GAIT ANALYSIS TO PREDICT NEURODEGENERATIVE DISORDER

Submitted in partial fulfillment of the requirements
Of the degree of

B. E. Information Technology

By

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2017-2018

CERTIFICATE

This is to certify that the project entitled **"GAIT ANALYSIS TO PREDICT NEURODEGENERATIVE DISORDER"** is a bonafide work of **"Rishi Joshi" (60003140023), "Vighnesh Misal" (60003140028), "Nahush Raichura" (60003140034)** submitted to the University of Mumbai in partial fulfillment of the requirement for the award of the degree of B.E. in Information Technology

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Project Report Approval for B.E.

This project report entitled **GAIT ANALYSIS TO PREDICT NEURODEGENERATIVE DISORDER**by **Rishi Joshi, Vighnesh Misal and Nahush Raichura** approved for the degree of Information Technology.

Examiners

1. ______________________________

2. ______________________________

Date:

Place:

Declaration

I declare that this written submission represents my/our ideas in my/our own words and where others' ideas or words have been included, I have adequately cited and referenced the original sources. I also declare that I have adhered to all principles of academic honesty and integrity and have not misrepresented or fabricated or falsified any idea/data/fact/source in my/our submission. I understand that any violation of the above will be cause for disciplinary action by the Institute and can also evoke penal action from the sources which have thus not been properly cited or from whom proper permission has not been taken when needed.

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ACKNOWLEDGEMENT

We thank the management of Dwarkadas J. Sanghvi College of Engineering and our Principal Dr. Hari Vasudevan for providing us with all facilities needed to complete the project.

We would like to convey our heartfelt gratitude to our Head of Department Prof. Neepa Shah, our project guide Prof. PurvaRaut for inspiring us to take up this project. Their valuable guidance, without which, we would have never been able to complete the project, cannot be forgotten.

Finally, we would like to express our gratitude for the faculty members of Information Technology Department of Dwarkadas J. Sanghvi College of Engineering and thank them for their co-operation and timely guidance.

We also thank all our teaching and non-teaching staff of Information Technology Department of Dwarkadas J. Sanghvi College of Engineering for their direct or indirect help in our project work.

Rishi Joshi, Vighnesh Misal, Nahush Raichura
Dwarkadas J. Sanghvi College of Engineering

1. ABSTRACT

The use of smartphones in clinical practice is steadily increasing with the availability of low cost/freely available "apps" that could be used to assess human gait. The primary aim of this manuscript is to test the concurrent validity of kinematic measures recorded by a smartphone application in comparison to a 3D motion capture system in the sagittal plane. Smartphones are equipped with a range of sensors that enable them to gather information about the world around them. Among these sensors are accelerometers and gyroscopes, which measure acceleration and rotation, such as that generated by a person's gait, or walking pattern. A smartphone, from its usual position in your pocket, is well placed to capture this information. The objective of the current study is to design and develop the alternative technology that can potentially predict health status and reduce health care cost. This study uses a smartphone as a wireless accelerometer for quantifying human motion characteristics from four steps of the system design and development (data acquisition operation, feature extraction algorithm, classifier design, and decision making strategy). Findings indicate that it is possible to extract features from a smartphone's accelerometer using a peak detection algorithm. Once the gait parameters have been extracted, the system will compare them with the predefined dataset for various diseases. Once a match in the database has been found, a report will be generated outlining the disease type, the severity or the stage in which the patient currently. If the dataset were to remain unmatched with any disease as well as with the normal human gait graph, then the patient will be placed under monitoring for a month to collect more data about the disease afflicting him and measure the deterioration in his health. All the patient health records will be maintained in the database to monitor patient health.

Table of Contents

1. INTRODUCTION

Traditional GAIT analysis involves doctors using their observation to try to deduce any abnormalities in a person's movement. Abnormal movement may involve a hunch when walking, stooping more on a particular side and placing more weight on a particular leg, aberrant step size etc. This method has one glaring disadvantage- subtle changes in a person's GAIT can be missed as human observation isn't meticulous when it comes to pointing out extremely subtle and miniscule changes in our environment. With the advent of electronic sensors, this problem has been mitigated to a certain extent as accuracy has been vastly improved.This has opened up new avenues in the field of GAIT analysis. Observations in the field of medicine that combines technology with the traditional approach on neurodegenerative disorders has given rise to some remarkable postulates. The onset of these neurodegenerative disorders like Parkinson's, Alzheimer's, Huntington's etc produce subtle changes in a person's GAIT before the full blown symptoms start to develop.These aberrations can be observed by plotting GAIT graphs derived from GAIT parameters. So standard GAIT graphs for diseases and their various stages of propagation became available. What this essentially means is that it is possible to detect the early onset of neurodegenerative disorders and take action in order to palliate their severity by starting physiotherapy early.

1.1. Problem Formulation

The current technology to achieve these results is expensive and highly rigid as it involves placing multiple sensors on a person's body to record the GAIT parameters. The person also moves in a certain way to achieve this. We have come up with a solution involving smart-phones that will provide a flexible alternative to this approach. We shall use processing techniques to remove the noise that occurs when a person moves in a way that isn't predefined. Apart from flexibility our solution is also a lot cheaper as we shall be using commodity hardware. A smartphone that costs INR 15k has sensors that are accurate enough for our analysis.

1.2. Scope of the project

- Objective of the project
    - Identify and predict the onset of neurodegenerative disorders in humans

- Make proper decisions in accordance to accepted standards and based on the various conditions

- Make use of cheap, commodity hardware.
- Build a patient database for monitoring the deterioration in their health and generate reports. These reports will be used by doctors to suggest treatment

- The future scope of the proposed solution is that we can scale up the project in order to incorporate even more diseases and also help identify unidentified diseases.

2. LITERATURE REVIEW: EXISTING SYSTEMS

2.1 (A) THE USE OF SMARTPHONE FOR GAIT ANALYSIS

Authors: Nantakrit Yodpijit, Manutchanok Jongprasithporn, Nicha Tavichaiyuth,Chalida Songwongamarit, Teppakorn Sittiwanchai

Existing Systems are based on a complicated wired network and system design which is very costly. This System demonstrates use of Smartphone in Gait Analysis. Accelerometer within Smartphone is a motion sensor that can be used to detect human movements. Compared to other major vital signs, gait characteristics represent general health status, and can be determined using smart phones. The objective of the current study is to design and develop the alternative technology that can potentially predict health status and reduce health care cost. This study uses a Smartphone as a wireless accelerometer for quantifying human motion characteristics from four steps of the system design and development (data acquisition operation, feature extraction algorithm, classifier design, and decision making strategy).

a). Data Acquisition

In this study, Smartphone is used for the gait analysis which has a built-in accelerometer with a measurement range of +/-8g. Acceleration data were collected using Smartphone's built-in accelerometer which is vertically fixed at the joint of the user. This position is suitable for the Smartphone's accelerometer to detect gait events in three dimensional directions (X:Horizontal, Y: vertical, Z: transverse).

b). Feature Extraction

Feature extraction is the process of defining characteristics that will be used for the analysis in the next process. First, high frequency noise above the cut-off frequency is eliminated using low-pass filter. Afterwards, the peak of magnitude is detected.

c).Classifier design

Classifier design is the essential stage of the system. Gait parameters (i.e., stride time, stance time, swing time, and cadence) can be extracted from gait peaks that have been calculated in this stage

4).Decision Making

This stage is to define the particular threshold values that separate the results by means of decision rules. In gait analysis, gait parameters in young healthy adults are defined to be criterion for testing normal and abnormal gait patterns.

2.1(B) A WIRELESS SENSOR NETWORK FOR BIOMECHANICAL ANALYSIS OF GAIT

Authors: F. A. O. Mota, V. H. M. Biajo, H. O. Mota and F. H. Vasconcelos

In this paper a data acquisition system based on wireless sensor networks to support the biomechanical gait analysis will be presented. This paper demonstrates that wireless systems are efficient for biomechanical analysis of GAIT. In traditional existing systems when biomechanical Gait Analysis is performed, it requires a complicated system design for its efficient functioning which comprises of a wired network. In Contrast, proposed system uses wireless network which is much more beneficial than former one in aspects of cost and system design. The system is composed by sensor nodes that can be fasten to the limbs of a person. The system starts working in a self-adjusting (auto calibration) phase. These modules are fitted on the body and can communicate wirelessly with a computer via the access point. The information is obtained by mean of accelerometers and gyroscopes and are processed computationally, that outputs the angles generated by the movement

3.2 PROBLEM DEFINITION:

This System demonstrates use of Smartphone in Gait Analysis. Accelerometer within Smartphone is a motion sensor that can be used to detect human movements. Compared to Other major vital signs, gait characteristics represent general health status, and can be Determined using smart phones. The objective of the current study is to design and develop

The alternative technology that can potentially predict health status and reduce health care Cost. This study uses a Smartphone as a wireless accelerometer for quantifying human motion

Characteristics from four steps of the system design and development (data acquisition Operation, feature extraction algorithm, classifier design and decision making strategy).

Scope

To develop an application that will replace the currently available systems that are seen as expensive and inflexible. The developed application will provide a reliable, cheap, flexible and robust solution to all the problems that plague the current generation of systems and will be made using readily available hardware i.e. smartphones. We shall use a graph processing software to compare the GAIT parameters.

2.2 Drawbacks of Existing System

- Expensive
- Rigid
- Not portable
- Inaccurate

3. APPROACH/ PROPOSED SYSTEM

3.1 Draft of Proposal

The goal of this proposed model is that it can detect gait abnormalities using commercially available smartphone sensors. The process of building an experimental model occurs in three stages. First, experimental data will be collected. Secondly, that data will be subjected to analysis and data mining techniques in order to extract patterns that are indicative of abnormal gait. These patterns form the basis of a model. Finally, the generated models will be assessed and analyzed. Their performance will be indicative of the potential for a model that can detect abnormal gait, and the patterns found in the test data provide insight into the aspects of human movement that characterize abnormal gait.

3.2 PROPOSED ARCHITECTURE

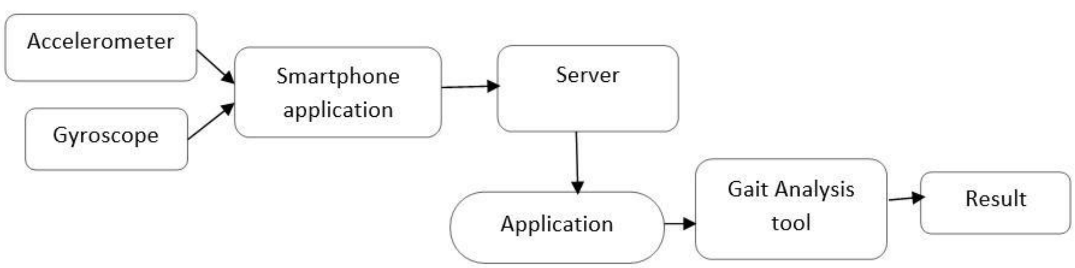


DIAGRAM 3.2: ARCHITECTURE

3.3 EXPECTED MODULES

Module 1: Android app for Measuring Gait Parameters

Android application developed for sending gait parameters through sensors and Gyroscope of smartphone.

Module 2: Server side scripting

Server for accepting gait parameters received from the smartphone.

Module 3: Application for recording dataset of Gait Parameters

Application is developed which studies the gait parameters for data analysis and generates the gait graph.

Module 4: Training of model via Datasets

A model is developed based on gait parameters of various gait abnormalities.

Module 5: Report Generation

A final report is generated which is completely based on the analysis and comparison with the trained model.

3.4 Features of proposed system

- The complexity of wired network is reduced which increases the ease and flexibility of the architecture.
- The cost will be reduced as there won't be any need to buy any special equipment apart from smartphone and a PC.
- The system as a whole is portable.

4. PROJECT MANAGEMENT
4.1 Schedule

Task Name	Start Date	End Date
Existing System Study	03/08/17	13/08/17
Requirement Gathering	16/08/17	21/08/17
Requirement Elicitation and Analysis	23/08/17	31/08/17
Research on Various GAIT Parameters	01/09/17	09/09/17
Planning and Designing	23/09/17	06/10/17
Preparation of Project Plan	23/09/17	06/10/17
Preparation of SRS	13/10/17	15/10/17
Detailed analysis of modules	17/10/17	31/10/17
Designing core modules and design Approval	02/11/17	18/12/17

Table 1: Project Schedule

4.1.1 Project Schedule

	Task Name	Start Date	End Date	Duration	Predecessors
1	Existing System Study	08/03/17	08/13/17	11d	1
2	Requirement Gathering	08/16/17	08/21/17	6d	2
3	Requirement Elicitation	08/23/17	08/31/17	9d	3
4	Research on current project	09/01/17	09/09/17	9d	
5	Feasibility Study	09/12/17	09/22/17	11d	5
6	Planning and Design	09/23/17	10/06/17	14d	6
7	Preparation of SRS	10/13/17	10/15/17	3d	
8	Detailed Analysis of project plan	10/17/17	10/31/17	15d	8
9	Programming of modules	12/18/17	12/26/17	40d	9
10	Implementation	01/01/18	01/20/18	16d	10
11	Verification	02/06/18	02/16/18	10d	
12	Quality Assurance	02/13/18	02/18/18	5d	11
13	Preparation of Test Plan	02/17/18	02/21/18	4d	12
14	Testing and Debugging	02/17/18	02/28/18	11d	14
15	Formulating Changes	03/01/18	03/10/18	10d	15
16	Documentation	03/15/18	03/20/18	5d	16
17	Final Project Closure	03/23/18	03/29/18	6d	17
18	Presentation	04/03/18	04/10/18	6d	

Figure 1: Gantt Chart Schedule

4.1.2 Gantt Chart

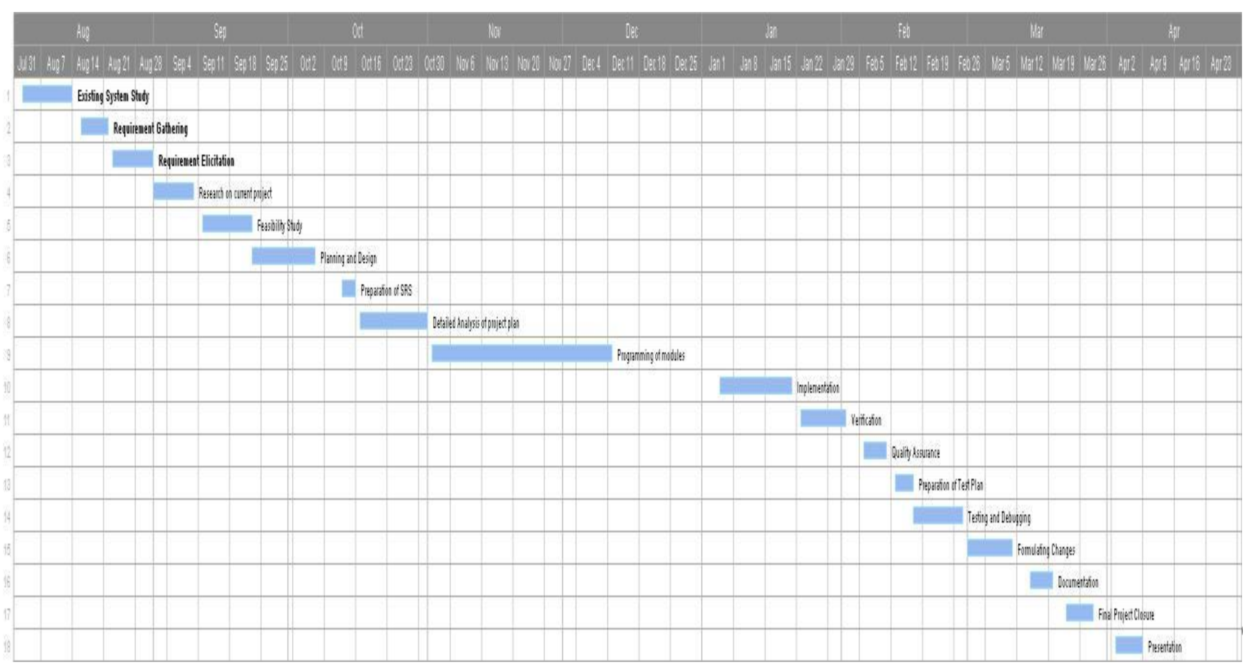


Figure 2: Gantt Chart

4.2 Feasibility Study of Proposed Solution

4.2.1 Technical Feasibility

- Open source programming languages such as java and python have a very strong and ever-increasing community of freelance developers, thus, increasing the exposure and reducing the costs required to get assistance from developers.
- Android application and server application will be developed using the open source software and APIs thus avoiding licenses and costs.
- This software requires a smartphone(Android).
- The application on smartphone needs to be connected to the same network to which server is connected.
- It is also developed on the most widely used operating system, Android, which helps in increasing its user base.
- The application is equipped with a simple to use GUI keeping in mind the target audience.
- The application provides wireless connectivity between server and the smart-phone there by increasing the ease of the diagnosis and flexibility
- Any other problems arising during the course of the development will be handled by the team thus making it operationally feasible.

4.2.3 Economic Feasibility

- All costs for the project are incurred at the beginning and there are no operation or maintenance costs.
- The application helps in saving the initial cost of smartphone and makes the system economically feasible.

4.3 Project Resources

The following is the cost table of all hardware and software components comprising the system.

Sr. No	Item Description	Cost (in INR)
1	Smartphone	12000
2	Server application (open source)	0
3	Analysis tool (open source)	0
	Total	12000

4.3.1. Hardware requirements:

- Processor: Intel i5® Core TM 16 CPU
- System Bus: 32-Bit.
- RAM: 3.5GB of RAM
- Hard drive: 50GB
- Smart phone with functioning sensors

4.3.2. Software requirements

- **MATLAB:** Use for comparing graphs
- ***PyCharm:*** IDE used for running the server scripts.
- ***Android Studio:*** Developing the mobile phone app that captures the GAIT parameters.

4.3.3 Operating Environment

- The application needs to be hosted on a Linux/Windows based server.
- The Android application needs to be hosted on a Linux platform.

4.4 Project Estimation

4.4.1 COCOMO Estimation Model

Basic COCOMO computes software development effort (and cost) as a function of program size. Program size is expressed in estimated thousands of source lines of code (SLOC, KLOC).

COCOMO applies to three classes of software projects:

- Organic projects - "small" teams with "good" experience working with "less than rigid" requirements
- Semi-detached projects - "medium" teams with mixed experience working with a mix of rigid and less than rigid requirements
- Embedded projects - developed within a set of "tight" constraints. It is also combination of organic and semi-detached projects. (Hardware, software, operational)

Software project				
Organic	2.4	1.05	2.5	0.38
Semi-detached	3.0	1.12	2.5	0.35
Embedded	3.6	1.20	2.5	0.32

Effort Applied (E) = $a_b(KLOC)^{b_b}$ **[person-months]**

Development Time (D) = $c_b(\text{Effort Applied})^{d_b}$**[months]**

People required (P) = Effort Applied / Development Time **[count]**

where, **KLOC** is the estimated number of delivered lines (expressed in thousands) of code for project. The coefficients a_b, b_b, c_b and d_b are given in the following table:

4.4.2 ***Estimates of effort, cost and duration***

Effort Applied = $a_b(KLOC)^{b_b}$ = $3(7)^{1.12}$ = 26.5235

Development Time (D) = $c_b(E)^{d_b}$ = $2.5(26.5235)^{0.35}$ = 7.8743

People required (P) = E/D = 26.5235/7.8743 = 3

4.5 Risk Mitigation Strategy

Risk	Category	Probability	Impact
Faulty mobile phone sensors	PS	Low	3
Disruptive noise in the sensor data readings	TE	High	1

Table 2: Risk Mitigation

Impact Values:

1 :- Catastrophic

2 :– Critical

3 :- Marginal

4 :– Negligible

A project team begins by listing all risks in first column of table. Each risk is categorized in the second column (PS-Project Risk, DE-Development Risk, BU-Business Risk, and TE-Technical Risk). The probability of occurrence of each risk is entered in the next column of the table.

<table>
<tr><th colspan="4">RISK INFORMATION SHEET</th></tr>
<tr><td>RISK ID
TS 001</td><td>DATE:18/10/2017</td><td>PROBABILITY:80%</td><td>IMPACT:HIGH</td></tr>
<tr><td colspan="4">DESCRIPTION: The gait parameters will be detected by smartphone and thus the any damage to the sensors ofsmartphone will lead to invalid data which will lead to misleading graph. Thus the report generated will be considered as invalid due to incorrect graph generation.</td></tr>
<tr><td colspan="4">Context:
1. The faulty manufacturing of smartphone hardware sensors will result in erroneous data.
2. The physical damage to the smartphone caused by the user.</td></tr>
<tr><td colspan="4">Mitigation Strategy:
1. Ensure standardized testing of all smartphones to mitigate the possibility of faulty sensors.
2. The smartphone should be used carefully without to prevent any damage to the smartphone</td></tr>
<tr><td colspan="4">Contingency Plan and Trigger: Automatic detection for the accuracy of the sensors.</td></tr>
<tr><td colspan="4">CURRENT STATUS:
15/10/17: Mitigation strategy initiated.</td></tr>
<tr><td colspan="2">Originator: Rishi Joshi, Vighnesh Misal</td><td colspan="2">Assigned: Nahush Raichura</td></tr>
</table>

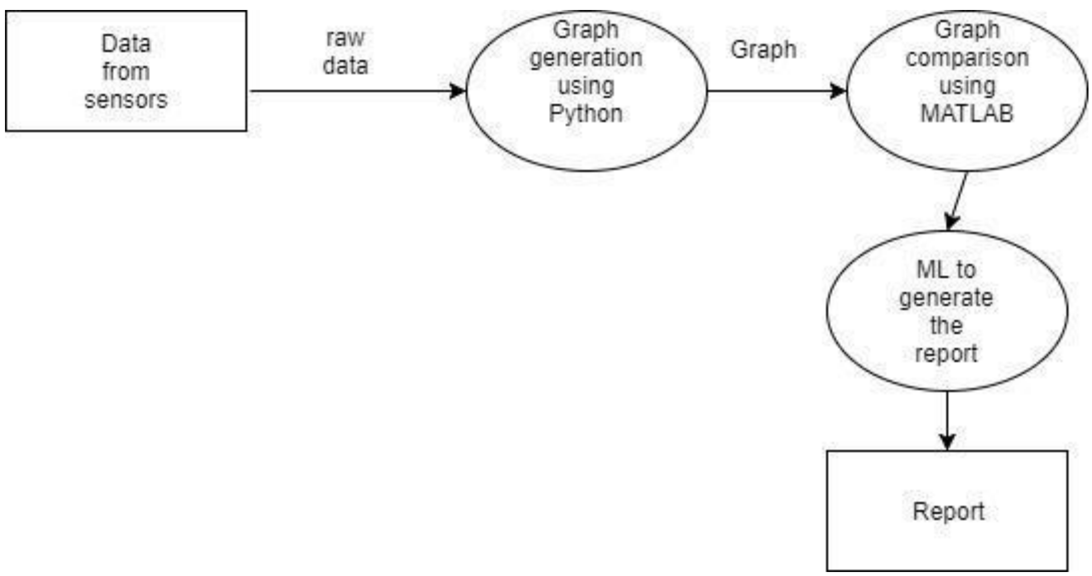
<table>
<tr><th colspan="4">RISK INFORMATION SHEET</th></tr>
<tr><td>RISK ID
TS 001</td><td>DATE:18/10/2017</td><td>PROBABILITY:80%</td><td>IMPACT:HIGH</td></tr>
<tr><td colspan="4">DESCRIPTION: There will always be noise present in the data due to the environment. This can disrupt thecalculation of GAIT parameters and have a profound impact on the generated result</td></tr>
<tr><td colspan="4">Context:
3. Noise is always present during the patient’s motion.
4. The data packets will be affected by noise during wireless transmission</td></tr>
<tr><td colspan="4">Mitigation Strategy:
3. Ensure the phone is strapped tightly to the person.
4. Use of proper software encoding to take care of the outliers.</td></tr>
<tr><td colspan="4">Contingency Plan and Trigger: Automatic detection for the accuracy of the sensors.</td></tr>
<tr><td colspan="4">CURRENT STATUS:
15/10/17: Mitigation strategy initiated.</td></tr>
<tr><td colspan="2">Originator: Vighnesh Misal,
Nahush Raichura</td><td colspan="2">Assigned: Rishi Joshi,</td></tr>
</table>

5. Project Design

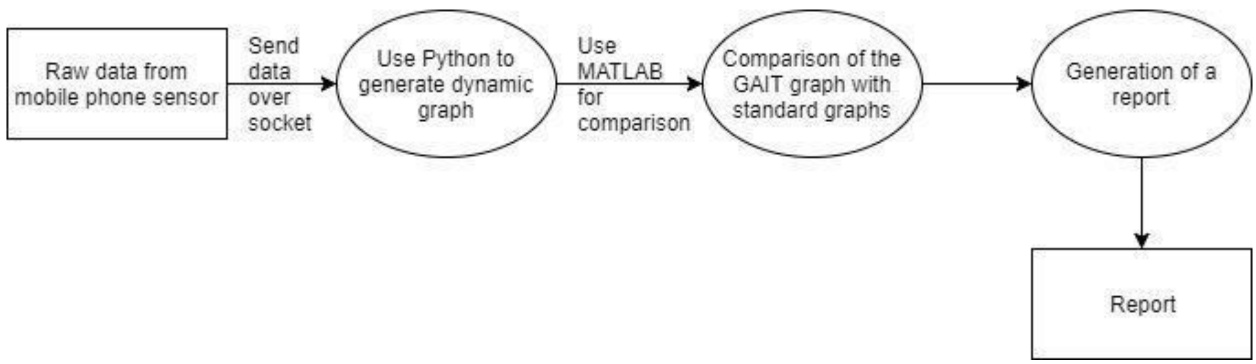
5.2 Data and Control Flow Diagram

5.2.1 DFD Level 0

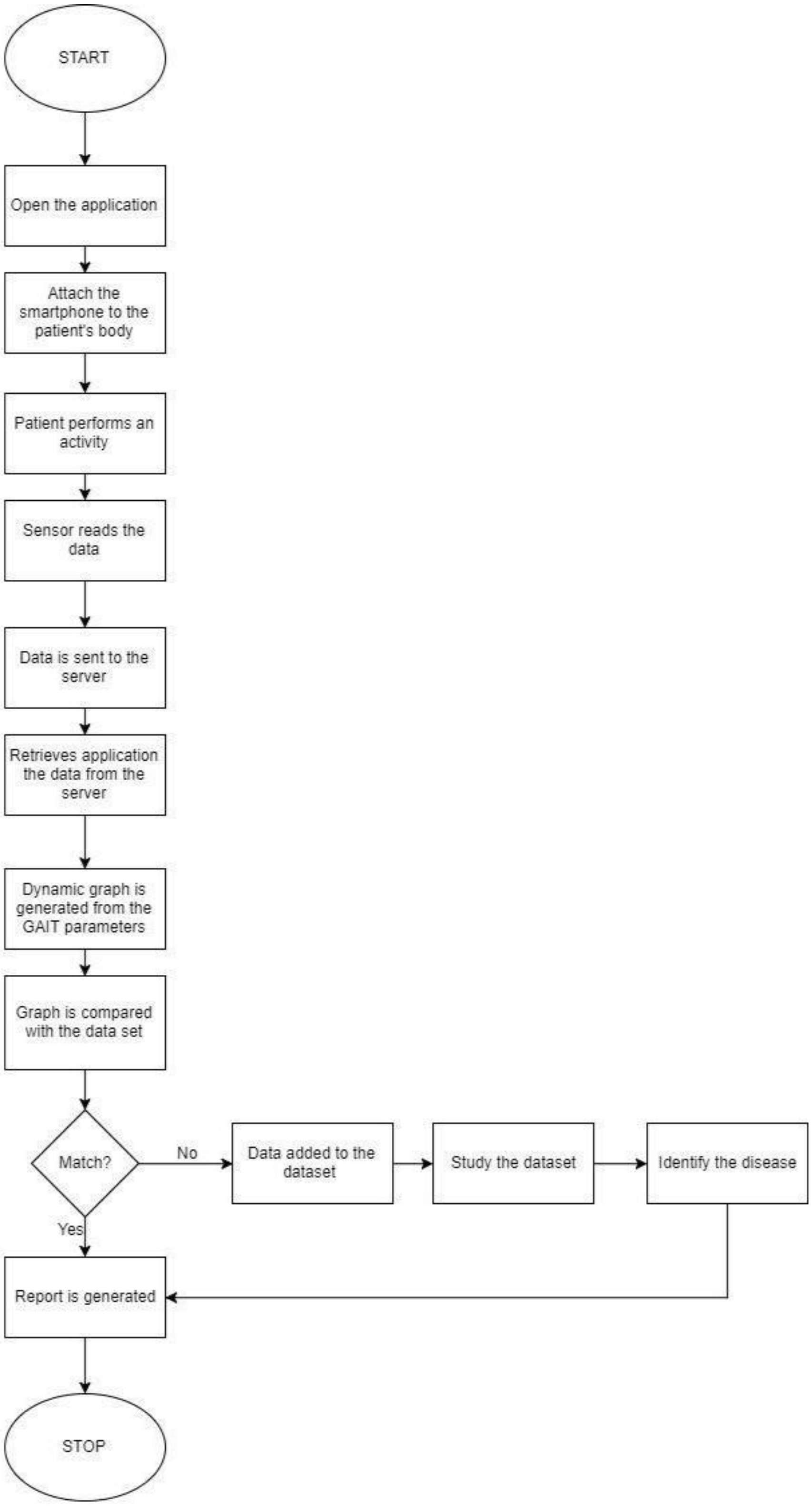
5.2.2 DFD Level 1



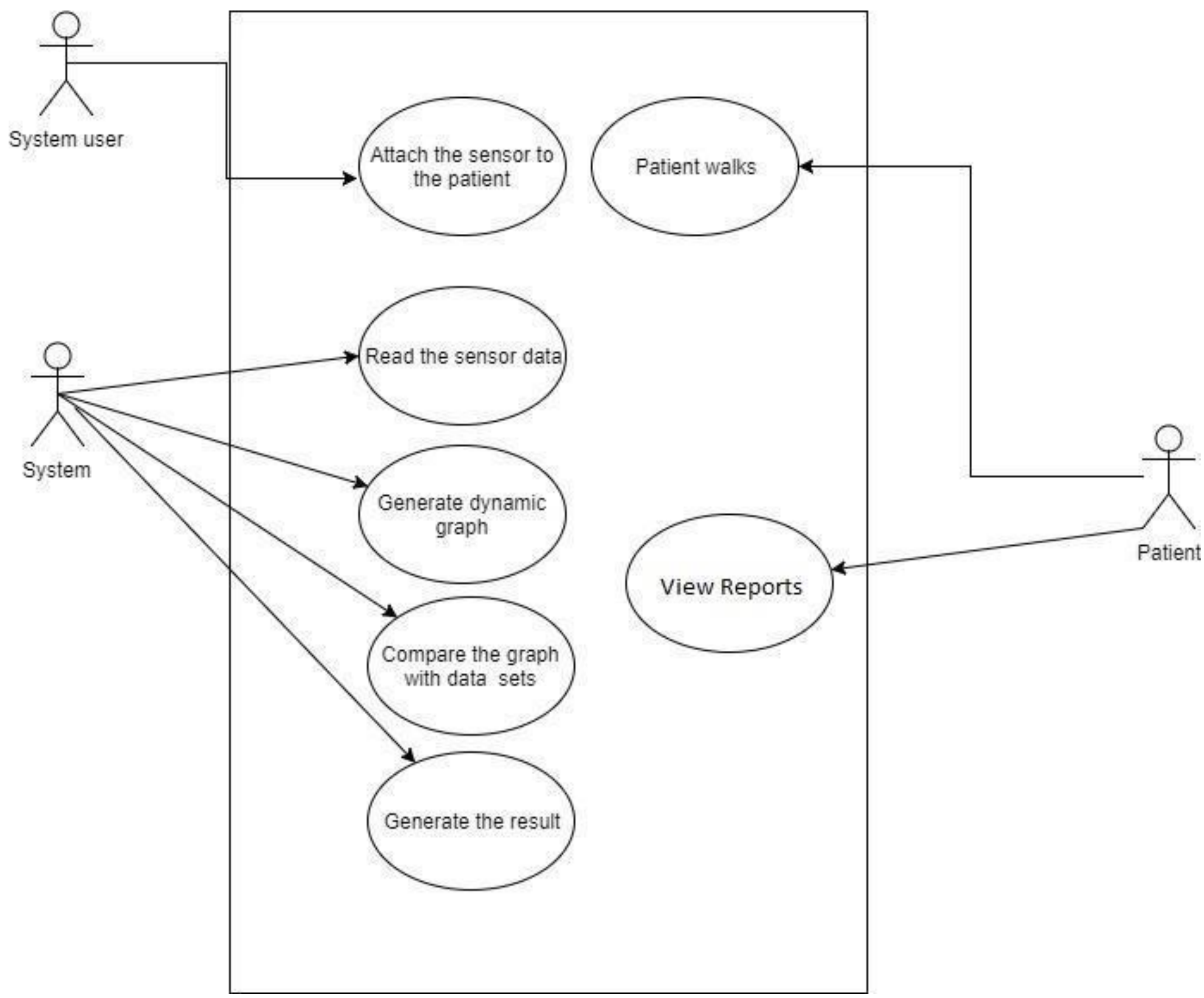
5.2.2 DFD Level 2



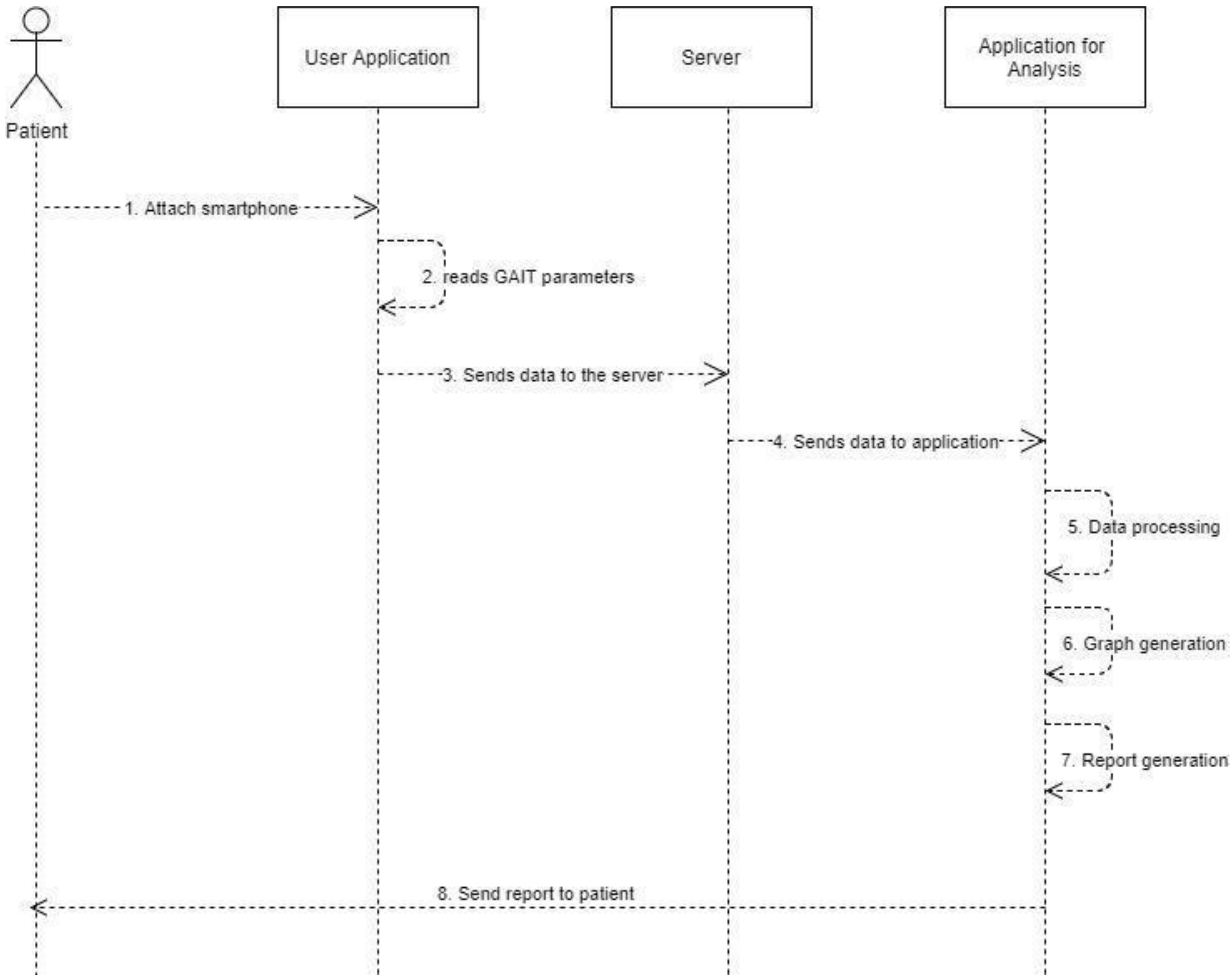
5.3 Design Diagram



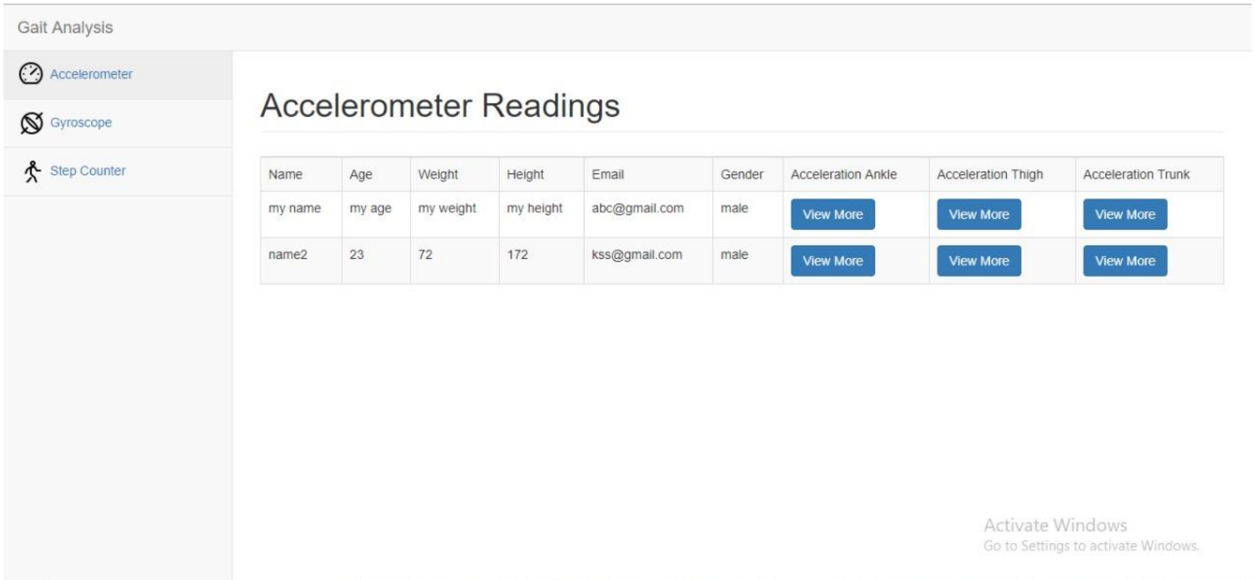
5.3.1 Use Case Diagram

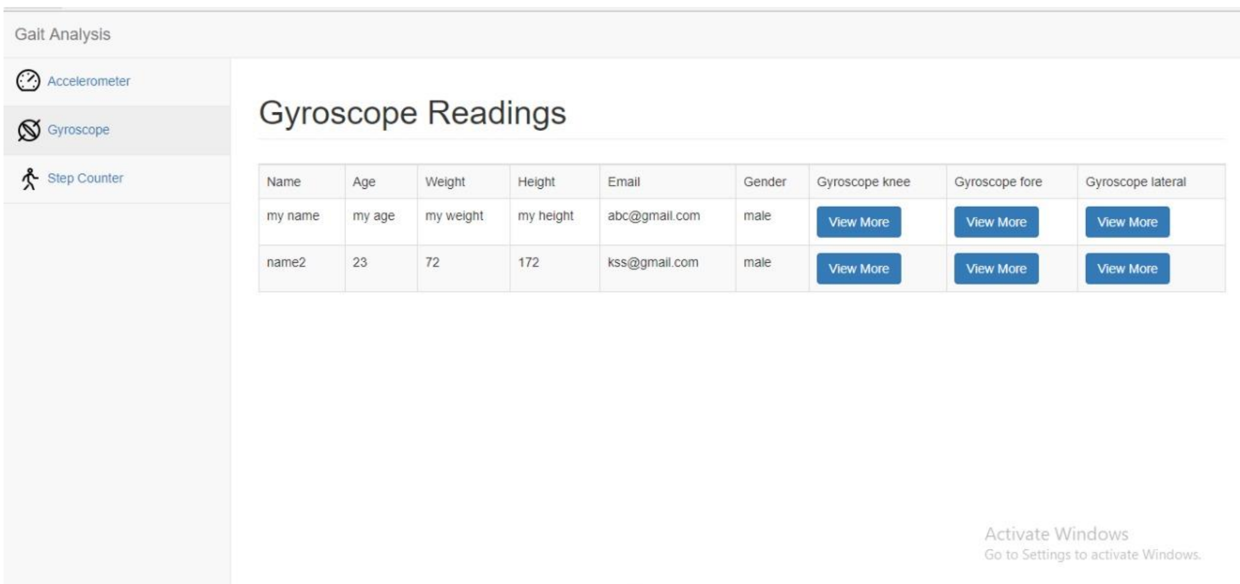


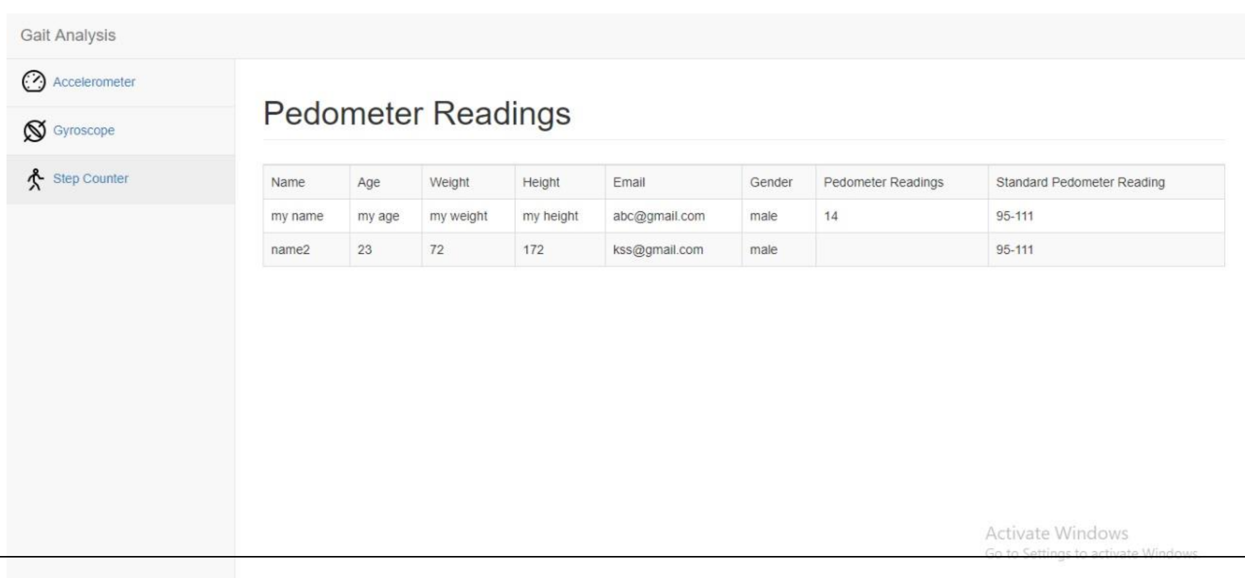
5.3.2 Sequence Diagram



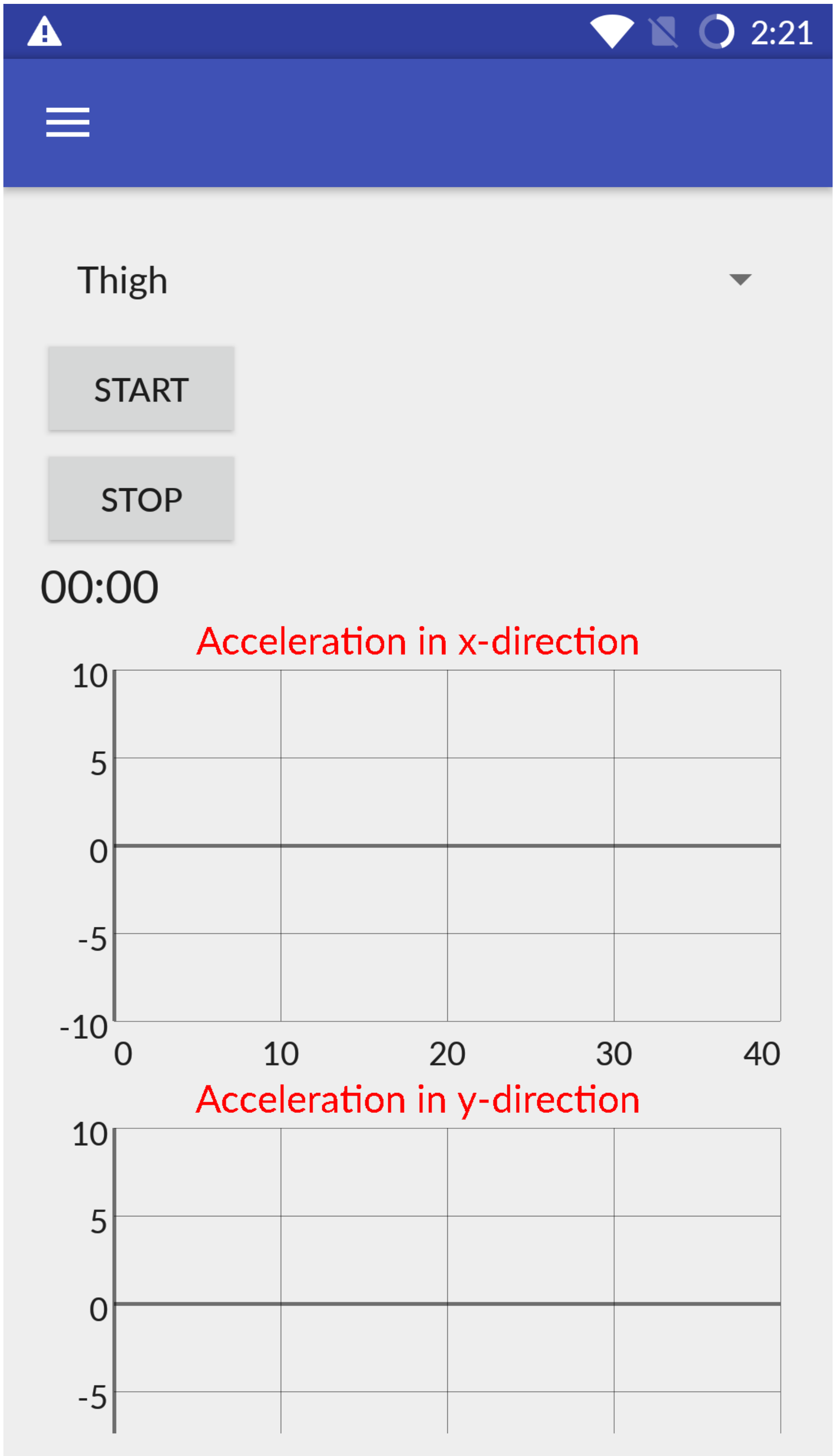
5.4 Interface design

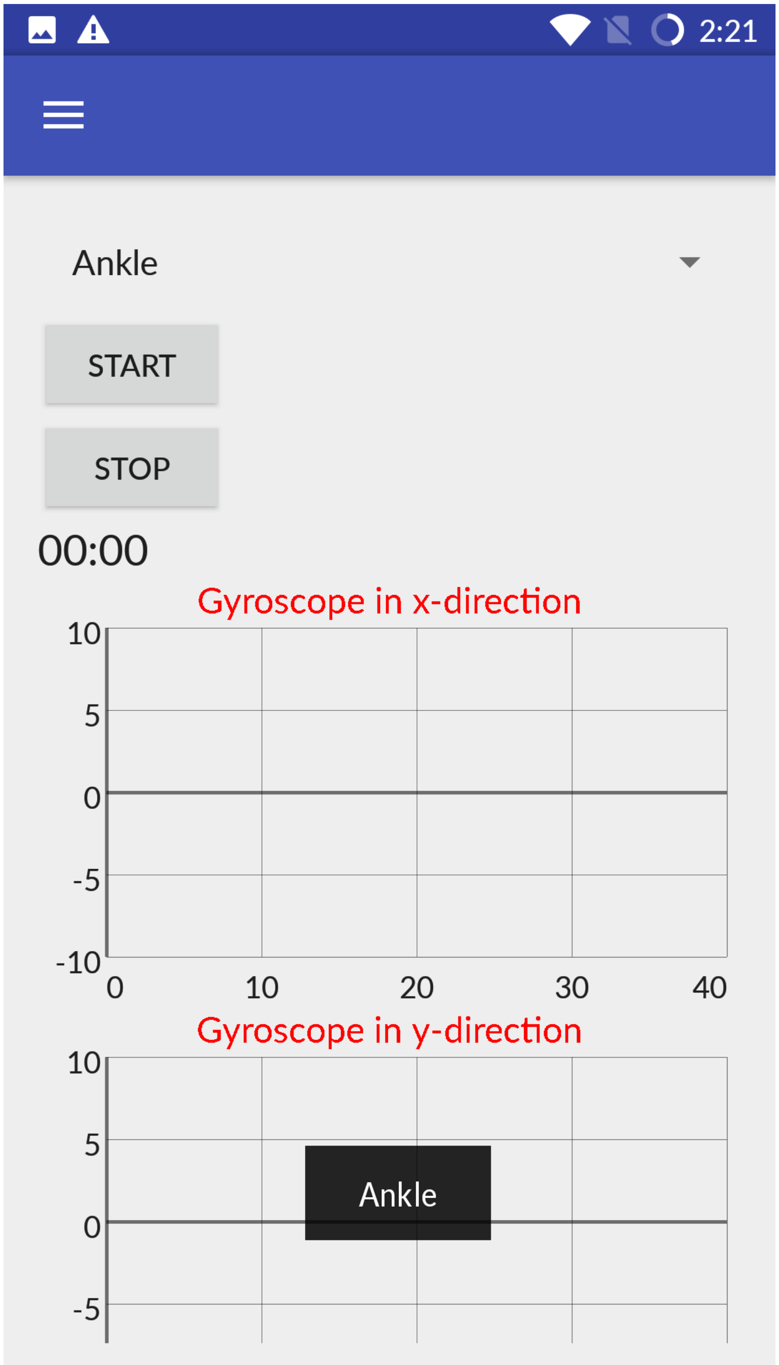




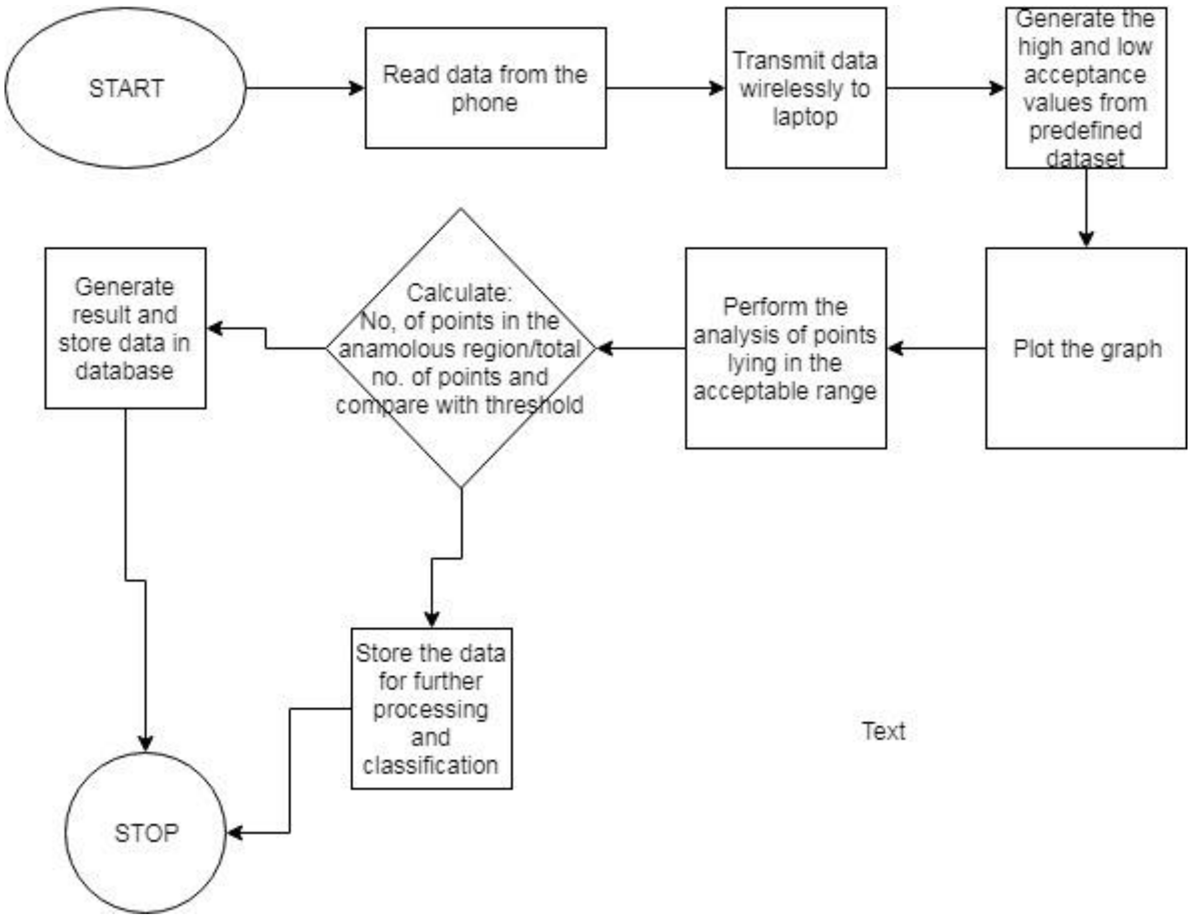



2:21
00:00
START PEDOMETER


2:21
Thigh
START
STOP
00:00
Acceleration in x-direction
10
5
0
-5
-10
0
10
20
30
40
Acceleration in y-direction
10
5
0
-5


2:21
Ankle
START
STOP
00:00
Gyroscope in x-direction
10
5
0
-5
-10
0
10
20
30
40
Gyroscope in y-direction
10
5
0
-5
Ankle

6. System Architecture



6.3 Algorithms / techniques / methodologies

```
for(var k=0;k<time_subject.length-1;k++)
    {


         data1_1.addRows([

        [parseFloat(time_subject[k]), parseFloat(ankle_total_subject[k])]
        ]);

           total_counter++;

           if(parseFloat(ankle_total_subject[k])<upper_average &&
parseFloat(ankle_total_subject[k])>lower_average)
            {
                 inside_counter++;
                //console.log('total counter:- '+total_counter);
                //console.log('inside counter:- '+inside_counter);

            }




    }
var result=(inside_counter/total_counter)*100;
    result_array.push(result);
```

7.1 TestPlan

Testing is the process which gives us a clear indication of how good or bad the developed system is, and also to what extent the developed system is able to satisfy the purpose and objectives that were envisioned in the most initial state of system development. It is a good practice to start testing a system from its initial stages as it gives a clear view of the progress and help to remove, reduce or correct the faults and errors that might take place in the process. We have adopted the same procedure.

1. *Design verification or Compliance test:* This stage of testing has been performed during the development and approval stage of the project.

2. *Test Coverage:* The design verification tests have been performed at the point of reaching every milestone in the project.

3. *Test Methods:* For each module, corresponding outputs were checked. For testing each module the output produced from running the code was checked against the expected output.

4. *Test Responsibility:* The team members working on their respective features and performed the testing of those features.

7.2 Test Cases

A test case is a set of conditions or variables under which we will determine whether the project is working correctly or not. We have used the following test cases to determine if the system is sufficiently scrutinized.

The table below describes the test cases used for verifying the working of project:

Test Case	Case Description	Expected Result	Actual Result	Pass/Fail
1.	The angle measurement.	The angle should be positive	The angle is positive	Pass
2.	The phone gives jittery results	The values obtained shouldn't be jittery	The noise is removed by preprocessing of data	Pass
3.	The phone battery dies	Data is stored in cache and can be recovered	Data is recovered from phone cache	Pass

7.3 Testing methods used

7.3.1 UnitTesting

Unit Testing is a level of software testing where individual units/ components of a software are tested. The purpose is to validate that each unit of the software performs as designed. We tested the individual modules of the project in this phase. Output of each unit was assessed for accuracy and if found incorrect, appropriate corrections were made.

7.3.2 IntegrationTesting

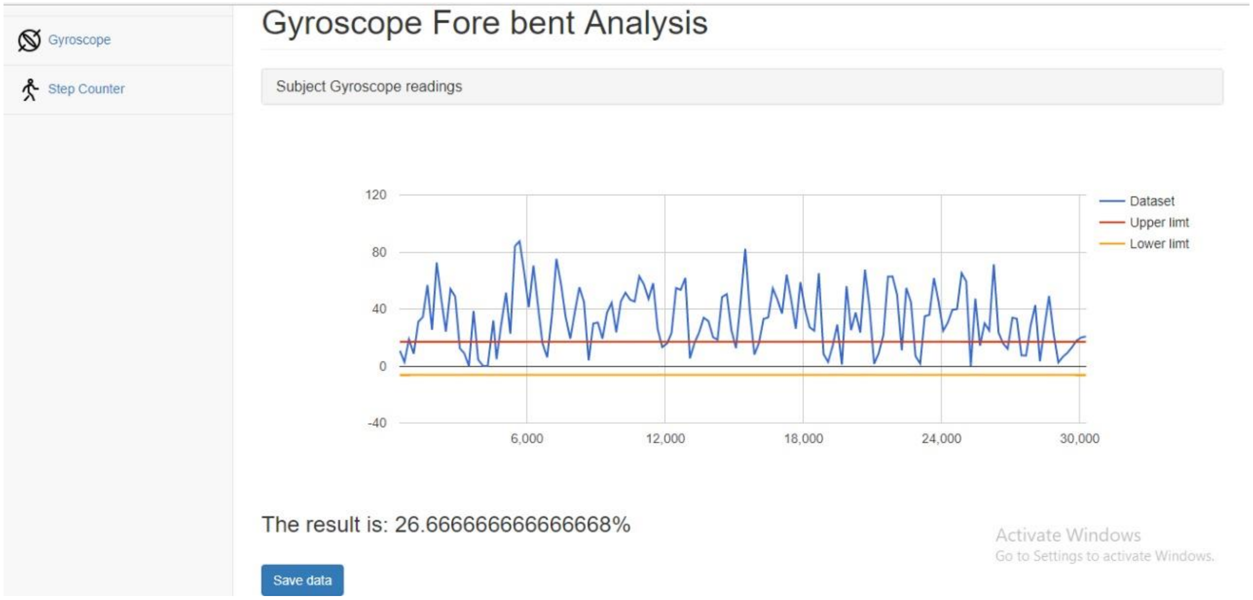
Integration testing is the phase in software testing in which individual software modules are combined and tested as a group. It occurs after unit testing and before validation testing. Integration testing takes as its input modules that have been unit tested, groups them in larger aggregates, applies tests defined in an integration test plan to those aggregates, and delivers as its output the integrated system ready for system testing. We performed this test after merging the various individually tested units(Modules) together.

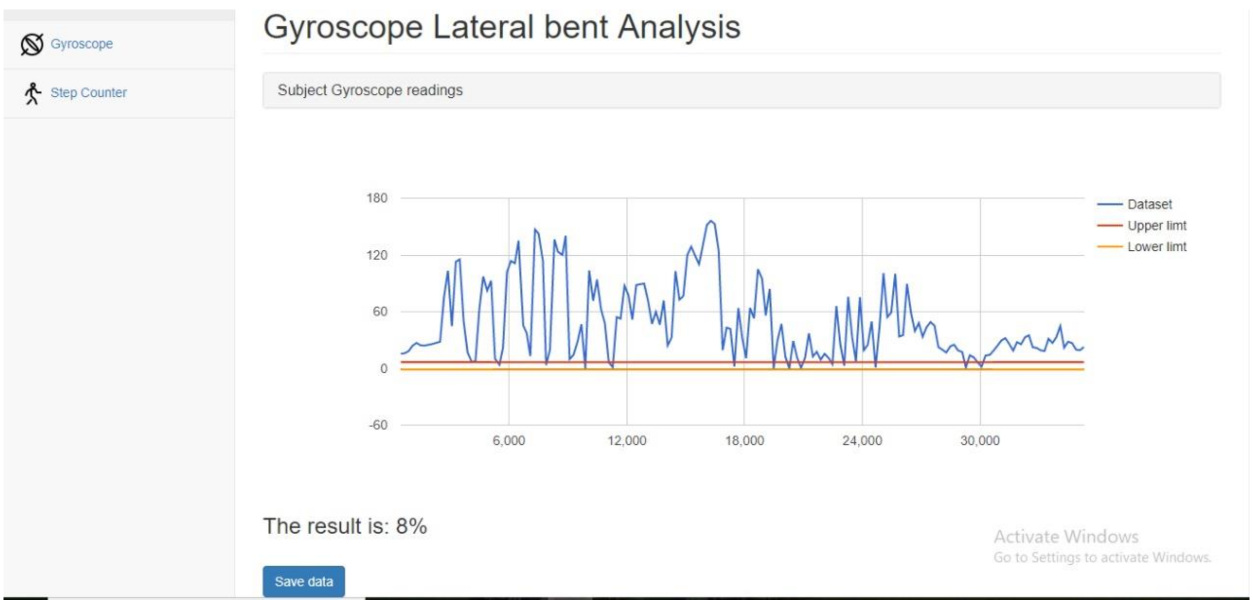
7.3.3 Systemtesting

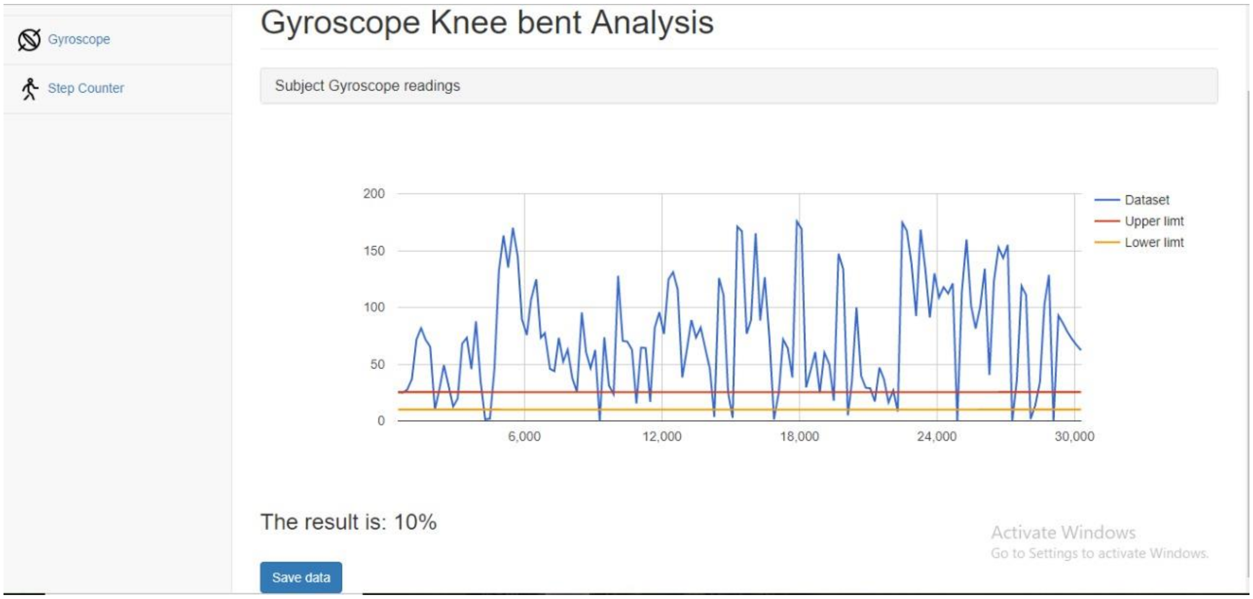
System Testing is a level of the software testing where a complete and integrated software is tested. The purpose of this test is to evaluate the system's compliance with the specified requirements. System Testing is performed after Integration Testing. We performed this testing to check if the modules worked correctly on our PC and platform.

7.3.4 AcceptanceTesting

The process of evaluating software during the development process or at the end of the development process to determine whether it satisfies specified business requirements. Validation Testing ensures that the product actually meets the client's needs. We performed this test to ensure that we were building the right product that encompassed all the features we had included as a requirement.


Gyroscope
Step Counter
Gyroscope Fore bent Analysis
Subject Gyroscope readings
Dataset
Upper limt
Lower limt
The result is: 26.666666666666668%
Activate Windows
Go to Settings to activate Windows.
Save data


Gyroscope
Step Counter
Gyroscope Lateral bent Analysis
Subject Gyroscope readings
Dataset
Upper limt
Lower limt
The result is: 8%
Activate Windows
Go to Settings to activate Windows.
Save data


Gyroscope
Step Counter
Gyroscope Knee bent Analysis
Subject Gyroscope readings
200
150
100
50
0
6,000
12,000
18,000
24,000
30,000
Dataset
Upper limt
Lower limt
The result is: 10%
Activate Windows
Go to Settings to activate Windows.
Save data

8. RESULTS AND DISCUSSIONS

The dataset for different types of diseases is generally found in the form of a table with each patient have multiple measurements performed on him. We have chosen to measure the angle of the knee, the hip and the back. We have split the original dataset into the two red lines observed. This splitting was the margin for error. The blue part of the graph denotes the actual patient performing an activity for us to measure in real time. We had asked the patient to perform each activity for 30 seconds. The readings that we received were plotted and we observed the number of points of this plot that lie in between the two red lines. The probability that a person is afflicted with a neurodegenerative disorder was calculated by comparing the number of points lying in the region by the total number of observational points. Our threshold was 75%.

9. CONCLUSION AND FUTURE SCOPE

The project is a healthcare project. In the long run several new features can be introduced to it. The primary focus for us until now was for the identification of neurodegenerative disorders. But with the advent of high speed internet infrastructure in the country, the project can be developed into something more. Use of wearable sensors such as smart watches is on the rise. By modifying the phone app to read this data and analyze it 24/7 using IoT and cloud based services, the scope of the project can be expanded to provide people with a history of heart diseases, diabetes etc round the clock monitoring. Heart attacks, heat strokes, insulin shocks can be identified in advance. Medical and emergency personnel can be dispatched to the location of at risk patients in order to save their lives.

10. REFERENCES/BIBLIOGRAPHY

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