible with Windows operating systems. This limitation arises from the use of "PyInstaller," a Python tool utilized in the creation of executable files for the app. PyInstaller is specifically designed to generate EXE files, which are only executable on Windows platforms. As a result, generating an executable version of the app compatible with other operating systems, such as macOS, is not currently feasible. This issue is recognized as an area for improvement, and addressing cross-platform compatibility is a priority for future iterations of the app.

6 Discussions and Future Works

6.1 Comparison with Relevant Works

Instead of limiting the focus to an app dedicated solely to data analysis and report generation, relevant research has been identified that examines the use of deep learning algorithms to enhance the understanding and diagnosis of Parkinson's Disease. As explored in one such study, the authors employ advanced computational techniques, specifically deep learning algorithms, to analyze patient data related to Parkinson's Disease.[18] This data-driven approach aims to improve diagnostic accuracy, refine treatment strategies, and advance the understanding of disease progression. The research highlights the critical role that data analysis plays in neurodegenerative disease research, particularly in the development of personalized treatment plans and the enhancement of early detection methods.

The researchers investigated the Unified Parkinson's Disease Rating Scale (UPDRS), an established standard for evaluating the severity of Parkinson's Disease (PD). By incorporating machine learning and neural network models, they performed pattern recognition and predictive analyses on positron emission tomography (PET) images. Through the comparison of various features and factors, their study provided valuable insights into how PD impacts brain function and structure.

To elaborate, the UPDRS is a widely used tool in the medical community for evaluating the progression of PD symptoms. In this study, the researchers leveraged advanced computational techniques, specifically machine learning and neural networks, to analyze PET images of patients with PD. By carefully examining the features and factors within these images, they were able to identify patterns and make predictions about how the disease impacts the brain. This comprehensive approach allowed them to gain valuable insights into the neural mechanisms underlying PD, which could ultimately contribute to improved diagnosis, treatment, and management of the disease.[19]

In the aforementioned study, the researchers employed volumetric segmentation to analyze brain imaging data, specifically targeting regions such as the substantia nigra and striatum, which are integral to dopamine synthesis and regulation [20]. This approach enabled a more accurate understanding of the structural and functional changes associated with Parkinson's Disease. Volumetric segmentation involves quantifying the size and morphology of relevant brain regions, thus facilitating the assessment of neurodegeneration [21]. Neurodegeneration is a critical factor in evaluating PD, as temporal changes in volumetric measurements can provide insights into disease progression and the effectiveness of therapeutic interventions.

For data analysis, several preprocessing steps were conducted, including noise reduction, alignment, and normalization of the imaging data. To isolate and quantify specific brain structures, the researchers employed advanced software tools such as FreeSurfer and Statistical Parametric Mapping (SPM), alongside manual delineation techniques. Convolutional neural networks (CNNs) were also utilized for segmentation and analysis. By integrating these methodologies with Unified Parkinson's Disease Rating Scale (UPDRS) data, the various feature variables helped reveal distinct characteristics within the analyzed images. This comprehensive approach not only facilitated the identification of potential disease pathways but also provided a foundation for exploring therapeutic solutions for Parkinson's Disease.

6.2 Future Developments

For the upcoming design updates to the app, several key aspects are planned for modification to enhance overall functionality and user experience:

- To further enhance the functionality of the application, it is proposed to incorporate additional features into the menu bar, without modifying the existing ones. In particular, considering the potential use of this app in medical environments such as hospitals, where healthcare professionals like nurses and doctors are responsible for generating patient reports and reviewing patient performance, adding a file management feature would be highly beneficial. This feature would simplify the handling of patient data files, enabling users to easily organize, access, and save reports. By streamlining data handling, the application would better support healthcare providers in managing large volumes of patient data while ensuring accuracy and accessibility in the report generation process. This addition would improve workflow efficiency, allowing medical professionals to focus on data analysis and interpretation rather than manual file storage management.
  The feature could allow users to download files from a designated source, such as a hospital website where "Newlan" app data files are collected. It could be designed to allow users to select specific files, like those generated on a particular day, and automatically rename and save them into a designated folder. While the initial idea of implementing a direct download feature from the AWS server was considered, it was ultimately deemed impractical due to access restrictions and login constraints on the server. Moreover, the existing manual download practice made the direct server download feature redundant. However, the development of an effective file management system remains a crucial enhancement to the app's usability and efficiency, especially in hospital settings.
  It is important to note that the features to be added should be informed by feedback collected once the app is in use. After gathering insights and suggestions from users, further adjustments can be made to ensure the system meets their needs effectively. This user-driven approach will help streamline workflows and improve the overall performance of the application.
- Secondly, integrating generative AI into the analysis report process could greatly enhance both its efficiency and effectiveness. By leveraging the capabilities of generative AI, the report generation can be automated while maintaining adherence to the established template. Instead of relying on

predefined conclusions, the AI could be supplied with specific data insights and judgments, enabling it to generate tailored conclusions that emphasize the unique aspects of each analysis.[22]

To implement this, relevant data judgments could be manually input into a PDF file, allowing the AI to learn from this information. The AI could then focus on generating conclusions for 'abnormal' data—those that deviate from the healthy range—while also acknowledging the well-performing data.[23] This targeted approach ensures that the report is not only comprehensive but also highlights areas requiring attention, making the analysis more focused, impactful, and clinically relevant.

Additionally, generative AI's ability to rapidly search and compare information can be harnessed to incorporate the latest research findings on Parkinson's Disease into the report. This would enrich the report with additional context, helping users understand their situation better by including visual aids such as images and graphs alongside the test results.[24]

By integrating generative AI into the report generation process, the reports will be consistent with the established template while being customized to meet the specific needs of each analysis. This customization allows the AI to adapt its conclusions based on the unique data insights, ensuring that each report is relevant and targeted. Ultimately, this approach will enhance the overall quality and impact of the analysis reports, providing more precise and actionable insights for medical professionals.

- Thirdly,it is important to consider expanding the app's focus to include non-motor symptoms alongside the currently included motor symptoms. The "Newlan" app already incorporates tests for non-motor functions, such as pronunciation and intonation of sounds, memory tests involving the identification of blocks with different symbols, and other cognitive assessments. These tests provide valuable information on various aspects of brain function, including reaction speed, memory, recognition of pictures, pronunciation, and more.

  By analyzing both motor and non-motor symptoms in tandem, a more holistic understanding of the patient's overall condition can be achieved. For instance, in the drawing test, the analysis could extend beyond merely counting strikes to include an examination of the individual drawing actions, muscle reactions, and any errors or omissions made during the process. Such an approach would provide valuable insights into the patient's cognitive and motor coordination abilities, as well as their comprehension of the task.

  However, it is important to note that analyzing non-motor symptoms requires expertise in fields such as computer graphics and machine learning, which I am still in the process of mastering. Computer graphics are essential for visualizing the patient's cognitive and motor responses in a clear and interpretable manner.[25] Machine learning can help identify patterns and predict outcomes from large datasets.[26] These methods, including using decision trees for analyzing patterns, would enable a more detailed evaluation of cognitive functions.[27] The complexity of non-motor symptoms means that these advanced techniques require time and further development. As such, this feature is not included in the current version of the app but will be explored in the future as I gain the necessary skills.

  Moreover, integrating questionnaire data into the app could significantly enhance the ability to track the patient's condition over time. Monitoring changes in symptoms, medication usage, and dosages would allow for a deeper understanding of the disease's progression and the efficacy of treatment. This longitudinal data could play a critical role in informing adjustments to the patient's treatment plan, ultimately improving their overall quality of life.

7 Conclusion

In conclusion, Parkinson's Disease (PD) is a prevalent and serious brain disorder that poses significant challenges for both patients and healthcare providers. Its high rate of misdiagnosis, lack of a definitive cure, and progressive impact on brain structure and daily life make it a condition that demands our attention.

To address the challenges faced in monitoring Parkinson's Disease, our lab developed the "Newlan" app, which offers a platform for PD patients to perform tests and complete questionnaires, assisting them in tracking their condition and providing valuable insights for medical consultations. However, recognizing the need for a more in-depth analysis of the collected data, I took the initiative to design and develop the Parkinson Analyzer app.

The Parkinson Analyzer app has been developed to facilitate the analysis of motor symptom data collected via the "Newlan" app. This project encompasses the application's conceptualization, structural design, functional implementation, and iterative testing and refinement. The primary aim of the Parkinson Analyzer app is to provide patients and healthcare professionals with enhanced insights into the progression of Parkinson's Disease and its effects on motor function. By offering a comprehensive analysis, the app seeks to support improved patient care and contribute to better clinical outcomes.

The app primarily consists of four main sections.

- First, the menu bar will hold basic functions or features that are not directly related to the core functionality of the app, which focuses on data analysis and report generation.
- Second, the user information section will store the patient's details, which can be entered manually or imported using the function in the menu bar. This information, along with the selected patient picture, will also be displayed in the generated report.
- Third, the analysis and graph area marks the beginning of the core analysis and report generation process. Five individual test buttons are linked to five tab canvases, with each canvas displaying the basic analysis results to help the user understand the variables. The tabs are uniquely designed to present the content specific to each corresponding test. Additionally, buttons below the tab area allow users to clear the canvases or export the analysis report.

  The analysis report consists of three main sections: User Information, Test Result Analysis, and Comprehensive Analysis. Each section follows its template, and the content displayed will vary based on the analysis results.
- Lastly, the Knowledge Learning section. This part is straightforward: a combo box allows users to select the aspect of Parkinson's Disease they are interested in. By clicking the button on the right, the corresponding website will open, providing further information on the chosen topic.

In addition to focusing on the app's functional capabilities, significant emphasis was placed on ensuring its overall stability and reliability. A fault-checking mechanism was incorporated to allow the app to maintain seamless functionality, even in instances of incorrect user interactions. This feature is critical for preventing crashes and ensuring a smooth user experience, thereby enhancing the app's usability and dependability.

Feedback was solicited from several friends to evaluate the app's strengths and weaknesses. Their insights, combined with a review of pertinent literature in the field, were essential in identifying areas for improvement and potential future developments. As the first iteration of the Parkinson Analyzer app, it is recognized that substantial opportunities exist for further refinement and enhancement.

The overarching goal extends beyond merely improving the Parkinson Analyzer app; there is also a desire to contribute to the broader development of the "Newlan" app. By integrating the analyzer as a central component of the larger platform, a more comprehensive and effective tool can be provided for the management and understanding of Parkinson's Disease, thus advancing both patient care and research efforts.

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9 SW Narrative

9.1 Class Contribution

Three classes played a significant role in the development of the Parkinson Analyzer app:

(1) STATS 202: Modeling and Predicting.
This course offers a comprehensive overview of fundamental strategies for data treatment. By contrasting the characteristics of available data with the specific requirements for subsequent application usage, the appropriate data treatment methods for distinct datasets can be determined. For example, during the data treatment process involving data from healthy individuals and the creation of template data sections, customized approaches were employed for each test.
The selection of treatment methods is contingent upon the intended use of each variable. Notably, the treatment of variables may vary not only across different data files but also within the same file, depending on the indicators associated with those variables.
The preparation of data for healthy individuals was performed manually, without relying on the app's coding for decision-making. This manual approach to data preparation also influenced the methodology for treating and comparing patient data. Consequently, the preprocessing of healthy individuals' data directly impacted the subsequent treatment and comparison of patient data.

(2) COMPSCI 306: Intro to Operating Systems
This course has provided the foundational principles for application development and system design. Although the focus of the work is on the creation of a computer application rather than an operating system, the underlying concepts are still relevant to the app design process. One such concept is the development of a closed-loop system, which ensures overall functionality and logical coherence throughout the application.
In the context of the Parkinson Analyzer app, which complements the Parkinson's Disease testing process by addressing the analysis gap present in the Newlan app, it operates as a self-contained system. Users can gain insights into their test results and acquire related knowledge through the app, ultimately aiding them in improving their physical condition. Consequently, these improvements are reflected in subsequent test data and analysis reports.
Furthermore, the function logic that guarantees system operation through the utilization of various supporting measurements has also informed the design of a fault-checking mechanism within the app. This feature has been incorporated to address instances where users may not adhere to the user manual's instructions. The fault-checking component ensures that the system, or the app as a whole, continues to function even in the event of function misuse, thereby preventing the app from becoming stuck or failing to load.

(3) COMPSCI 308: Design & Analysis of Algorithms
This class has provided valuable insights into the essential features to consider when designing algorithms, with a focus on analyzing their characteristics. Despite the emphasis on mathematical algorithms during the course, these principles

have been extremely beneficial in the design process of the Parkinson Analyzer app. Given that the app is function-driven or content-driven, it is crucial to ensure the proper functioning of each function and the seamless connections between them. Each function within the app can be conceptualized as a visualization of the underlying algorithms, with the overall performance of the app representing a comprehensive algorithm that governs the individual algorithms associated with its components. For example, signal-slot functions were employed in the app's design to ensure that specific functions update multiple parts of the main window upon activation. Furthermore, the report generation process depends on the editing status of previous sections, highlighting the interdependence of the app's components.

The efficiency and speed of algorithms are crucial in the design and functionality of the app. For instance, during the report generation process, rather than loading user information at the time of report creation, the current information displayed in the main window was utilized. Raw data charts were directly incorporated into the report, ensuring a more streamlined, efficient process. This approach not only enhances convenience but also contributes to a faster response time, ultimately improving the overall user experience and satisfaction.

9.2 Capstone Contribution

The capstone classes provided a structured framework for managing the development of the signature project. Each week was meticulously planned, allowing for the efficient allocation of time to other concurrently required courses, while maintaining focus on the completion of the project. This organizational strategy proved essential in ensuring consistent progress and adherence to deadlines.

Interactions with the mentor were conducted with flexibility, as opposed to a fixed weekly meeting schedule. The mentor's trust in the independence of the project allowed for communication on an as-needed basis, particularly when multiple questions arose. To maintain transparency, detailed documentation of weekly accomplishments was prepared, and notes were taken throughout the process of creating and refining the app's code and templates.

The informal and supportive atmosphere during these discussions, coupled with the recognition received from the mentor, significantly reduced the anxiety typically associated with the development of a signature project. This nurturing environment fostered personal growth, enhancing both competence and confidence in the successful completion of the project.