VIRTUAL PHYSICAL THERAPIST APPLICATION WITH HUMAN POSE DETECTION

BY

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FACULTY OF INFORMATION AND COMMUNICATION TECHNOLOGY

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It is hereby certified that Chan Jia Yi_ (ID No: 1903003) has completed this final year project entitled "Virtual Physical Therapist Application" under the supervision of Dr Ng Hui Fuang (Supervisor) from the Department of Computer Science, Faculty of Information and Communication Technology.

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ABSTRACT

In general, the accessibility of tele-physical therapy faced more difficulties especially when the strikes of COVID-19 hits. In this project, the problems in the targeted users in accessing physical therapy at home will be discussed, as well as the previous existing works from other researchers are also be studied and discussed in this paper. After researches on different works, it is shocked that the applications with monitoring mechanism to prevent patients from performing wrong action and assessment mechanism for therapist to make further diagnosis are still sparse in the market. The proposed solution will attempt to solved the current problems to enhance a better performance for the existing application. As result, patients could have access to rehabilitation treatment so that they could continue to improve their health condition during Covid-19 outbreak.

A mobile application is chosen as a solution to assists patients and therapists in accessing the physical therapy session at home. The aim of this project is to develop an improved assistance system for physical therapy with enhanced flexibility and functionalities that could assist both therapists and patients for remote physical therapy. Hence, functionalities such as Body Detection and Pose Estimation System, Real-time Guidance System and Assessment System will be designed and developed. It allows patients to receive real-time instructions and corrective messages during exercising, visualize performance results to patients and therapists and able to perform body pose tracking instantly. All of these functions can be carried out with a small device like smartphone. The project will be developed using Dart language with Flutter, database with Firebase, and mechine learning solutions from Google Mediapipe Framework. Waterfall methodology is used to develop this application.

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LIST OF ABBREVIATIONS

3D	3 Dimensional
AR	Augmented Reality
API	Application Programming Interface
SDK	Software Development Kit
UI	User Interface
GUI	Graphical User Interface
VR	Virtual Reality

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CHAPTER 1 INTRODUCTION

1.1 Problem Statement and Motivation

Problem Statements

i. Existing telehealth physical therapy applications do not feature real-time monitoring to guide the patients during their exercise, which may resulting in incorrect exercise techniques being performed and causing further injury;

The targeted users that might face this problem are the stroke patients. During COVID-19 pandemic, patients are encouraged to carry out telerehabilitation by themselves. However, existing rehabilitation applications provide only instructions during exercising. Patients will not receive any real-time feedback and corrective messages if they are performing wrong. When the patients continuously performing wrong exercise techniques without knowing, the rehab progress might be delayed or worse, further injuries may occur.

ii. Existing telehealth physical therapy applications does not provide a reliable and valid measuring mechanism for the assessment of the user's performance, which may cause the therapist to make wrong assumptions on the user's progress.

The targeted users that might face this problem are the therapists. From the viewpoint of therapists, the patient's performance to the assigned treatment was hardly be tracked, causing the effects of self-exercise became questionable. Without physical monitoring, the therapists had no reliable and valid measuring mechanism to assess those self-reported exercises' results. In consequence, it might cause the therapists to make wrong assumptions in diagnosis.

Motivation

In this pandemic, the targeted users faced more difficulties to perform telerehabilitation, but available solutions to resolve the issues is still sparse over the market. Even though we were amid the COVID-19 pandemic, other health conditions persist. Post-stoke patients continued to have movement disabilities, and strokes would continue to occur for those unfortunate people. Therefore, the motivation of this project is to develop an assistance system for physical therapy with enhanced flexibility and functionalities that could assist both therapists and patients for rehabilitation. Additionally, it is important to enabling patients to have access to rehabilitation treatment so that they could continue to improve their health condition and fully engage in life, school, or work. The motivation of this projects is to assist therapists to guide post-stroke patients with a more reliable, flexible, and valid platform. Therefore, this project is going to develop an AR-based mobile physical therapy application to assist patients in providing real-time guidance and feedback, as well as help therapists to visualize patient performance for diagnosis.

1.2 Project Scope

The scopes and boundaries of the project are listed as below:

i. The application capable to capture humans' body movements using only webcam or phone camera, without other special equipment.
ii. The type of physical therapy is mainly designed for post-stoke patients.
iii. The proposed solution is primarily building on the Android platform for mobile devices.
iv. The application capable to capture, interpret and evaluate the users' movement, and present to the therapists to help diagnosis.

In the end, this project is going to deliver an AR-based mobile application of a virtual physician therapist to create an immersive tele-rehabilitative experience for therapists and patients. This application is an improved version of current rehabilitative mobile applications, with greater flexibility, usability and portability.

In general, this application will provide real-time instructions and guidance to patients during their tele-physical therapy session to simulate a virtual therapist in real-life. Moreover, this application will perform a more accurate human body detection and pose estimation by capture, interpret and evaluate the patient's performance. In order to create an immersive and interactive experience, AR-based 2D objects will be utilized to overlayed on the real-world.

Then, the therapist can keep track on the performance's results and make diagnosis for each patient through the application. As an output, users can always get real-time feedback and perform the exercises correctly, while therapist can keep track on user's performance and make diagnosis efficiently.

1.3 Project Objectives

a. To analyze the effective functionalities in the existing tele-physical therapy applications to improve flexibility, user-interaction, and portability

The purpose of this projects is to analyze the functionalities provided in existing solutions to assist and motivate post-stroke patients in their daily exercises while also eliminate frequent needs for repeated visits to rehabilitation hospitals. The available functionalities will be analyzed to determine its flexibility, user-friendliness, portability, usability, etc.

b. To design an instant pose estimation system with high-fidelity full body-pose tracking during rehabilitative exercises through a smartphone camera.

One of the main objectives of the proposed system is to deliver an AR-based virtual physical therapist which provide whole body movement tracking in post-stroke rehabilitative exercises. In this project, a machine learning model with higher accuracy in human body detection and pose estimation will be used. For each human motion in the video frame, the module will map 2D objects with detected body landmarks on the real-world human body, forming an AR experience for patients to check their pose clearly. The detected landmarks will then be used for the next objective.

c. To deliver an on-device real-time physical therapist that giving real-time instruction, providing corrective feedback and visualizing the performance results

Based on the detected landmarks from the pose tracking, the system algorithms will analyse whether the patient is doing correctly. For instance, the application will first generate real-time instructions and feedbacks on the screen. Then, based on the patient motions, a counter will count the completed repetitions for each set of exercise. This application will also generate congratulation messages if the users completed the exercises to motivate them. After patients completed a set of exercises, the performance data will be visualized and presented to therapists. When they want to check on a particular patients' progress, they just need to view the activity dashboard for that patient. Then, therapists can make evaluation and diagnosis based on their performance dashboard, and make sure their patients is completing the assigned tasks.

d. To analyze the effectiveness and performance of the developed application

Testing plans will be carried out to evaluate the system performances on the functionalities. For example, try and compare the differences of human body pose tracking mechanism, the readability of the performance results, and the time delay in giving the real-time instructions and corrective feedback.

1.4 Contribution

This application is aimed to developed to provide targeted users with an enhanced user experience in using virtual physical therapy application for them, to ease the access to rehabilitative exercises. In this project, an AR-based virtual physical therapy mobile application with human body pose estimation will be delivered to resolves the inconvenience and weaknesses in existing applications, involved new features such as real-time corrective mechanism, instant guidance with instructions, immersive physical therapy experience with AR technology, and better visualization on user's performance.

Firstly, at the end of the project, the developed application enables their users, including therapists and the patients to have more flexibility in their rehabilitation treatment. From the view of patient, patients allowed to access to rehabilitative treatment with their mobile phone, and they no longer required to pay visit to hospital regularly. This application provides a reliable mechanism to give real-time instructions and corrective messages to patients throughout the exercise, which totally has no big difference with a physical therapist. Therefore, any kinds of injuries caused by incorrect techniques during tele-physical therapy sessions can be avoided as much as possible. As consequences, even in the COVID-19 pandemic, patients can easily access tele-rehabilitative session through the designed application. As results, patients capable to continually improve their health conditions at home, without worrying self-injury may occur.

Then, this application also benefits therapists to save time on tracking the rehabilitation progress for each patient. They are no longer required to physically monitor the patients for each rehabilitation session, as well as collecting patient and performance data manually. When they want to check on a particular patients' progress, they can simply view the activity dashboard at any time. As a result, their workload will be reduced and they will be able to devote their time and effort to other more significant tasks, such as evaluating patient's performance and design more suitable treatment programs for patients.

1.5 Background Information

Statistics

In Malaysia, Stroke Disease (SD) was emerging as a significant public health problem. Every year, approximately 15 million people worldwide suffer from stroke disease, which caused the death of 5 million people and permanent disability of another 5 million. [11]

Stroke Effects

Stroke happens when the blood flow to a region of brain is blocked or reduced, causing the brain tissue deprived of oxygen and nutrients. The severity of a stroke is determined by the location of the blockage and the extent of brain damaged. As consequences, the affected region of brain may cause inability to perceive and move one or more limbs on one side of the body. For example, if the stroke strikes towards the back of the brain, one's may face vision disability. Other sides effects also include patients might unable to interpret words, formulate speech, or even seeing one side of the visual field.[11]

Problem of tele-rehab

Strokes can be treated in many approaches. One of it is Physical Therapy. Most of the traditional rehabilitation services provided in Malaysia were outpatient programs that require regular hospital visits. Firstly, from the viewpoint of patients, pay regular visit to the hospital to access the traditional rehabilitation cost a lot of time and effort, especially those who in the rural area. This had increased financial burdens and inconvenience on patients because they are not physically independent and normally acquire companions for visits. [14] Other than hospital session, physical therapists was responsible to encourage their patient to carry out telerehabilitation or home exercising program themselves for efficient recovery. Telerehabilitation sounds good conceptually, but in fact, there exists several downsides. For instance, patients may forget what exercises are assigned to them, or how to execute particular pose. Physical therapists could only hope that their patients would remember the assigned exercises and practise them accordingly and report their performance to therapists. However, self-reported performance may lack accuracy, specificity and may be biased for assessment. Even worse, patients may perform the exercises incorrectly and causing further injuries. [6]

Existing Solutions

In recent years, the amount of smartphone users increases dramatically. With the characteristic of mobile, many healthcare applications are developed to promote and support people "workout" from home, including rehabilitation application for different kind of disease. Generally, these mobile applications are modelling the instructors, provides instructions and demonstrates videos to guide the patients.[12] Yet, there are downsides of the mobile rehabilitation application. The major issue is that most of the applications are not providing reliable mechanism to monitor and assess the user performance in real-time.[13] Hence, even though the patients were following the demonstrating video, but they could still perform incorrectly without their knowledge. Besides, real-time therapeutic corrections are not usually included in the applications, which may lead to ineffective rehab treatment.

In this project, a mobile application is proposed to assist patients in their recovery journey and help physical therapists to monitor their patients in every physical therapy session. The development of this application also aims to solve the problems that are currently facing the mobile physical therapy applications in the market and make further improvements in terms of flexibility, accuracy, functionalities and visualization.

1.6 Report Organization

The report consists of six chapters: Chapter 1 Introduction, Chapter 2 Literature Review, Chapter 3 System Design, Chapter 4 System Implementation, Chapter 5 System Testing and Results, and Chapter 6 Conclusion. The first chapter provides an overview of this project including a problem statement, project background and motivation, project scope, project objectives, project contribution, project highlights, and report organization. The second chapter analyzes the strengths and weaknesses of a variety of rehabilitation products currently available on the market. In the third chapter, we outline the overall system design of this project. Chapter four provides information about how to implement the design of the system. Furthermore, the fifth chapter presented the results of module testing while the last chapter summarize the key points of the projects.

CHAPTER 2 LITERATURE REVIEW

The purpose of the literature review is to explore and evaluate different rehabilitation assistance system that enables the user to perform rehabilitation activities with AR-based virtual objects. Also, this literature review will list out the advantages and disadvantages of the reviewed system on the feature and functionalities. In the last section of the chapter, some critical issues in the current studies will be pointed out. By this, it would help to understand the challenges and difficulties that are currently faced by the AR-based virtual physical therapist system in assisting patients to perform recovery exercises.

2.1 Rehab Guru Pro

Rehab Guru Pro is a telehealth platform that provides more than 4,000 exercises for therapists, health and medical professionals to prescribe exercises to their patients. Each exercises have own metadata. Hence, user of Rehab Guru Pro can filter their searching by mentioning the type of “Equipment”, “Exercise Goal”, “Movement Direction” and many more. Moreover, the app provided more than 100 pre-made treatment templates that containing defined exercises, and a library with over 5000 exercises. Physical therapist can become a programme creator in the app, which they were flexible to design therapy programmes, no matter they want to load exercises from an existing template, from the application’s library or create their own exercises from scratch. Once created, the programmed details would be sent to the patient’s email address. Every set of exercises assigned to a patient is named as “prescription”. In order to improve visualization, the app presented the exercises through hand-drawn stick men in the forms of images and videos, in with HD digital prescriptions that increase adherence and projecting a professional image. For storage purpose, Rehab Guru Pro retains a log of every programme that was sent to client [2].

Strength

Since the time spent on creating rehabilitation programme was significantly reduced by the pre-made templates and libraries, it maximized the efficiency of therapists at work. The therapists can complete more tasks for different patients, compared to designing programmer manually to each patient individually in the old days. Besides, beautiful designed programmes can be designed in few click, and the animation of hand-drawn stick men were used to demonstrate the exercising. This shows clear examples of correct form and techniques. Other than that, all exercises contains over 100 pieces of metadata to perform accurate filtration. The filtering is fast, making instant search as user typing in the searching box.

Weakness

According to *figure 2.1*, the assessment was made based on the user's self-reported performance. Without physically monitoring mechanism, self-reported performance may lack accuracy, specificity and may be biased for physical therapist to make assessment. For instance, patients may perform only half-way of the prescribed exercises but reported as completed.

Suggestion

A body pose tracking system is needed to track the body movement and body pose of the patients during exercising. After patients have completed a programme, or a set of exercises, their performance should be record in the database for future use. Data should be visualized and presented in dashboard, where therapists could clearly see and understand the patient's performance.

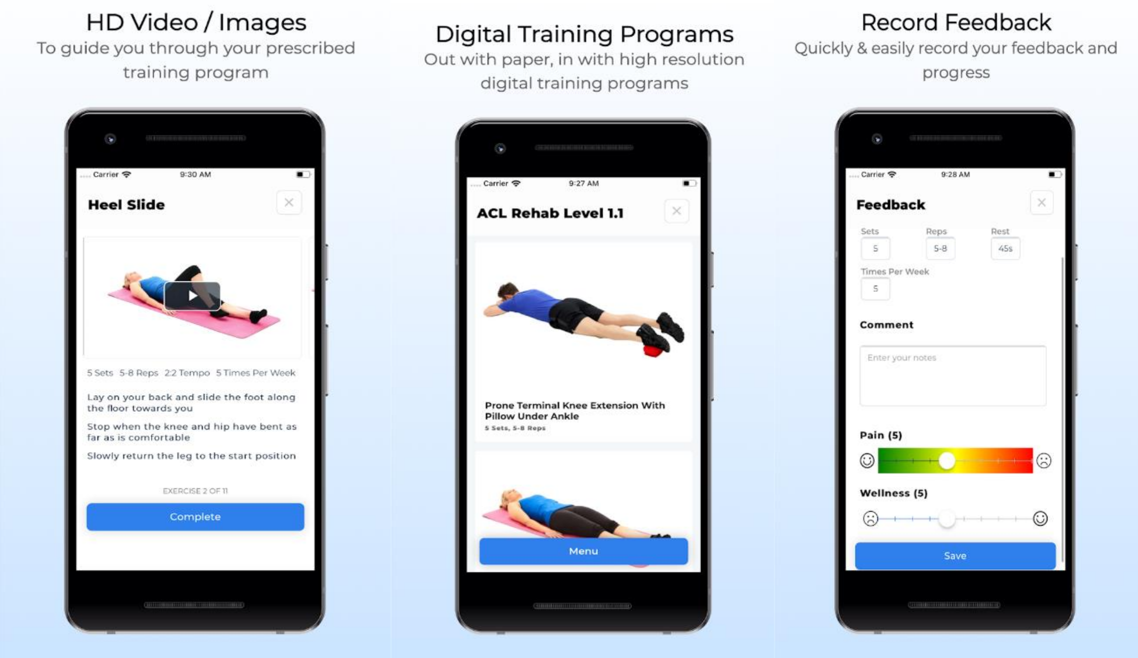


Figure 2.1.7: User Interface of HD Guidance Video (left), Available Training Programs (middle) and Patients Feedback (right)

2.2 GenVirtual

GenVirtual is an augmented electronic game developed in Italy, which stimulating colour and sound memorization for motor and cognitive rehabilitation. The patient who suffered from cognitive disabilities normally relied on assistive equipment to use musical instruments and computers. Therefore, the researchers then utilized the advantage of AR that provide an interacting environment without videogame console assistive equipment and input devices such as mouse or keyboards. In GenVirtual, users could just use bare hands and feet to interact with the games and gain a better feeling of presence and reality judgement, according to Correa [7].

The goal of GenVirtual was to follow and play a sequence of sounds and colours emitted by virtual objects. According to *Figure 2-1,* each note was associated with one virtual cube. Before starting, the users were required to memorize each virtual cube and its corresponding musical notes. Then, they were asked to select a melody and a sound sequence in MIDI format (a series of 8-bit bytes files system primarily used for musical file) for the selected melody would be generated. The MIDI file would then be used by the system to search for matching musical notes [7].

When the user's hand or feet overlapped with virtual cubes, the systems play a corresponding melody. When the user had completely played the selected sounds sequence, a new sequence that combined the previous sequence with more musical note was generated to increase the game challenge [7].

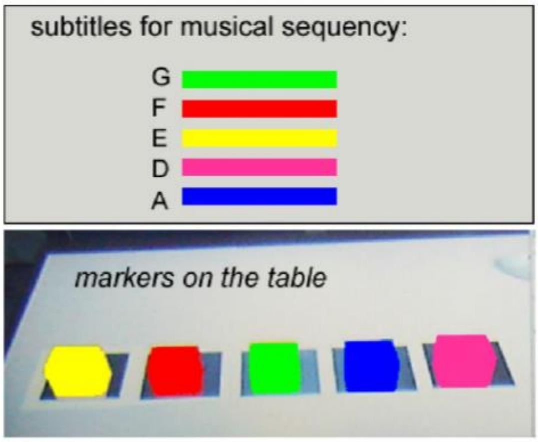


Figure 8.2.1: Markers and Matching Color of Musical Notes and Cubes

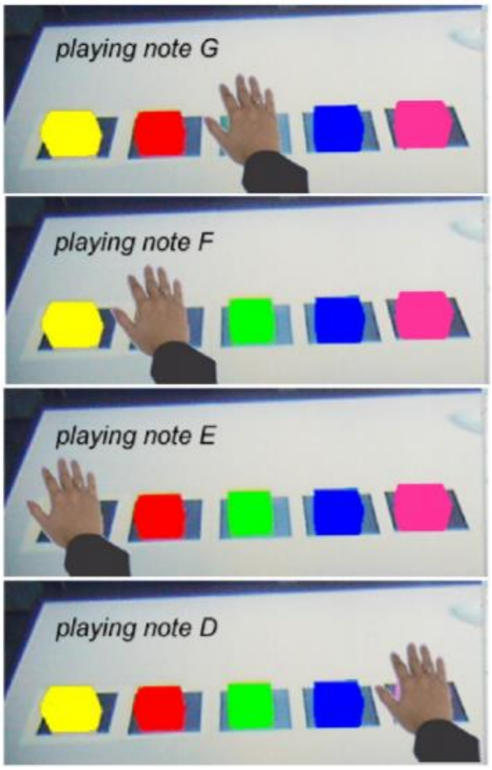


Figure 2.2.2: Interacting with GenVirtual Markers of Virtual Objects

Strengths

The strength of GenVirtual was it enabling the therapists to control, customize, and generate music melodies through its user interfaces. They would have flexibility to place the musical and visual elements, which allow them to create different scenarios to each patient.

Weakness

However, there were some problems related to GenVirtual. First, the system did not consider the use of real objects to enable users to touch and interact with real object. The patients might facing difficulties to realize their hands were penetrating the virtual objects without feeling them. Therefore, the amount of exercise was limited as the users did not had to apply too much strength to break through the challenge. Besides, the customization of rehabilitation exercise was limited to upper or lower body only, which means that users hardly involve their hands and feet together in the exercise. This is difficult for therapist to design whole-body exercises for their patients. Other than that, the system also relied on scanning the markers to produce virtual objects. Every time the users had to prepare at least 5 to 12 markers to begin the exercise which also caused some inconvenience when one of more markers were not found.

Suggestions

Since this system was developed a long time ago, there is plenty of technology available today to address these issues. To begin with, the action of touching a virtual object can be modified to grabbing or holding a physical object in real life. The mission of overlapping virtual objects by hands or feet can be replaced by holding real objects and moving them up and down while still projecting virtual images on physical objects. The problems of customization can also be resolved by providing a configuration interface for therapists to identify the movements that the patient would be required to perform.

2.3 AR-REHAB

As its name has shown, AR-REHAB was an Augmented Reality Rehabilitation framework developed by Atif Alamri for post-stroke patient rehabilitation.[4] The main goal of this framework was to increase patient's engagement in rehabilitation exercise with an entertaining and natural environment. Besides, the system also aimed to evaluate the patient's progress without the supervision of a physical therapist.[4]

In AR-REHAB, the virtual objects were generated to overlap the physical object for patients to touch by integrating with the real environment setup. For example, the patients could use a kitchen cup on their kitchen shelf to accomplish their objectives. As *Figure 2-3* shown:

a. AR-REHAB turned on for the first time after waiting 5 seconds seeing the mug and assigning tasks on the screen.
b. The horizontal bar displayed in the centre of the screen indicated that the patient had already travelled the object from left to right and was now returning.
c. The direction had shifted vertically while the patient progressed halfway up the route from the bottom.

d. The patient had already moved the object from the bottom to the top and is now on his way down.

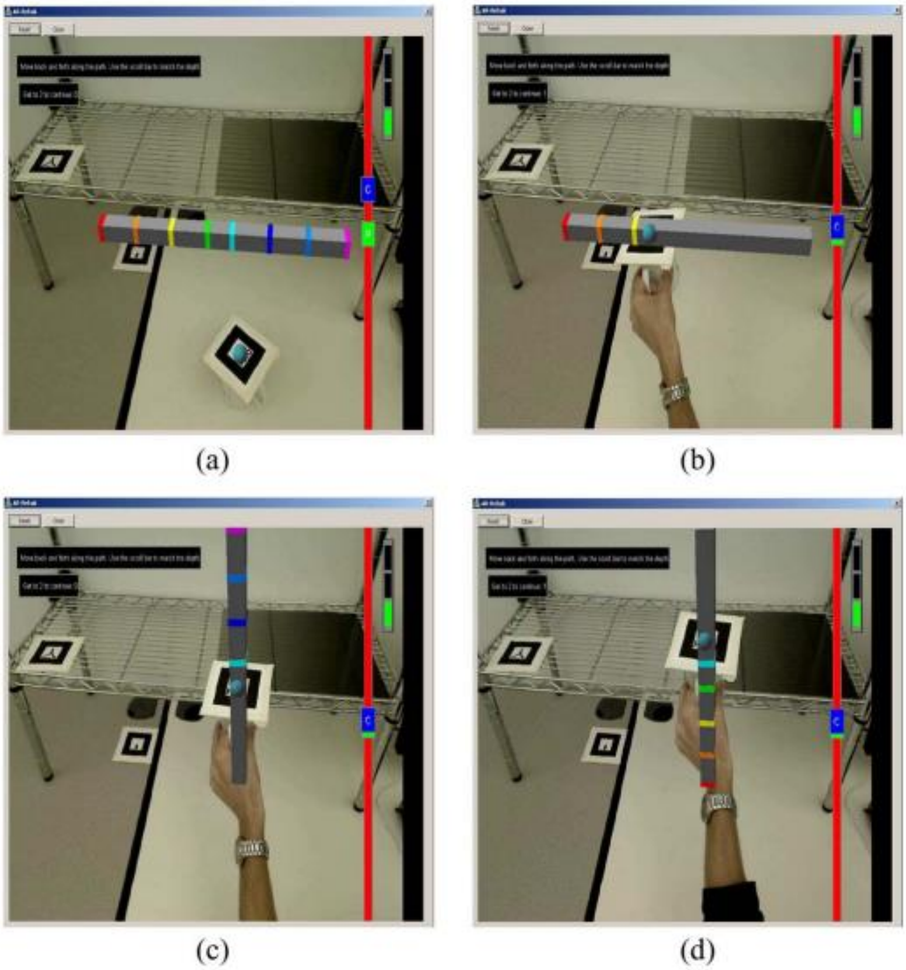
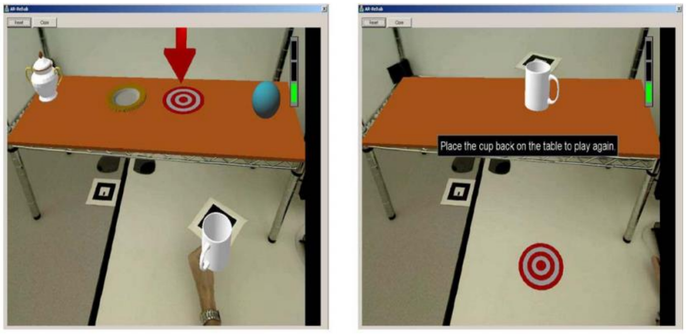


Figure 2.3.1(a),(b),(c),(d): Cup exercise used to reenact the motion of moving an object upwards and downwards through an AR environment.

Besides, the AR-REHAB was able to make suggestions on the treatment progress using a decision support engine. It would monitor the patient's performance and determine if the training should be advanced to the next degree. Typically, the suggestion was generated based on continuous long-term analysis of patient data, which entailed several sessions of patient data recording. According to Almari [4], by capturing the patients' interactions with the virtual objects, its evaluation metrics could calculate the task-completion time and compactness, as well as the speed of hand motion.



(a) (b)

Figure 2.3.2: Shelf exercise used to reenact the motion of placing and removing an object on a shelf through an AR environment.

Strengths

One of the strengths of AR-REHAB was that the patients were able to interact with simple objects and experience the real force while they perform their exercises. Thus, the patient could perceive the environment as a real environment instead of a virtual environment. Also, another strength of AR-REHAB was that the system also quantitatively measured the patient performance and treatment progress without having the direct supervision of a therapist.

Weaknesses

However, there were some weaknesses in AR-REHAB too. The exercise designed was only limited to hand's movement such as grasping and holding. Eventually, patients were not able to carry out more challenging exercise since this framework only provides simple exercise. Other than that, the sensor could not function without sensing the fiducial markers, as shown in *Figure2-3* and *Figure 2-4*. Thus, it could not provide a portable interface while user was forced to spend time to pre-setup the exercise.

Suggestions

To resolve these issues, the system could be tweaked to extend their exercises to include the whole body scanning without using the AR markers in today's technology. For example, using devices such as Microsoft Kinect and Captury. These devices could capture human motions and enable user-system interaction without using fducial marker. As a result, full-body exercise could be tracked easily, thus allowing more challenging exercises to be designed instead of basic hand grasping exercises.

2.4 MirrARbilitation

MirrARbilitation was an AR rehabilitation system embedded with gesture detection and recognition mechanism [4]. It was developed to provide guidance in rehabilitation exercises, correcting users' performance, in addition to motivating them, then tracking and evaluating their performance. The main technology that had been utilized in the system include a Microsoft Kinect motion sensor to monitor users' 3D skeleton motion.

One of the features found in this system is the therapists have the flexibility to customize the exercise. For instance, they could configure the parameters such as movement precision and tolerance time for error, which represents the amount of time the system could accept for a wrong movement. [6]

Besides, the system also provided an evaluation mechanism to guide the user to perform the exercise correctly. This evaluation was being the movements were captured through the Kinetic RGB camera from Microsoft. Throughout the exercise, the users would be given instructions and movement correcting messages if errors were found in their actions. If the users make the same errors repeatedly, the physiotherapist could adjust the tolerance time for error for a particular patient.

Aside from that, MirrARbilitation also provided motivating features such as a scoring system. For instance, each time the user performed their movements correctly, they would be rewarded with points. When they reached a certain number of points, a congratulations message would appear and moved the users to a higher level.

For illustration, *Figure2-5* had shown how MirrARbilitation works.

(A-C) Firstly, elements and interface were presented, including the basketball, basketball net, collective points and motivational messages;

(D-E) The figures showed that the patient was reaching and catching game dynamics;

(F) Once the mission was completed in each level, the system displayed a motivational message: "Well done, now try the next level.";

(G-I) The system was displaying guiding instruction to correct wrong movement or posture, such as "Align your shoulders" and "Extend the elbow".

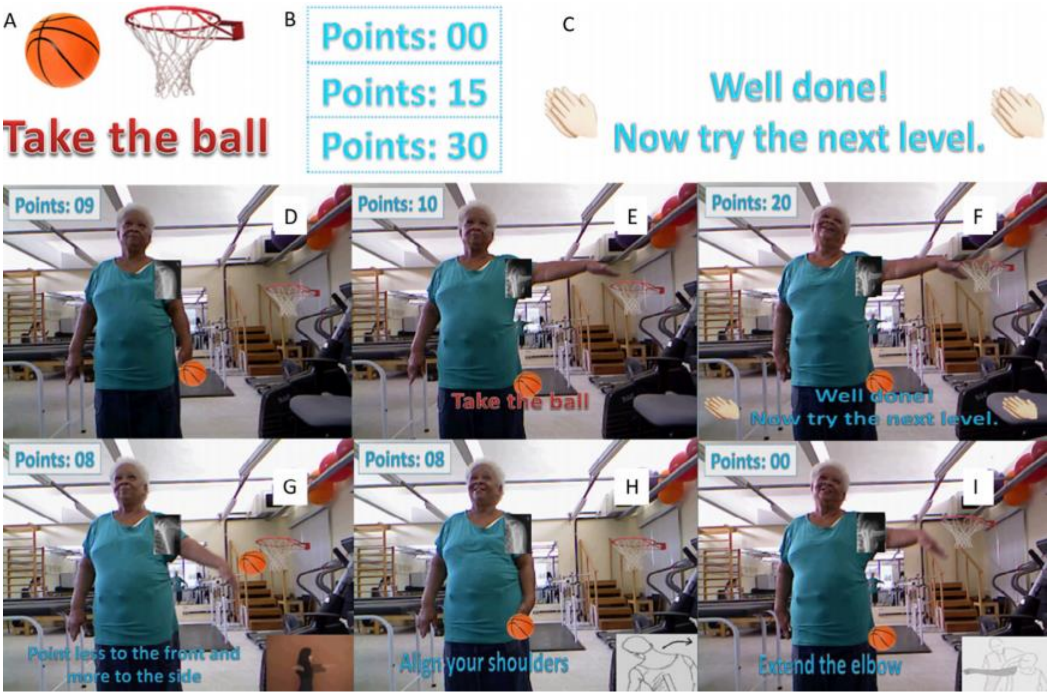


Figure 2.4.1: Therapeutic Exercises with MirrARbilitation

Strengths

One of the strengths of MirrARbilitation was it not only captured the users' motion like the previously discussed systems but also guide, motivate and correct patients' movements during rehab sessions, as well as evaluate their performance. The system would keep providing real-time feedback to the users to ensure users' engagement without having direct supervision of the therapist. The position can be configured according to the user's maximum range of motion or the angle which the physiotherapist desires the patient to attain. Other than providing a good user experience, the biggest novelty of it included the use of a low-cost and marker-less AR sensor. This sensor could function without sensing the fiducial markers and thus providing a portable and cost-effective interface to users.

Weaknesses

The system seemed to be perfectly matched whatever the patient and therapist need. Nonetheless, there were still some drawbacks to the system. Initially, the camera of Kinect sensor only capable to capture 30 frames per second, which means they can only detect simple motions (such as walking or jumping) and may miss-capture for rapid motion. Thereupon, this system was only suitable to design simple exercise.

Suggestions

The system is recommended to improve the algorithm on body pose tracking which able to capture more frames per seconds along with the incoming videos. Hence, more complicated exercise could be designed with the application to fulfil different treatment needs.

2.5 Summary for Strength and Weakness of Existing Systems

	Strength	Weakness
Rehab Guru	• Therapists are flexible to create therapy program • Demonstrating the exercises with animation, enable patients to understand easily	• Does not utilize AR technology to create immersive exercising experience • No valid mechanism to check the reliability of reported performance
GenVirtual	• Enables therapists to control, customize, and generate music melodies through user interface • Allows therapists to create different scenarios to each patient	• Exercises limited to either upper or lower body part • Limited effectiveness as not much strength required against virtual object • Function with fiducial markers • Less accurate to represent human body part
AR-REHAB	• Interact with real objects and experience the real force during exercises • Perceive the environment as a real environment • Quantitatively measured the patient performance and treatment progress	• Exercises limited to hand's movement such as grasping and holding • Function with fiducial markers • Less accurate to represent human body part
MirrARbilitation	• Provided real-time feedback • Provided guidance, motivation to users • Correct users' performance	• Only capture for 30 frames per second

	• Therapists could configure the exercises based on patients' condition • Using Kinect sensor which was low-cost and marker-less	• Kinect sensor was not capable to capture fast motions • Only basic exercise is applicable • Kinect only extracted skeleton that consist only 20 joints

Table 2.5.3 The summary of Strengths and Weakness of different AR systems.

2.6 Critical Remarks

This section points out three common, but critical problems encountered in the extant systems.

i. **The previous studies were unable or failed to accurately localize more key point to represent human pose.**

Current studies had several issues in portraying key points of the human body. In Rehab Guru Pro and GenVirtual, no topology was used to represent body parts. Meanwhile, MirrARbilitation utilized a human body topology but only had 17 landmarks to represent the whole body. As shown in *Figure 2*-6, it only localized to the ankle and wrist points, without scaling the details for hands and feet. These two approaches would face the same difficulty on guiding users to perform single body parts exercises. E.g.: tracking whether users were moving their thumbs was difficult when the algorithm only used single point to represent the hand palm. As a result, evaluation performance would be limited on certain body parts.

ii. **The previous studies were limited to resolves a critical problem in current pose estimation's approaches: occlusions.**

Occlusion is the situations when the body parts or other objects are occluding limbs as seen from the camera. Therefore, the pose recognition algorithm proposed in the previous studies would not able to function and infer the human body pose when the exercises required users to lay down.

iii. **The previous studies were limited to resolves the limitation of sensors performance.**

The effectiveness of sensors was limited while it could only capture 30 frames per second. As a result, those exercises with higher motion speed are not available. It was lacking flexibility for therapists to design exercises for their patients.

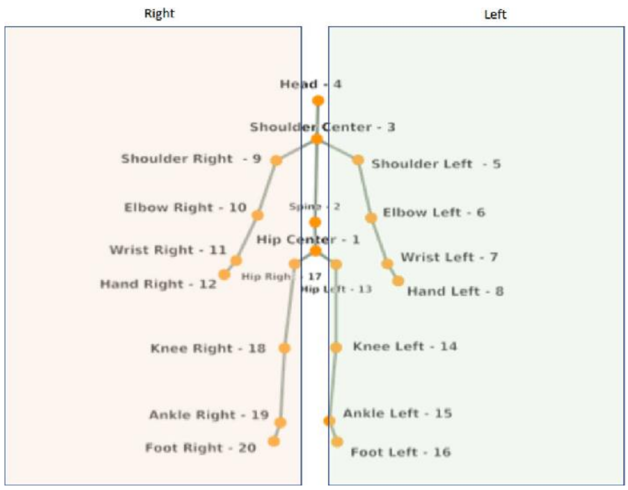


Figure 2.6.1: Topology of the 3D human, skeleton joints as derived by the Kinect sensor

Hence, the mobile application to be developed will be focusing on these 2 questions: What is the current topology available with higher performance and accuracy? How does it possible to be integrated with the system to be developed? In short, these limitations can be resolved by discovering the technologies with new topology with higher accuracy and performance to localized body key points.

The following table shows the comparison between different applications with the proposed system:

	Rehab Guru Pro	GenVirtual	AR-REHAB	MirrARbilitation	Proposed System
Accurate Body Key Points Detection	✕	✕	✕	✕	✓

Real-time Instructions	✕	✓	✓	✓	✓
Solved Occlusion for Body Detection	✕	✕	✕	✕	✓
Full-body Exercises Available	✓	✕	✕	✓	✓
Capture High Speed Motion	✕	✕	✕	✕	✓
Marker-less AR Sensor	✕	✕	✕	✓	✓
Performance Evaluation	✕	✕	✕	✓	✓

Table 2.6.1: Comparison in Reviewed Systems and Proposed System

CHAPTER 3 SYSTEM METHODOLOGY AND APPROACHES

3.1 System Methodology

The methodology used to design the project is the waterfall model. The Waterfall model is a methodology that divides the system development process into five stages: requirements, specification, design, implementation, testing, and maintenance. This model is selected because the application to be developed in this project is considered as small projects where its requirements are clear and not equivocal in specification phase. It is unlikely to have changes in requirements since this project is not sponsored and does not have to deal with different stakeholders. As shown in *Figure 3-1*, the phases of the processes are look like a flow in a linear and sequential form.

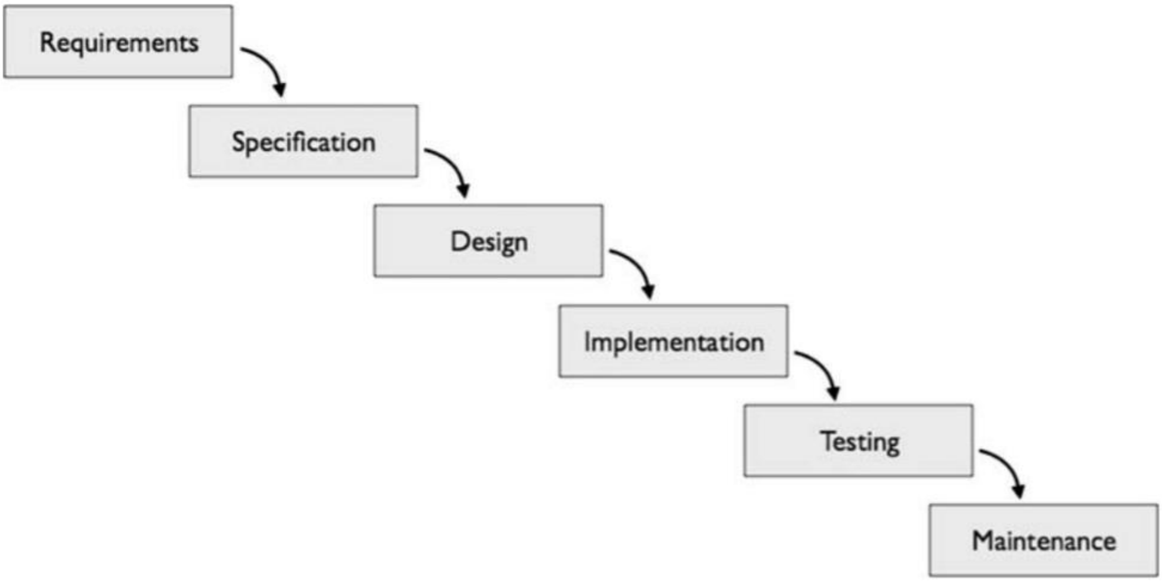


Figure 3.1.1:Diagram of the waterfall software development process model

CHAPTER 3 SYSTEM METHODOLOGY/APPROACH

The following statements describes activities in each phases of waterfall methodology:

1. **Requirement and Specification**

   The system's functionality and requirements that must be achieved are defined. The system is specified to be able to capture frames from device camera, process the incoming frame to render AR components on the frame, and present it the processed frame to the user. Also, it should perform body movement tracking, provide real-time instruction during the rehab training verbally and visualy, count the user's repetition, and send feedbacks to the user's email. Lastly, the system should be able to provide full body exercises to users and able to capture the exercise video for future reference.

2. **Design**

   In this phase, the system's architectural design in accordance with system requirements is prepared. Python is the main language selected to implement the deep learning model of human body pose from Google Mediapipe. Other software platform such as Electron and Nylas are discovered and selected to be develop the main function including GUI and email module in the project. Other than that, post-stroke exercises that target to different body part are also gathered to be developed in the project.

3. **Implementation**

   This phase is going to implement the system design from design phase. In this project, the flow of implementation will go with first developing the main exercise module, including perform body detection and movement tracking in real-time. Then, it is followed by developing other module such as implementing counter for exercise performance, instruction guidance, feedback module and video history module.

4. **Testing**

   Module testing is carried out to ensure human body can be well detected. After module testing, all of the pieces of code for each sub-module are integrated and deployed in the testing phase to ensure the system's consistency and efficiency. The integrated version of application will undergo a list of testing for debugging purpose. Apart from debugging, the system is examined to ensure it meets the requirements.

5. **Maintenance**

This project will not undergo the maintenance phase because the built system is still in the prototype stage.

3.2 Use Case Diagram

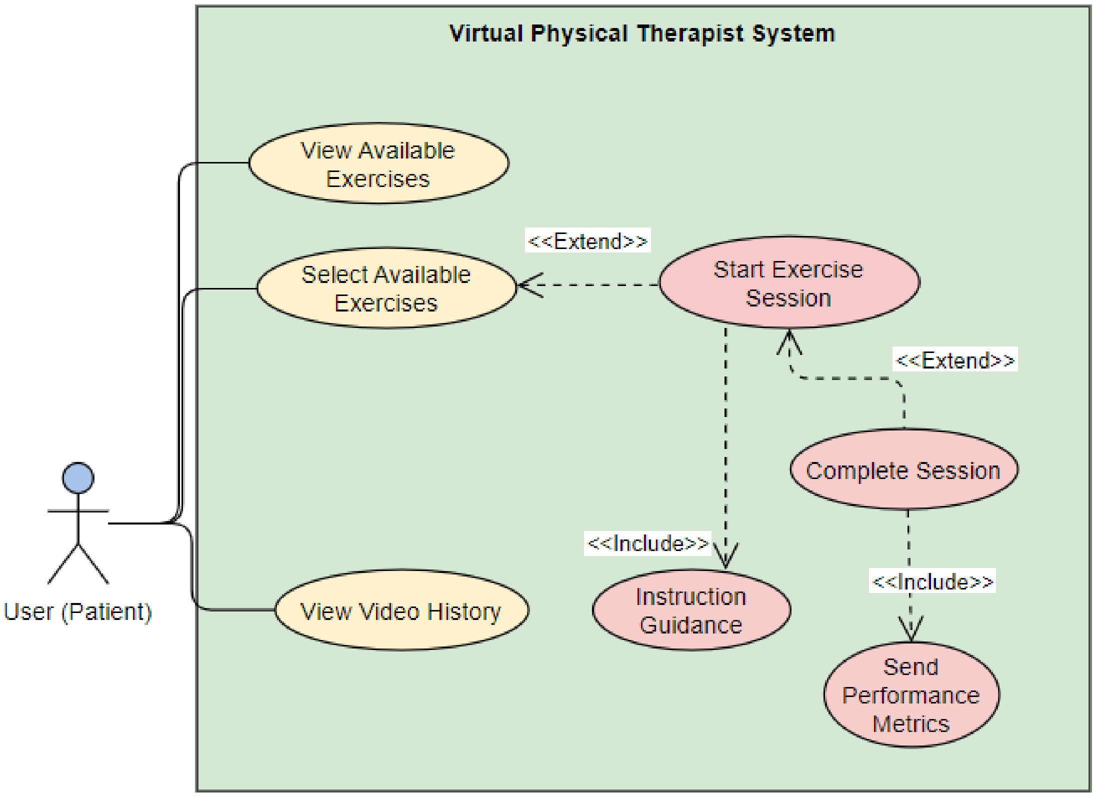


Figure 3.2.1 Use Case Diagram

The main system users in the Virtual Physical Therapist System are Patients. As a Patient user, they can view and select available rehabilitative exercises from the GUI to start an exercise session. Once a exercises set is completed, the performance results, such as performance duration and mistakes will be sent to user's email. Simultaneously, the process of exercising will be recorded and uploaded to cloud. Then, patients can assess their performance by viewing recorded video through the video history dashboard.

3.3 Activity Diagram

Rehabilitation Session with Body Detection and Pose Estimation

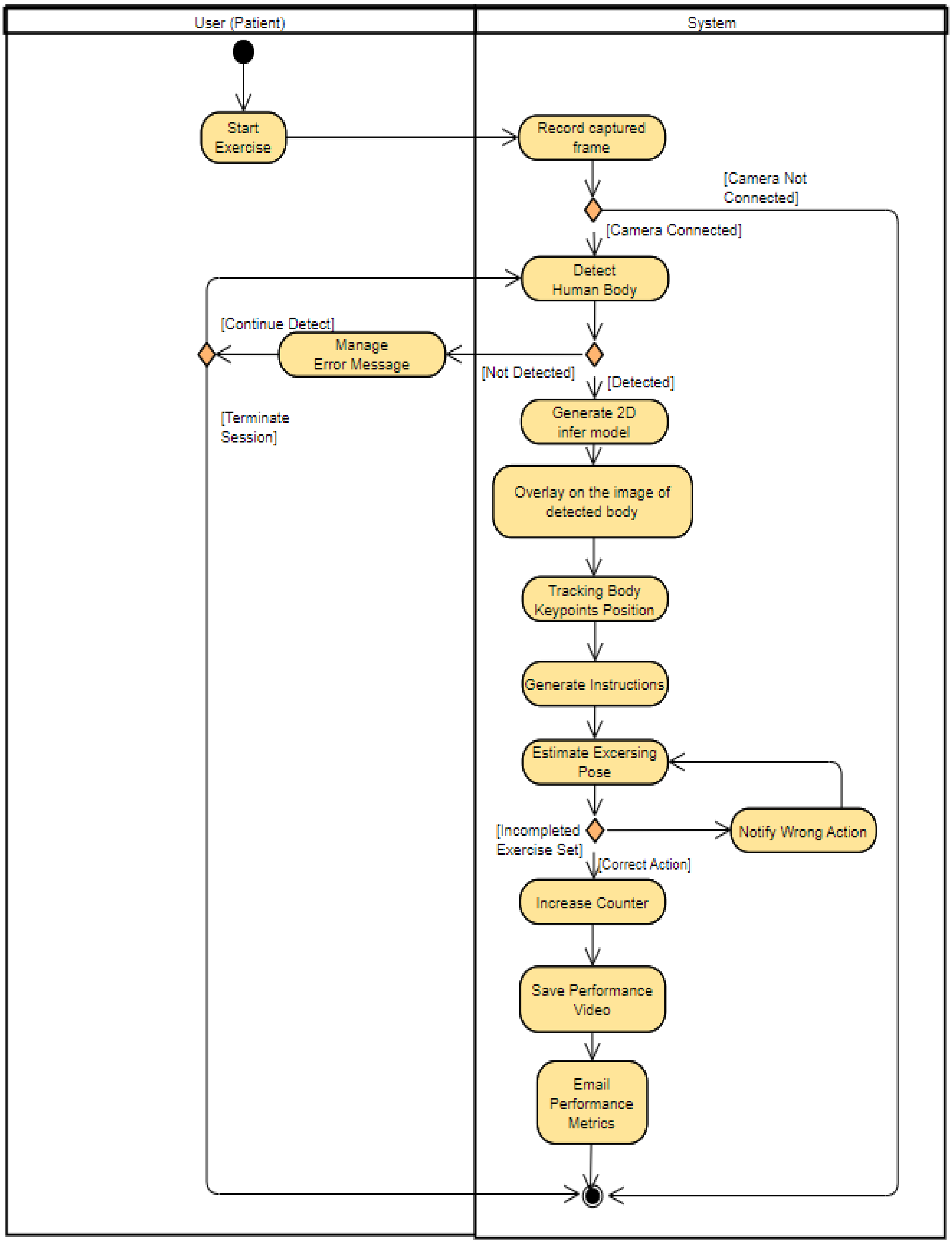


Figure 3.3.1 :Activity Diagram of body pose detection and estimation

Viewing Performance Video Dashboard

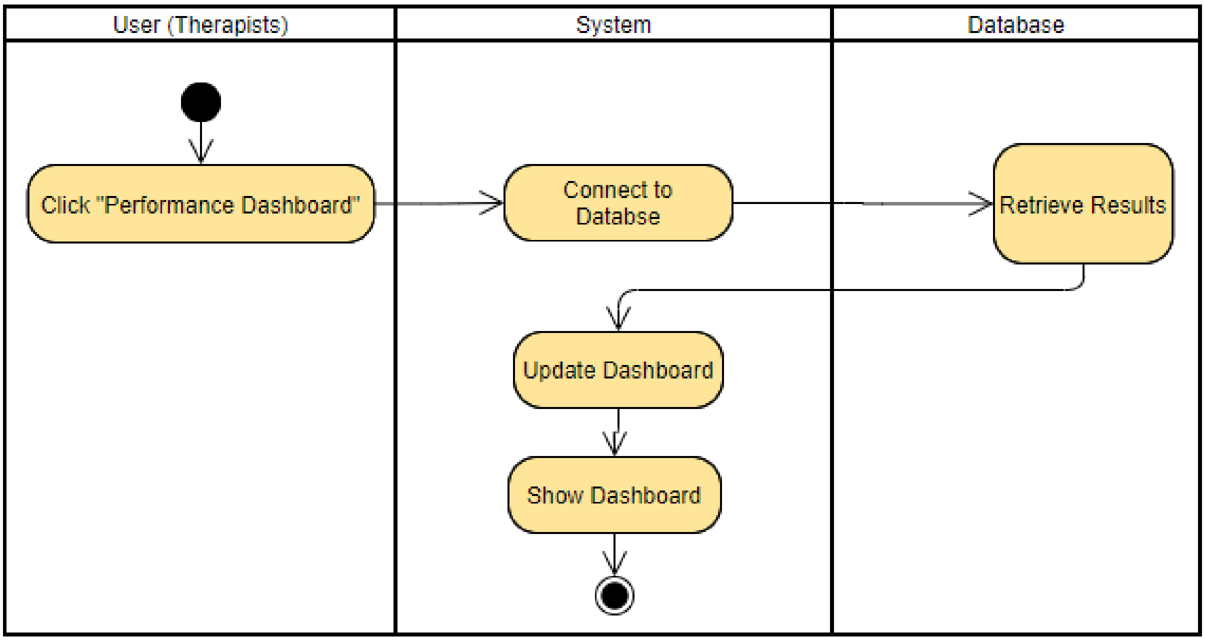


Figure 3.3.2 :Activity Diagram of body pose detection and estimation

3.4 System Design Specification

3.4.1 Key Softwares and Frameworks

a. Google BlazePose Framework

BlazePose is a real-time body gesture recognition tool from Google. Using BlazePose, it can accurately localize more body key-points to represent human pose compared to other approaches such as COCO. It resolves the critical problem of occlusions and enables the inference to run at over 30 frames per second on a Pixel 2 mobile phone. As *Figure 4-2* shows, the pose model will be generated based on the superset of COCO, BlazeFace and BlazePalm topologies to infer 33 landmarks of a body.

In this project, after the model detected the human body landmarks, these landmarks will then be overlayed on top of the human body in real-world, creating an AR-based immersive user experience. The overlays are able to assists users to see their posture clearly.

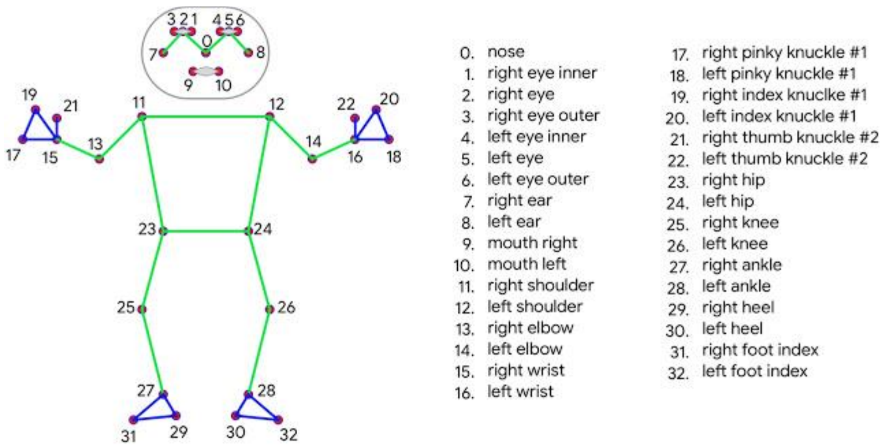


Figure 3.4.1.1: Topology of the 3D human in landmarks as derived by the BlazePose, Google

b. Open-source computer vision (OpenCV)

OpenCV is the most widely used open-source computer vision and machine learning software library, with a focus on real-time computer vision. With hundreds of computer vision algorithms, OpenCV offers a shared architecture for computer vision applications.

c. Electron

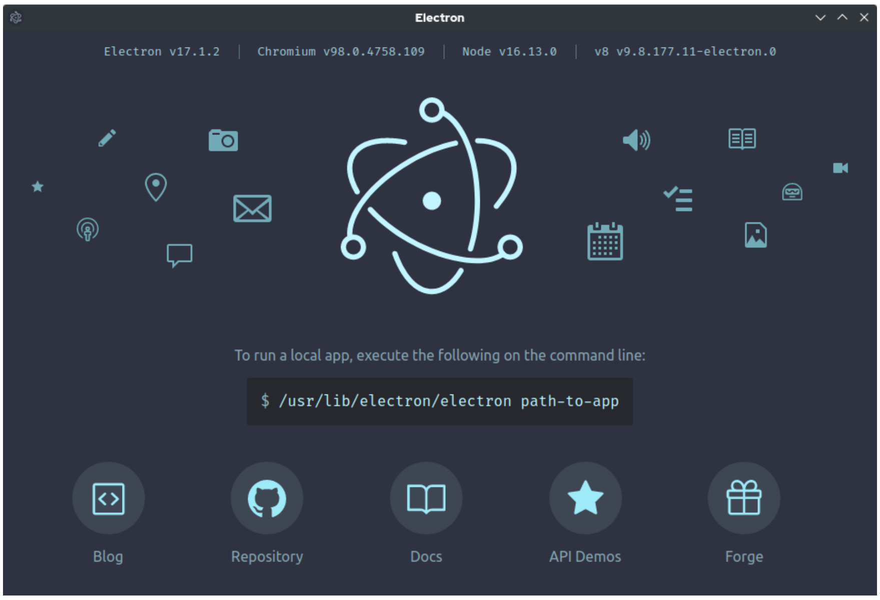


Figure 3.4.1.2 Electron Software Framework

Electronic is developed and maintained by GitHub and is free and open-source software. It combines the Chromium rendering engine with the Node.js runtime to enable the development of desktop GUI applications. It is used in front-end development and communicate to back-end python in this project.

d. Microsoft Visual Studio Code

The integrated development environment (IDE) Microsoft Visual Code is used in this project to create web applications. It comes with many built-in programming languages, including C, C#, and C++. It also includes many functional tools such as a source code editor, debugger, GUI design tool, all of which are needed in this project. It is the main environment used to code, run and test the system.

e. Open-source computer vision (OpenCV)

OpenCV is the most widely used open-source computer vision and machine learning software library, with a focus on real-time computer vision. With hundreds of computer vision algorithms, OpenCV offers a shared architecture for computer vision applications.

f. Nylas

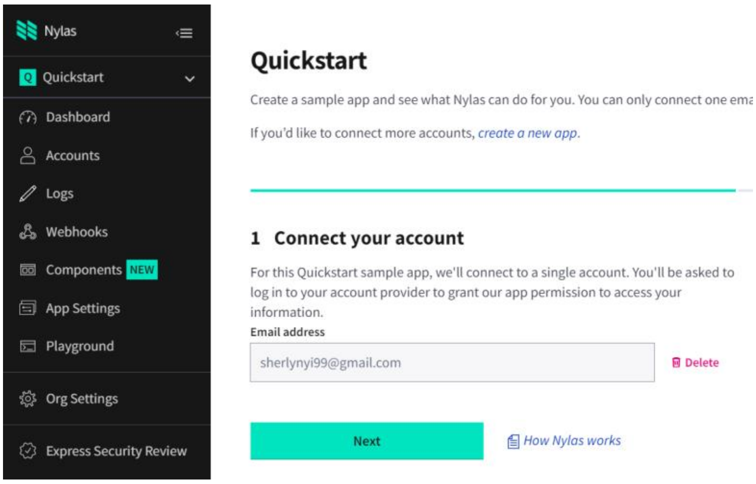


Figure 3.4.1.3 Nylas GUI

Nylas is a software platform that provides email API that enable developers to connect their applications to their user's inboxes while no code skill is required. Nylas is used to schedule email and send feedback email to users whenever they have completed a set of exercise.

3.4.2 Hardware

1. **Laptop**

System Type	Microsoft Windows 10
Processor	Intel® Core™ i7-8750 CPU @ 2.20GHz
Graphics Processor	Intel® UHD Graphics 630
Graphics Card	NVIDIA GeForce GTX 1050
RAM	16.0GB DDR4 2666MHz

Operating System	Microsoft Windows 10 (Home Edition)

Table 3.4.2.1 Hardware specifications of Laptop

3.4.3 Tools to Use

Software Development Tools

Particulars	Tools
Operating System	Window Subsystem for Linux (Ubuntu), Microsoft Window 10
Integrated Development Environment (IDE) and Framework	Visual Studio Code, Jupyter Notebook, Anaconda Distribution, Electron
Programming Languages	Python, HTML5, CSS, JavaScript
Libraries, Database	OpenCV, Google Firebase, Flutter, Google Mediapipe, gTTS
Platform	Nylas

Table 3.2: Software Tools for Development

3.4.4 User Requirements

Functional Requirements

- The user should be able to check available exercises.
- The user should be able to start the exercises with mobile phone.
- The user should be able to view exercise instructions.
- The user should be able to receive corrections message when they erxercise wrongly.
- The user should be able to check remaining repetitions during exercises.
- The user should be able to check their performance results in dashboards.

Non-Functional Requirements

- The system should be able to detect human body in the incoming frames.

- The system should be able to detect human body when it is presented in various angle.
- The system should be able to track human pose even when the user is moving.
- The system should be able to localize body key points and marks every key point with corresponding landmarks.
- The system should be able to overlay the landmarks on the human body.

3.4.5 System Performance Definition

To achieve better human body detection, topology with higher performance and accuracy will be used, which able to detect at least 33 human body key point. Hence, the system should be able to access and capture the incoming frames when it is connected to an opened camera.

For pose tracking, no matter the users is presented in what angle (e.g.: side-standing or sitting), or whether they are changing their pose, pose tacking in the system should always work fine, as long as the device camera is capturing the whole body. If the user is performing the exercises wrongly, the system should able capture the wrong action and send the alert message.

In terms of speed, the system should be able to quickly localize and marks the human body key points, shows exercise counter, and instructions and overlaying these objects on top of the frames, creating an AR-based immersive rehab session. Once the human body is shown to the camera, the system should able to overlays the objects on the device screen within 1 second. After patients completed a rehab session, the system should process and visualize the data and presented it to the therapists within 5 seconds.

Chapter 4 SYSTEM DESIGN

4.1 System Block Diagram

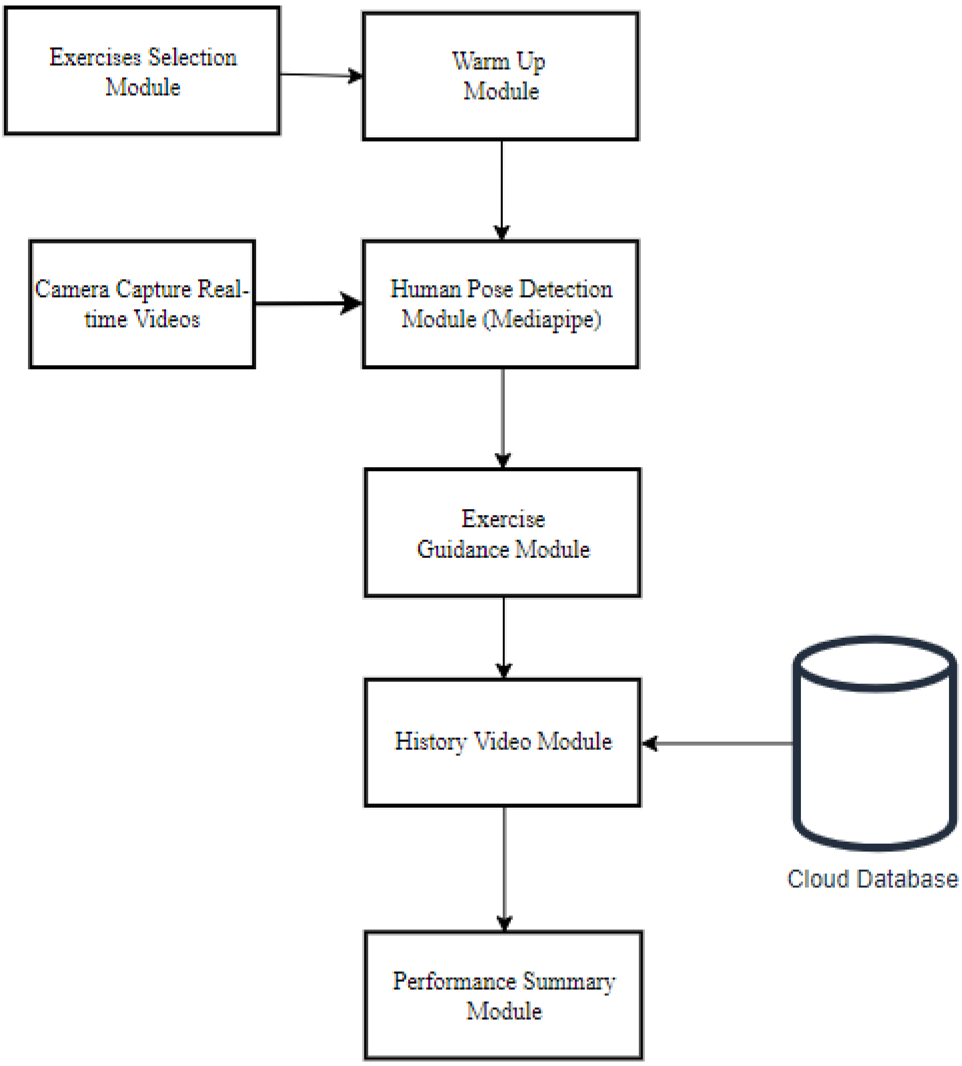


Figure 4.2.19: System Block Diagram

Basically, users will first enter the main menu when they entered the application. When they enter the exercise interface, they will have multiple choice of exercise to be started. When the exercise was chosen, it will show the illustration of the exercise in the form of picture and give a warm up session by counting down 3 seconds for user to prepare. When the exercise began, Physio Helper will validate that the exercise was being done correctly by examining the angle between different joints. During the exercise, counter will increases if the user perform correctly until total rep was being completed. While the user complete the exercise, they will receive their training statistics in their email. At the same time, their performance will be recorded in the form of video and upload to cloud storage. They can view it anytime in video history interface. During the trainer detects the human being in a video stream using machine learning algorithms and returns the location of body joints and body parts.

4.1.1 Exercise Selection Module

Sets of rehabilitative exercises is available in the local storage of the app. The type of exercises is mainly focused for rehabilitation of pro-stroke patients. The set of exercises is taken from the article by Margarita Tartakovsky from *Healthline* [1], which is the author for Psych Central for more than a decade. Exercise such as 'Weight Shifting', 'Ball squeeze', 'Knee Extension' and 'Standing Hip Abduction' are extracted from the article '8 Exercises for Spasticity After a Stroke' written by him [1]. With set of available exercises, users can selects and starts a particular exercise, the camera automatically turns on to capture the user's process. When the connected camera is opened, the system will perform human body detection based on the incoming frames.

4.1.2 Body Pose Detection and Movement Tracking Module

The system provides body pose estimation that tracking the user's movements in real-time. During exercises, the system will keep tracking their movements and the overlayed objects will keep follows the human body movements. Besides, corrective messages will be pop out if patients are performing wrongly.

4.1.3 Exercise Guidance Module

When the user starts the exercise, the system will provide 3 seconds of warmup notice visually and verbally. For example, it will notice the incoming exercise, saying: 'up next is Leg Extension exercise' and count down '3', '2' '1' and 'Start!'. The human body will be detected and marked with white color once the exercise started. Once the user did the exercise correctly, the body marked will turns green and the system will count the completed reps verbally. Also, when users completed one rep, the system will notice them the number of counter in verbal.

4.1.4 History Video Module

When the user had completed a rehab session, the video during exercise will be captured. The captured video will be stored locally. Then, the system will compare all file name exist in local file and Firebase Storage to check if there is new file nam. If yes, the system will upload new video file to the Firebase Storage. When the user enter history video module, the system will load target video list from Firebase Storage and return all the video in list. Then, the system allow user to access the video anytime. When the recorded video is playing, user can choose to enlarge or download the video anytime.

4.1.5 Performance Summary Module

When the users completed a set of exercise, the system will send the performance summary including the exercise type, count of repetitions, and the exercise duration to the user email.

CHAPTER 5 SYSTEM IMPLEMENTATION AND TESTING

5.1 System Implementation

5.1.1 Body Pose Detection and Movement Tracking Module

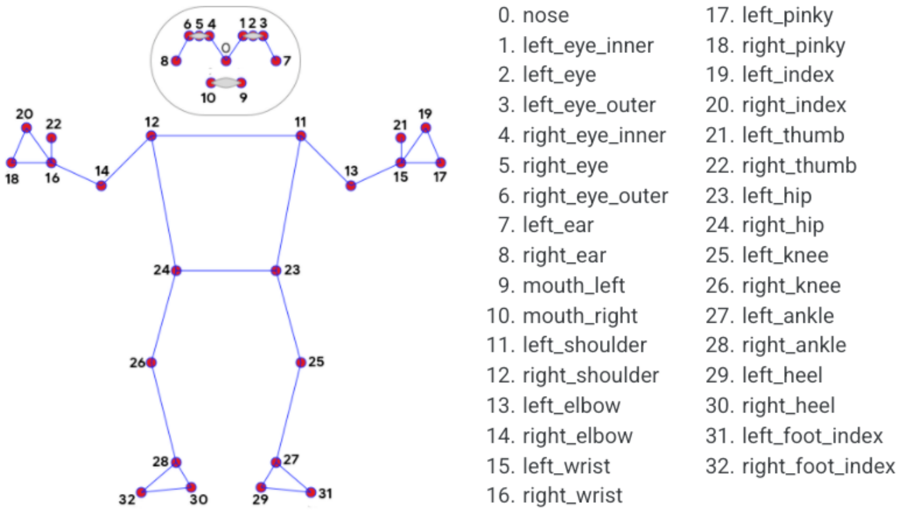


Figure 5.1.1.1: Pose Detection Model from Mediapipe

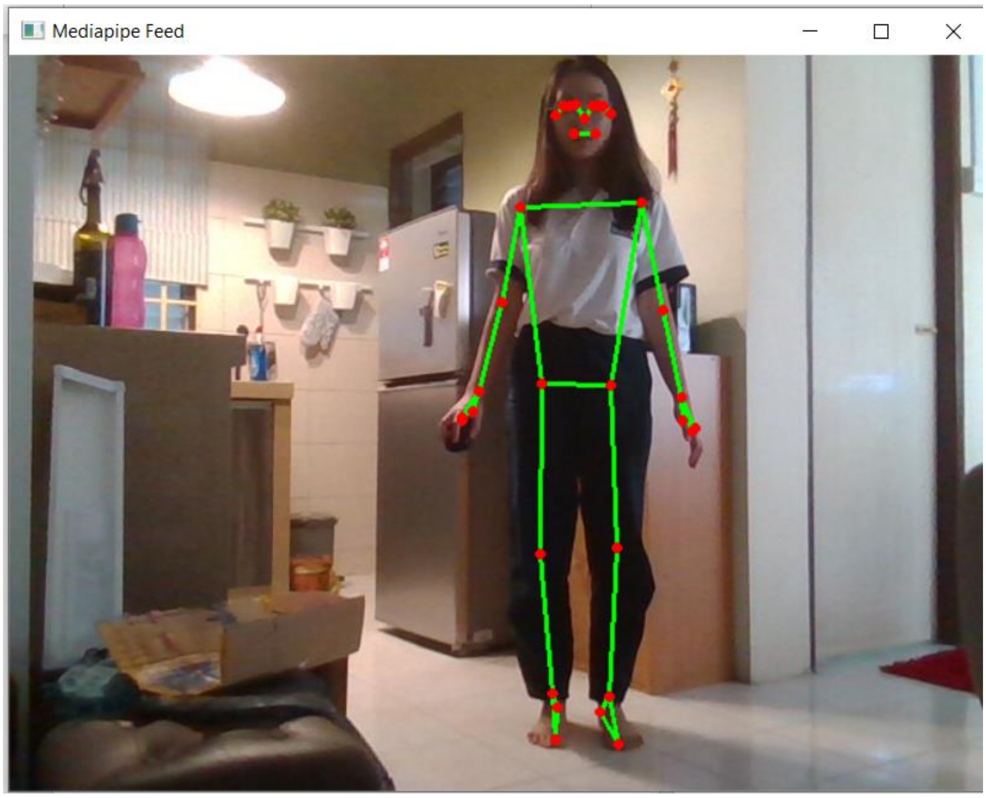


Figure 5.1.1.2: Pose Estimation with full body

Using Python and Mediapipe, Physio Helper is able to extract (x,y) coordinates of human joints or body parts in an image using ML as shown in *Figure 5.2.1*. Device camera is required to connect to the program and read the frame from it. Mediapipe and OpenCV library were required to import for body detection. Due to Mediapipe only process image in RGB format, incoming frames must be recolored to RGB format before passing to the model. Mediapipe also provided numerous deep learning model such as Face Detection, Iris, Hands, Pose, etc. During detection, Pose model was being used to perform full-body detection to return the localized body joints. By using the drawing utilities from Mediapipe, every detected joint can be visualized by marking and linking them as showsn in *Figure 5.2.2,* forming an effect of overlaying AR-based objects on top of the actual world.

5.1.2 Exercise Selection Module

Every exercises are designed by applying methematical functions to calculate the angle between targeted joints. The chosen exercise for full or half-body training includes Leg Lifting, Weight Shifitng and Hip Abduction. Each of these exercises is implemented by extracting the starting and ending angle between different joints.

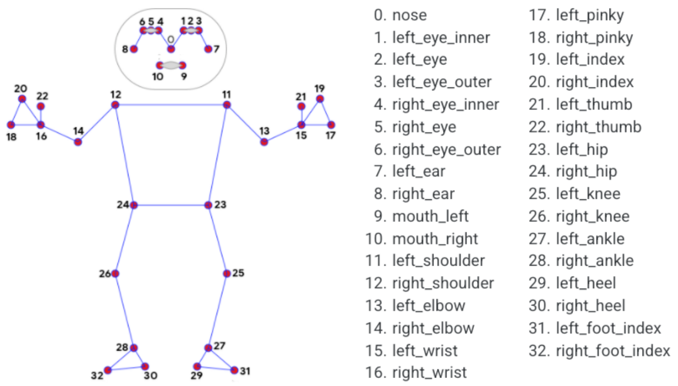


Figure 5.1.2.1: Pose Detection Model from Mediapipe

Full-body Exercise with Mediapipe Pose Model

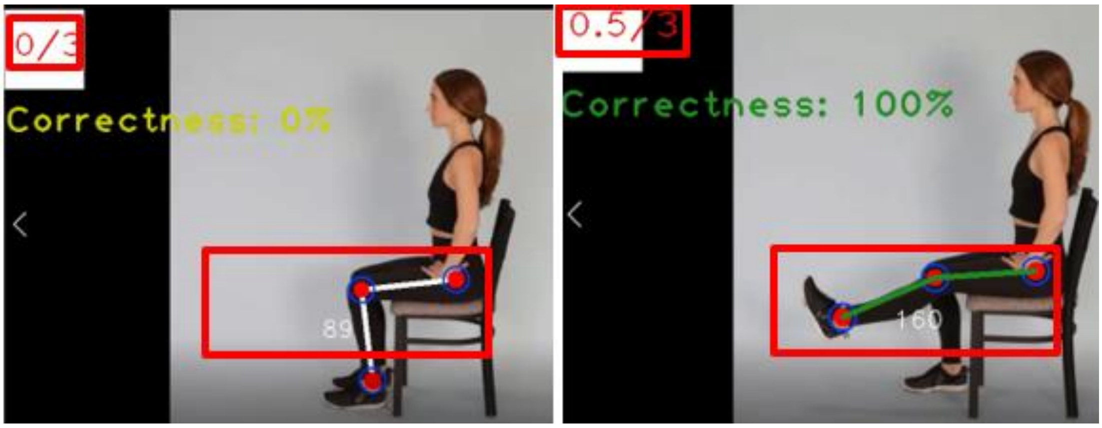


Figure 5.1.2.2 Angles extracted for Leg Lifting Exercise for Correct and Wrong Posture

Take the leg extension exercise as an example, the demo video will first be imported to the application as an input to extract the data for correct motion. the pose landmarks of 23, 25 and 27 in *Figure 5.1.2.1* are extracted to measure the angle of left knee, left hip and left ankle. With the extracted angle, the starting point and ending point of the angle could be defined for the Leg Lifting exercise.

```
def repitition_counter( self,per, count, direction):
    if per == 100 and direction == 0:
        count += 0.5
        direction = 1
    if per == 0 and direction == 1:
        count += 0.5
        direction = 0
        if int(count) != 0:
            print("here")
            speaker_thread = threading.Thread(
                target=text_to_speech, args=(str(count)), kwargs={}
            )
            speaker_thread.start()
    return {"count": count, "direction": direction}
```

Figure 5.1.2.3 Implementation of Repetition Counter

Other than extracted angle, the stage of the body parts was essential to be recorded. This is to prevent the counter keep increasing when a correct motion keep being detected in the incoming frames. For example, the initial stage is initialized to ‘0’. Wthe leg was lifting up until a desired angle between joints are detected, the stage should change to ‘1’ and counter will increase 0.5. Then, the stage should return to ‘0’ if the leg was positioned to the original point and counter will add on 0.5. The combination of stage ‘0’ and ‘1’ will help the counter to recognize a repetition has been completed.

while the angle change from 90 ° to 180°, the system will mark it as correct action and the counter increases 0.5. While users drop down the leg to original position, counter will further increase 0.5, which mean 1 rep of the set is completed.

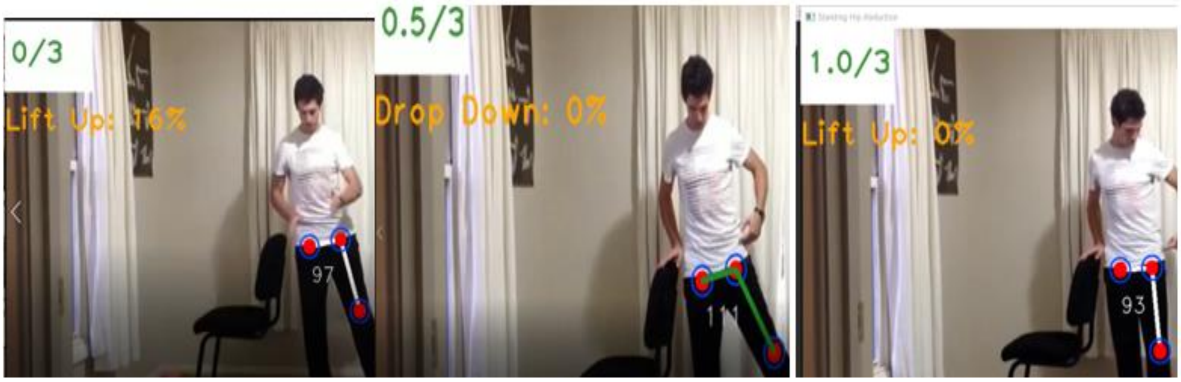


Figure 5.1.2.3 Angles extracted for Standing Hip Abduction Exercise

Other exercise had the similar implementation of Leg Lifting. For Standing Hip Abduction exercise, landmarks of 24, 23, 25 that represents right hip, left hip and left knee were extracted to perform the action with the threshold angle from 95 ° to 110°.

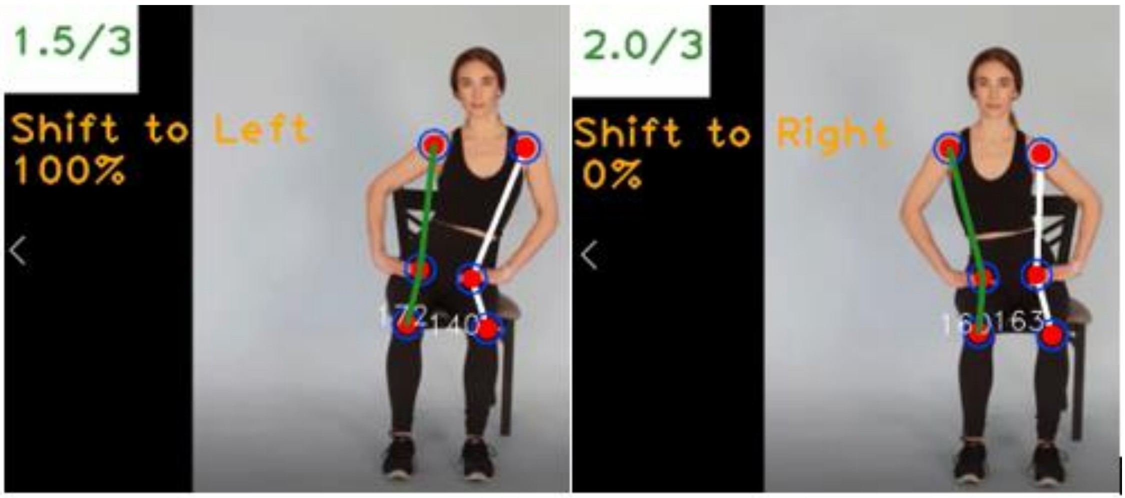


Figure 5.1.2.4 Angles extracted for Weight Shifting Exercise

Weight Shifting exercise was extracting landmark of (12, 24, 26) to measure the angle between right shoulder, right hip and right knee. The threshold angle was set between at 164° and 172°.

Hand Exercise with Mediapipe Hand Model

The selected exercise for hand movement was hand griping, which is also meant to make a fist. Hand model from Mediapipe was imported. The imported model was able to detect 21 key points of a human hand. In order to detect a hand griping movement, every fingers coordinates was extracted using a loop. The fist could be detected when a joint 7,11,15,20 and 4 falls below the coordinates of 5, 9, 13, and 17.

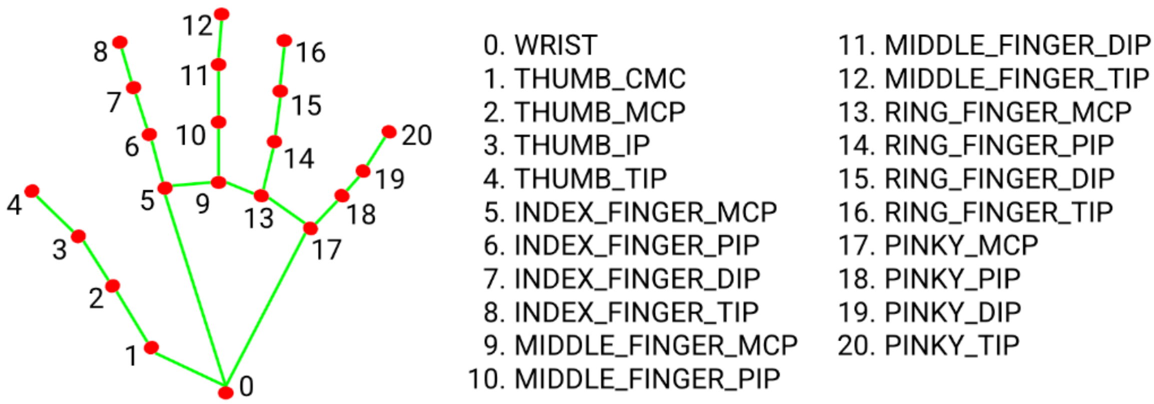


Figure 5.1.2.5 Hand Landmarks Detection from Mediapipe

Measurement of Performance

```
while count < total_reps:
    success, img = cap.read() # read input stream
    img = detector.find_person(img, False) # detect person
    landmark_list = detector.find_landmarks(img, False) # detect all landmarks

    if len(landmark_list) != 0:
        left_leg_angle = detector.find_angle(img, 23, 25, 27, draw=True) # find and print angle for ri

        # Calculate left leg performance
        per = np.interp(left_leg_angle, (90, 159), (0, 100)) # angle, convert the correct angle range
        bar = np.interp(left_leg_angle, (90, 159), (0, 100))

        color = utilities().get_landmarks_color(per) # different exercise status, get different color

        if per == 0 or per == 100:
            rep = utilities().repitition_counter(per, count, direction) # return count, direction
            count = rep["count"]
            direction = rep["direction"]
        detector.draw_performance_bar(img, per, color, 23, 25, 27)
```

Figure 5.1.2.6 Defining Starting and Ending Angle between Joints

Figure 5.1.2.7(a) Performance visualised in percentage (before)

Figure 5.1.2.7(b) Performance visualised in percentage (after)

According to the red box in *Figure 5.3.1,* the threshold of the min and max angles was defined in *Figure 5.3.2* and converted to the range of 0 to 100 to calculate the completeness of the movement.

5.1.3 Exercise Guidance Module

Warm Up Session and Counter with Speech

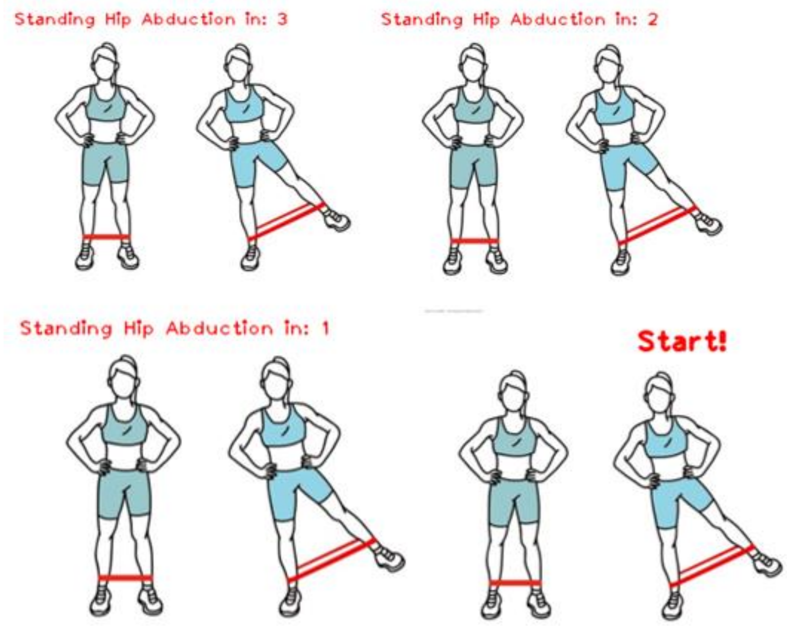


Figure 5.1.3.1: Warm up session withcountdown counter

Before the exercise started, the system gives a warm up notice in 3 seconds. The system will notice the coming exercise, saying: 'up next is Exercise 1' and count down '3', '2' '1' and 'Start!'. Also, when users completed one rep, the system will notice them the number of counter in verbal.

```
while seconds > 0: # close windows when seconds=1
    img = cv2.imread(example)
    img = cv2.resize(img, (980, 550))
    # print("in here1")

    time.sleep(1)
    speaker_thread = threading.Thread(
        target=text_to_speech, args=(str(int(seconds))), kwargs={}
    ) # notice warmup duration for each second
    speaker_thread.start() # thread throw 1 and 2 and 2 to text_to_speech()
    # time.sleep(1)
    cv2.putText(
        img,
        exercise + " in: " + str(int(seconds)), # shows 3,2,1 second
        (350, 50),
        cv2.FONT_HERSHEY_PLAIN,
        3,
        (0, 0, 255),
        5,
    )
    time.sleep(1)
```

Figure 5.1.4: Mutilthread for countdown counter

The countdown timer and exercise counter is implemented by running multiple threads at once together with the time module and its sleep function. A while loops in executed to run until time becomes 0. To prevent the windows closes immediately, one could use time.sleep() function to make the code wait for one second.

```
from datetime import datetime
import datetime
import speech_recognition as sr
from gtts import gTTS
import os
from io import BytesIO
from playsound import playsound

language = 'en'

def text_to_speech(text):
    output = gTTS(text=text, lang=language, slow=False)
    date_string = datetime.datetime.now().strftime("%d%m%Y%H%M%S")
    filename = "voice"+date_string+".mp3"
    output.save(filename)
    playsound(filename)
    os.remove(filename)
```

Figure 5.1.5: Text to Speech function

Warm up session is coming with displaying exercise illustration and playing audio sound to count down the remaining warm up seconds. Python playsound library and Google Text To Speech library were utilized to implement this function. The gTTS function will pass the text and language to the engine and the converted audio will be saved in OS in mp3 format; while playsound will play the converted audio during the exercising in real-time.

5.1.4 History Video Module

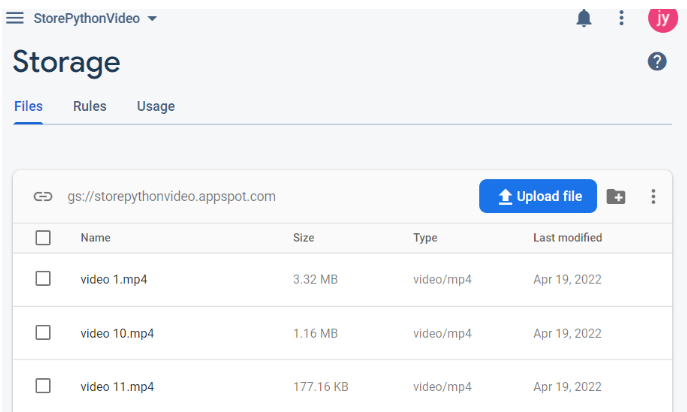


Figure 5.1.4.1: Recorded video stored in Firebase Storage

When the users starts an exercise, a python script will be executed from JavaScript. During the exercises, camera frames will be collected, recoded and save to a local file. Once a set of exercise is completed, a python function will be called to upload video to Firebase. Every filename in Cloud and local will be compared to check if there is any new video recorded, when new file is discovered, the upload function will be triggered to upload new local video to cloud. Then, firebase will return list of video url and stored in a JavaScript array. The returned URL will then append the HTML code to embed video on the page. All the stored video can be accessible through the URL.

5.1.5 Performance Summary Module

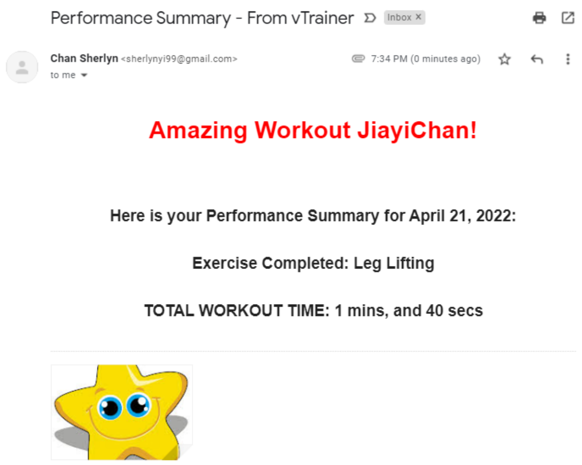


Figure 5.1.5.1: Performance metrics feedback to user through email

Nylas is a software platform that provides email API that enable developers to connect their applications to their user's inboxes while no code skill is required. While connected to Nylas API, Nylas is used to schedule email and send feedback email to users whenever they have completed a set of exercise. Physio Helper registered an account on Nylas, by using Nylas client ID, client secret and access token, the application is able to send performance metrics to the user email address.

5.2 System Testing

Listed below are the proposed testing result for each module testing.

5.2.1 Home Page Testing

Modules were displayed on the application home page. Users should be able to interact with the application by clicking the module as an input.

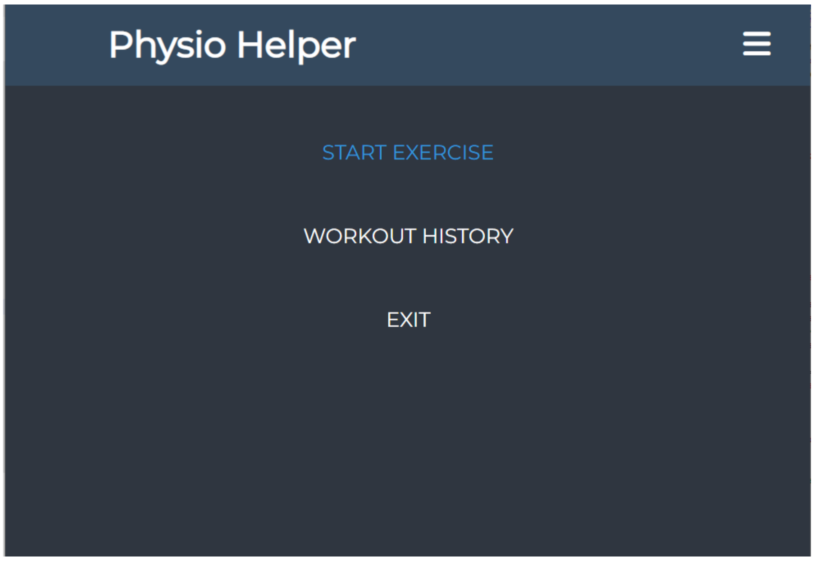


Figure 5.2.1.1 Home Page

Upon launching the application, the system should display main pages that display the main function of the application.

Test Action	Expected Result	Meet Expectation (√/×)
User click ‘start exercise’.	System directs user to Exercise interface.	√
User click ‘workout history’.	System directs user to Workout History interface.	√

Table 5.2.1.1 Test Result for Home Page

5.2.2 Exercise Selection Module Testing

Upon launching the Exercise interface, the system should display available exercises that display the main function of the application.

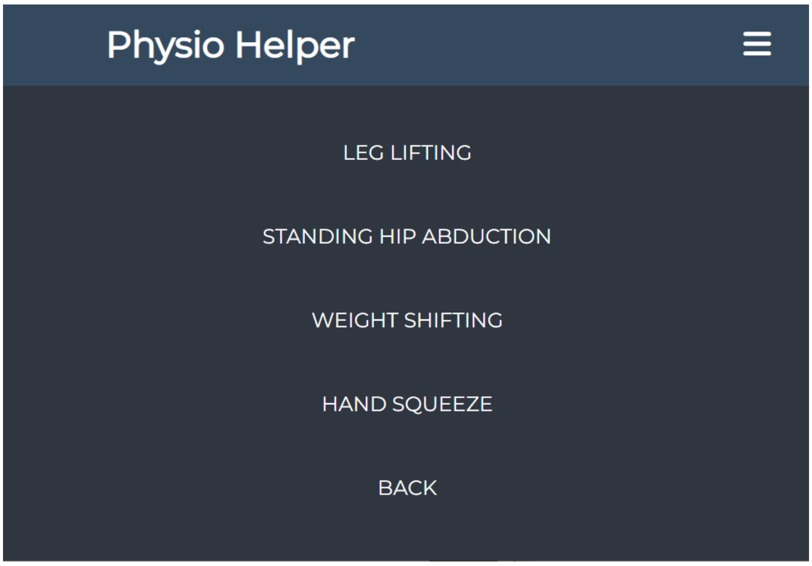


Figure 5.2.2.1 Exercise Page

Test Action	Expected Result	Meet Expectation (√/×)
User click 'Leg Lifting'.	System directs user to the corresponding Exercise interface.	√
User click 'Standing Hip Abduction'.	System directs user to the corresponding Exercise interface.	√
User click 'Weight Shifitng.	System directs user to the corresponding Exercise interface.	√
User click 'Hand Suqeeze'.	System directs user to the corresponding Exercise interface.	√
User click 'Back'.	System directs user to the Home Page.	√

Table 5.2.2.1 Test Result for Exercise Page

5.2.3 Video History Module

When the user had completed a rehab session, the video during exercise will be captured and updated to the user database. This information can be retrieved and accessed by the patients in the history module. Each of these video should be stored in cloud storage for future access.

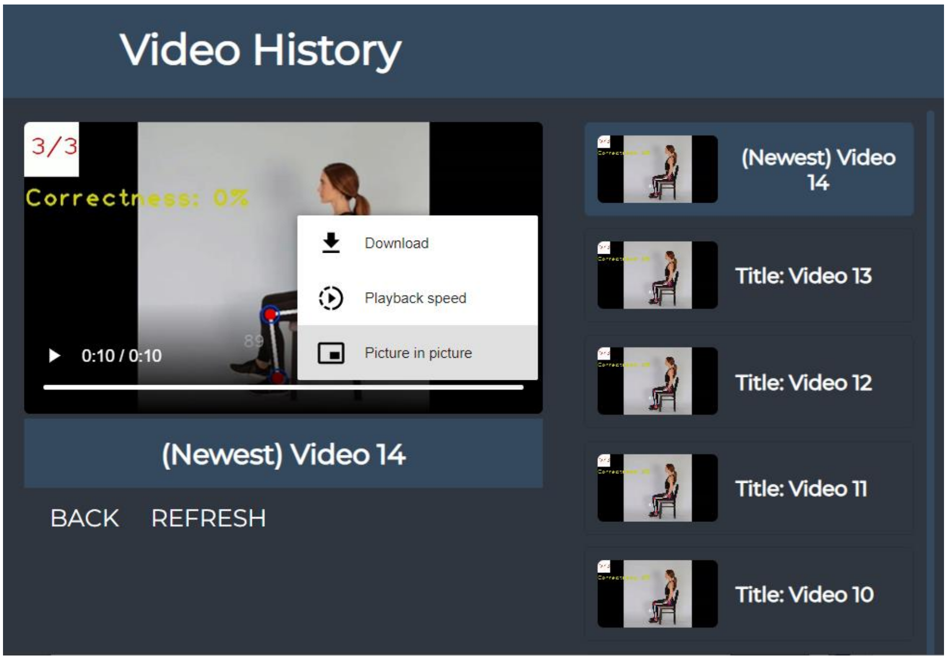


Figure 5.2.3.1 GUI of Video History

Test Action	Expected Result	Meet Expectation (√/×)
User click on any video.	System plays the corresponding Exercise video.	√
User click ‘download’.	System downloads the corresponding Exercise video.	√
User click ‘refresh’.	System refresh the video list and shows newest video.	√

User click 'enlarge' button on the playing video.	System display video in the enlarged version.	√
User click 'Back'.	System directs user to the Home Page.	√

Table 5.2.3.1 Test Result for Video History Page

5.2.4 Email Module Testing

Test Action	Expected Result	Meet Expectation (√/×)
User finished the exercise.	System sent performance metrics to users.	√

Table 5.2.4.1 Result of Email Module Testing

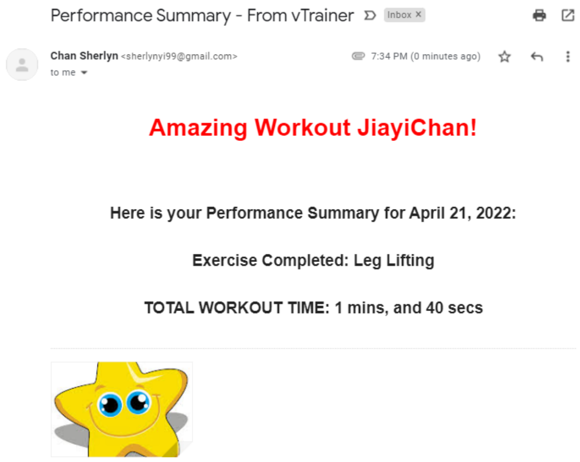


Figure 5.2.4.1 Result of Email Module Testing

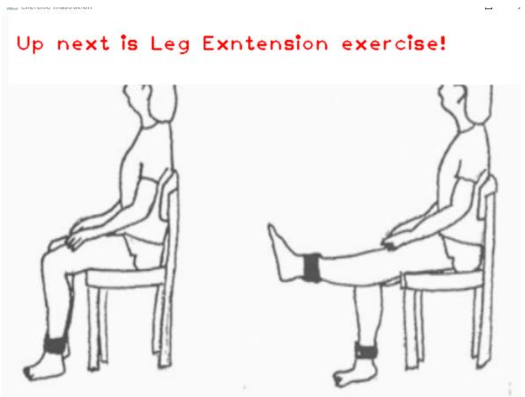
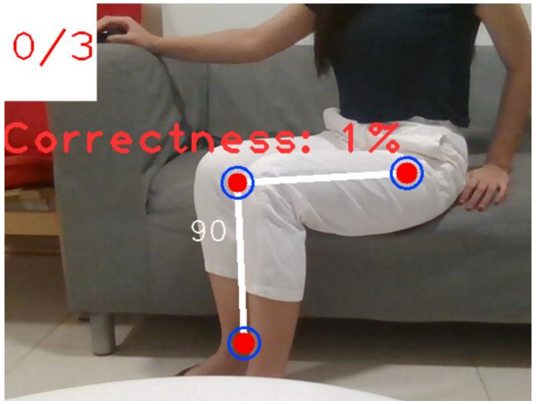
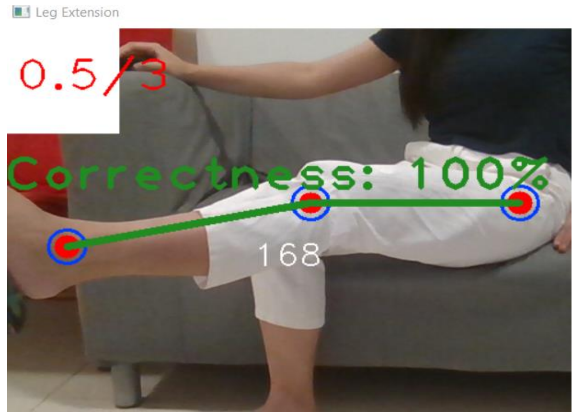
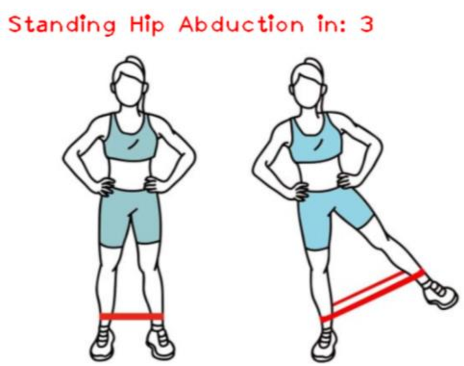
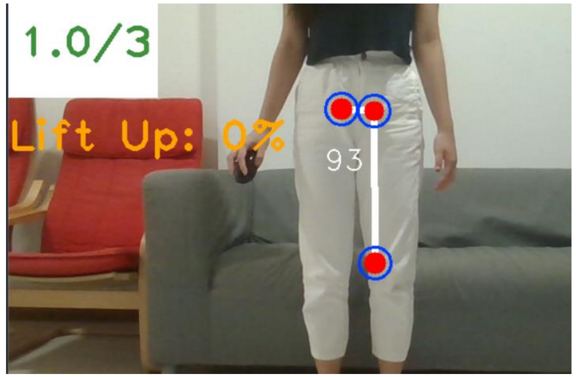
5.2.5 Exercise Guidance/Training Module Testing

In the implemented pose estimation system, if the user changes their pose or do some movements, the overlayed objects is able to follow their motions. During exercise session, instruction and a counter will be shown on the phone screen. When the user performs correctly with the given instructions, the counter will increase. *Table 5.6.3* shows the warm up countdown counter before every training started, working counter and changing of guidance message when the user properly perform the exercise.

The module testing below works for 4 types of exercises designed in Exercise Module.

Test Action	Expected Result	Meet Expectation (√/×)
User selected an exercise.	Countdown counter illustrates next exercise and countdown 3 seconds for warm up.	√
User perform exercise correctly.	System increase counter, display the targeted body part in green color landmarks and inform the results verbally.	√
User finished the exercise.	System close the pop up exercise window and store exercising video.	√
User does not perform the exercise correctly.	System will display the targeted body part in white color landmarks.	√

Table 5.2.5.1 Result of Training Module Testing

	Exercise Illustration during Warm Up	User perform exercise wrongly.	User perform exercise correctly.
Exercise 1: Leg Extension Exercise			
Exercise 2: Standing Hip Abduction			

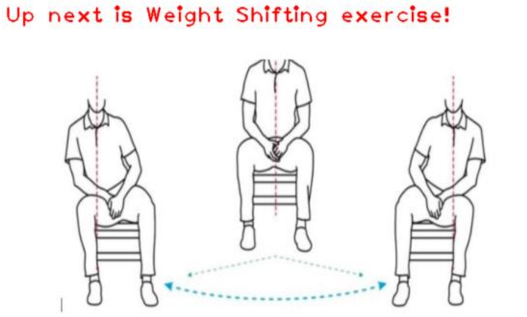
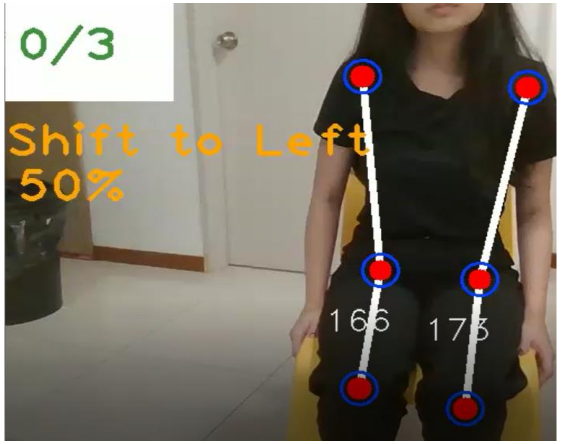
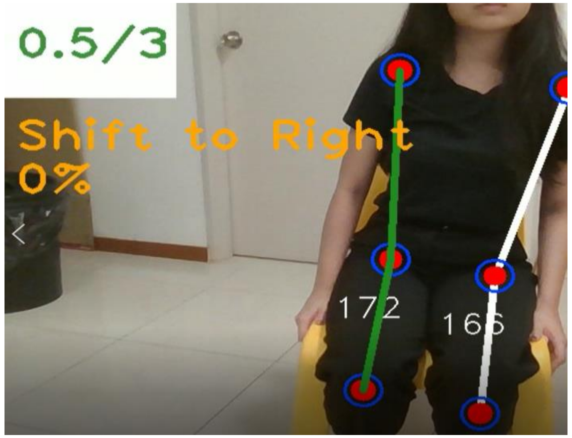
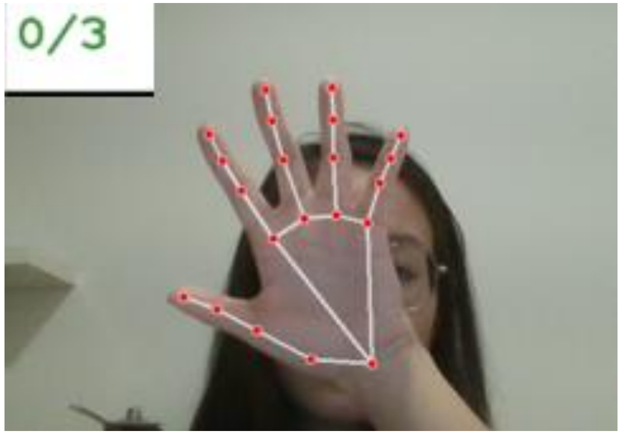
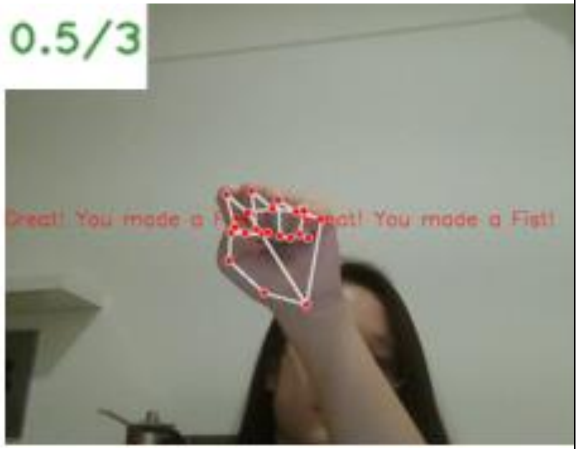
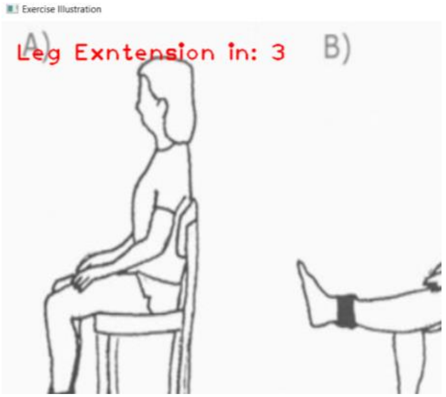
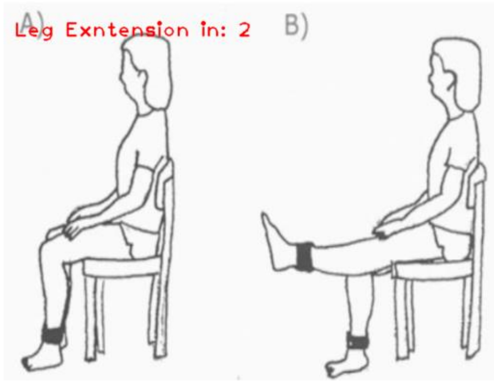
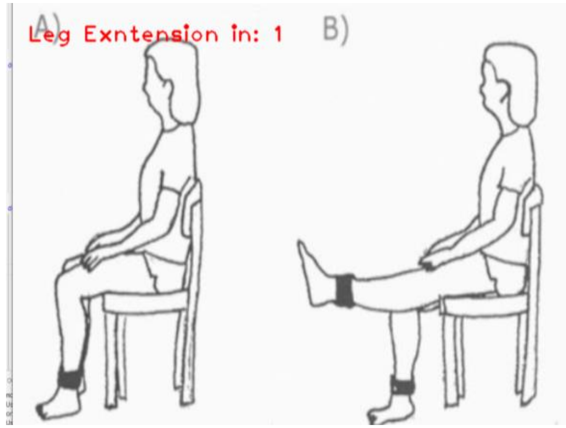
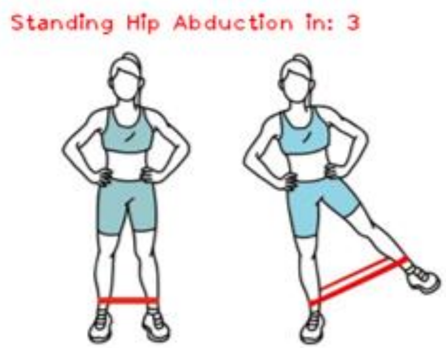
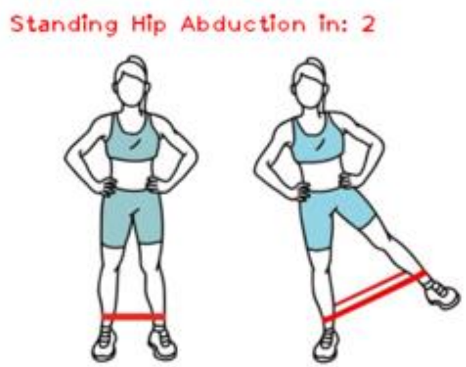
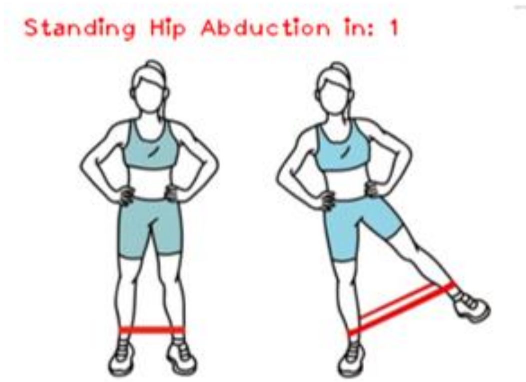
Exercise 3: Weight Shifting Exercise	 	 	
Exercise 4: Hand Griping Exercise	 	 	

Table 5.2.5.2 Test Result for Training in Exercise Guidance Module

	Warm Up Countdown Counter at second 1	Warm Up Countdown Counter at second 2	Warm Up Countdown Counter at second 3
Exercise 1: Leg Extension Exercise			
Exercise 2: Standing Hip Abduction			

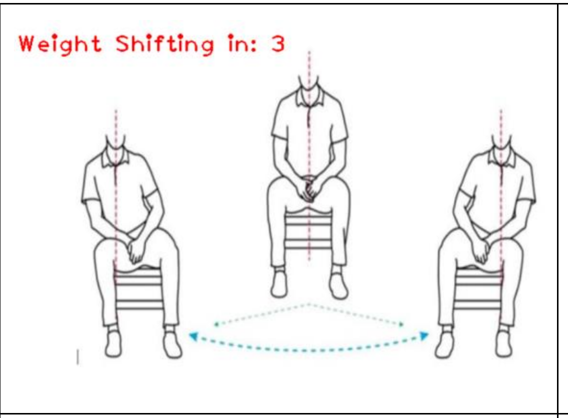
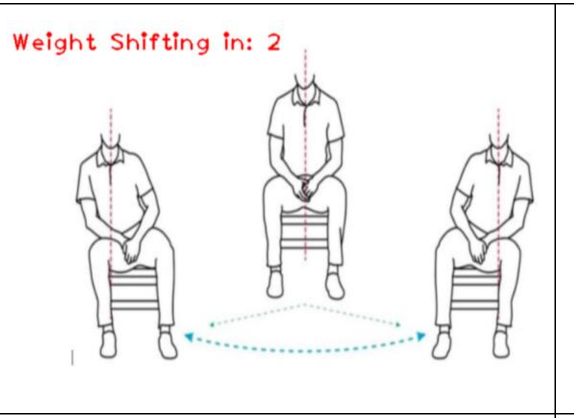
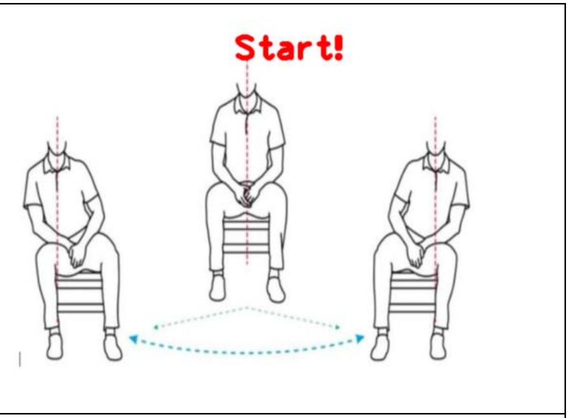
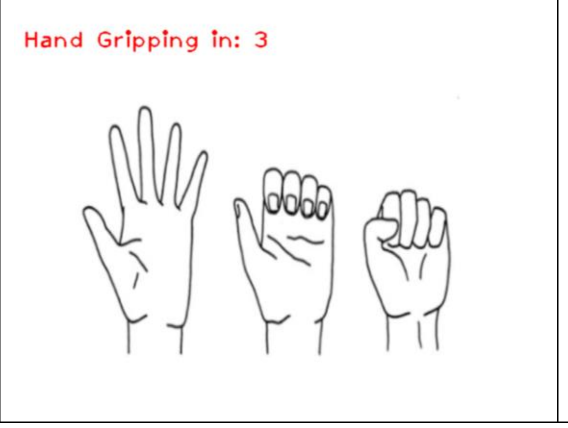
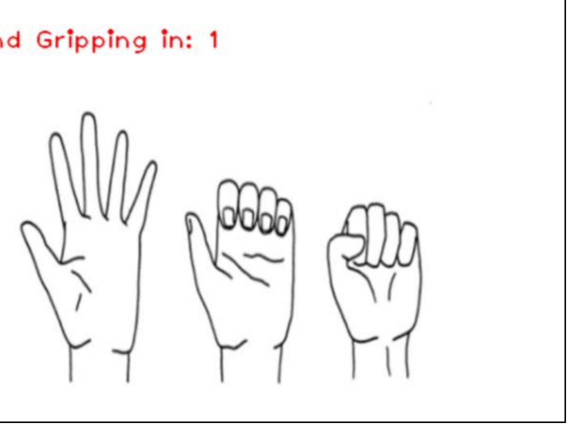
Exercise 3: Weight Shifting Exercise			
Exercise 4: Hand Griping Exercise			

Table 5.2.5.3 Test Result for Warm Up in Exercise Guidance Module

5.2.6 Human Body Pose Detection

As long as the user is standing in front of the camera, the system can detect their bodies. As a result, the 2D objects are superimposed onto the real world. Based on the figures, the system is capable to detect the human body even when only half of it is shown to the camera. When the user is showing their side to the camera, the system still able to capture and detect the human body and infer the 2D AR-based objects on the real world. Hence, it can be clearly seen that the objective to solve occlusion is being resolved in this system.

The module testing below works for moving human body designed in the captured frames.

Test Action	Expected Result	Meet Expectation (√/×)
User stand in front of the device camera.	System is able to capture human body and render landmarks.	√
User move their body parts..	System is able to track user's movement and render landmarks in real-time.	√
User stand side by side.	System is able to capture human body and render landmarks.	√
User shows only half body.	System is able to capture human body and render landmarks.	√

Table 5.2.6.1 Result of Human Body Pose Module Testing

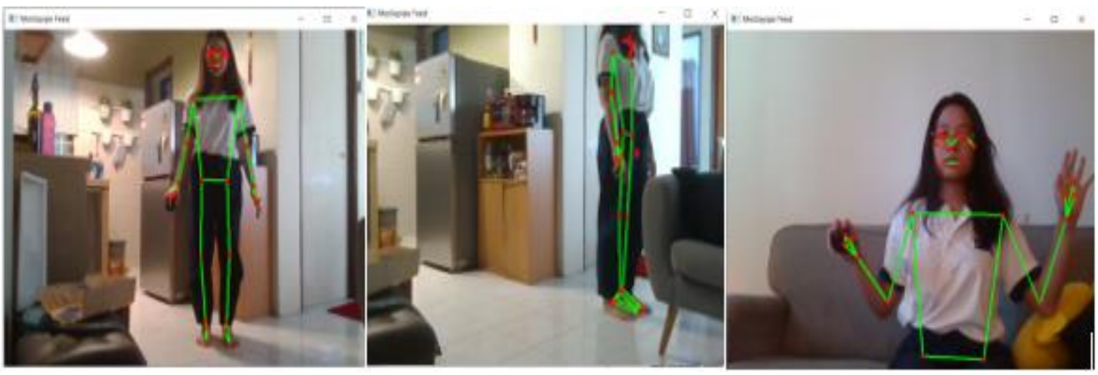


Figure 5.2.6.1 Result of Human Body Pose Module Testing

CHAPTER 6 CONCLUSION

6.1 Summary of Problem Statement, Motivation and Proposed Solutions

This application is aimed to developed to provide targeted users with an enhanced user experience in using virtual physical therapy application for them, to ease the access to rehabilitative exercises. Up to this point, the main objective in this project has been achieved, which is to:

- to develop an on-device real-time virtual physical therapist with real-time corrective mechanism, instant guidance with instructions, immersive physical therapy experience with AR technology
- to implement a high-fidelity human body detection and movement tracking to guide user correctly perform rehabilitation
- to provide better visualization on user's performance.

6.2 Novelties and Contributions

Firstly, at the end of the project, the developed application enables their users, including therapists and the patients to have more flexibility in their rehabilitation treatment. From the view of patient, patients allowed to access to rehabilitative treatment with their mobile phone. This application provides a reliable mechanism to give real-time instructions and corrective messages to patients throughout the exercise, which totally has no big difference with a physical therapist. Therefore, any kinds of injuries caused by incorrect techniques during tele-physical therapy sessions can be avoided as much as possible. As consequences, even in the COVID-19 pandemic, patients can easily access tele-rehabilitative session through the designed application. As results, patients capable to continually improve their health conditions at home, without worrying self-injury may occur.

6.3 Limitations and future research

There are some problems and difficulties faced when developing the proposed system. Firstly, the performance of the proposed system might be affected by the processor speed of the smartphone. Since the system needs to process incoming frames for pose estimation, it requires a lot of processing power and memory. The proposed application may not be able to work perfectly or crash in some low-spec smartphone. Pose tracking is always processed by the key joints detected from the body detection module. If the users left the captured region, the algorithm would perform body detection again before pose tracking. Sometimes, the body detection may take seconds to process. Hence, if the users keep back and forth to the captured region, the algorithms may also face delay. Therefore, future work of optimization of the algorithm is needed to let the application be as user friendly as possible.

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APPENDIX A – FINAL YEAR PROJECT I WEEKLY REPORT

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 1, Year 3	**Study week no.: 2**
Student Name & ID: Chan Jia Yi, 19ACB03003	
Supervisor: Dr Ng Hui Fuang	
Project Title: Virtual Physical Therapist Application With Human Pose Detection	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

- Discovered the software needed to implement the designed exercise.
- Successfully built the AR function that is able to guide user to exercise
- Provide basic UI of the application

2. WORK TO BE DONE

- Integrate Google Mediapipe Framework on Electron to perform python-electron communication

3. PROBLEM ENCOUNTERED

- No problem encountered

4. SELF EVALUATION OF THE PROGRESS

- So far so good.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(ProjectI I)

Trimester, Year: Trimester 1, Year 3	**Study week no.: 4**
Student Name & ID: Chan Jia Yi, 19ACB03003	
Supervisor: Dr Ng Hui Fuang	
Project Title: Virtual Physical Therapist Application With Human Pose Detection	

1. WORK DONE [Please write the details of the work done in the last fortnight.] Integrate Google Mediapipe Framework on Electron to perform python-electron communication
2. WORK TO BE DONE Implement more exercises that includes different body parts. Implement counter with speech to guide user in verbal.
3. PROBLEM ENCOUNTERED Unfamiliar to different model on Mediapipe
4. SELF EVALUATION OF THE PROGRESS Have to self-learn on Electron framework and Mediapipe Hand model to detect hand movement such as a hand gripping motion.

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 1, Year 3	**Study week no.: 6**
Student Name & ID: Chan Jia Yi, 19ACB03003	
Supervisor: Dr Ng Hui Fuang	
Project Title: Virtual Physical Therapist Application With Human Pose Detection	

1. WORK DONE [Please write the details of the work done in the last fortnight.] Done building 4 exercises that targeted different body parts.
2. WORK TO BE DONE Implement the video record feature to record video during work out
3. PROBLEM ENCOUNTERED Unfamiliar to Firebase and less tutorial found on Firebase connection with Python
4. SELF EVALUATION OF THE PROGRESS So far so good

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 1, Year 3	**Study week no.: 8**
Student Name & ID: Chan Jia Yi, 19ACB03003	
Supervisor: Dr Ng Hui Fuang	
Project Title: Virtual Physical Therapist Application With Human Pose Detection	

1. WORK DONE [Please write the details of the work done in the last fortnight.] Done implementing the video record and retrieve feature
2. WORK TO BE DONE Develop email system and speech counter system.
3. PROBLEM ENCOUNTERED Progress in developing speech counter is quite slow because need to have self-learning on parallel programming
4. SELF EVALUATION OF THE PROGRESS Need to improve skills of time management to get work done

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 1, Year 3	**Study week no.: 10**
Student Name & ID: Chan Jia Yi, 19ACB03003	
Supervisor: Dr Ng Hui Fuang	
Project Title: Virtual Physical Therapist Application With Human Pose Detection	

1. WORK DONE

[Please write the details of the work done in the last fortnight.]

Developed a working counter system and email system.

2. WORK TO BE DONE

Develop a warm up module to tell user the coming exercise and illustrate the exercise in picture, coming with a count down counter.

3. PROBLEM ENCOUNTERED

No problem encountered

4. SELF EVALUATION OF THE PROGRESS

Manage to finish the works on time

Supervisor's signature

Student's signature

FINAL YEAR PROJECT WEEKLY REPORT

(Project II)

Trimester, Year: Trimester 1, Year 3	**Study week no.: 12**
Student Name & ID: Chan Jia Yi, 19ACB03003	
Supervisor: Dr Ng Hui Fuang	
Project Title: Virtual Physical Therapist Application With Human Pose Detection	

1. WORK DONE [Please write the details of the work done in the last fortnight.] Developed a warm up module
2. WORK TO BE DONE Carry out Module Testing
3. PROBLEM ENCOUNTERED No problem encountered
4. SELF EVALUATION OF THE PROGRESS Manage to finish the works on time

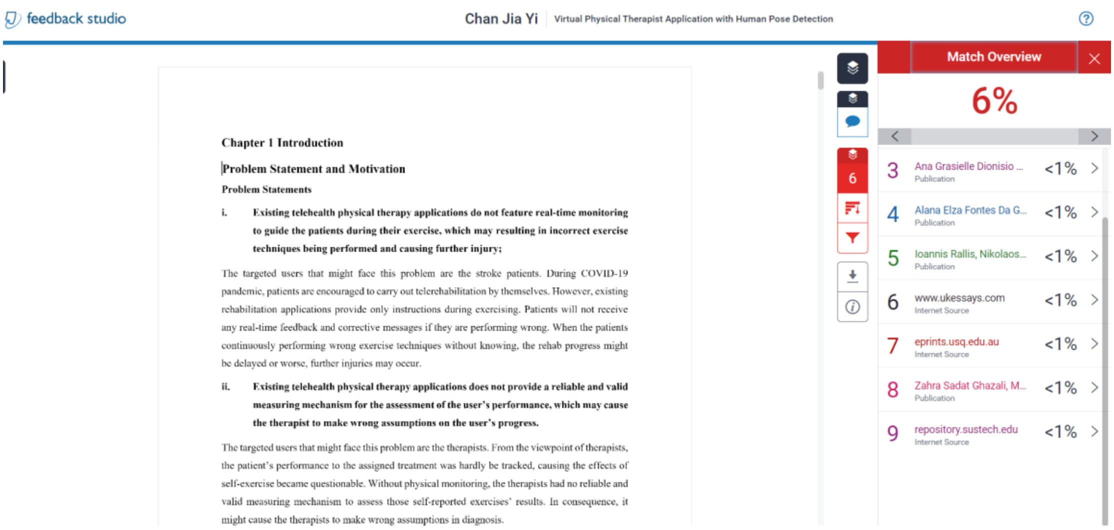
Supervisor's signature

Student's signature

POSTER

AR Virtual Physical Therapist
Mobile Application with Human Pose Detection
UTAR
Introduction
Rehab Pro, an AR-based assistive applications for therapists and pro-stroke patients to have a reliable and valid qualitative mechanisms to assess every physical therapy session at home.
Objectives
• Perform Human Body Detection
• Create a Pose Estimation system to assess patient's performance
• Give Guidance and Corrective message
• Visualize performances with Dashboard
Method
Camera Capture Real-time Videos
Human Body Detection Model (Mediapipe)
Body Pose Tracking System
Provide Corrective Guide
Collect Performance Results
Performance Feedback
Results
Pose Estimation algorithm is able to track user movement no matter sitting or standing. When user follows instruction to lift the leg correctly, the system will increase the counter with 1, and change the instructions.
Conclusion
It is an innovative system since there are only a few physical therapy mobile app available with limited functions. It combines monitoring system with pose estimation to guide patients in tele-physical therapy. In future, it will be penetrated with more functions, making it the best and effective digital physical therapist found online.
Prepared By Chan Jia Yi Supervised By Dr. Ng Hui Fuang
Faculty of Information and Communication Technology, University Tunku Abdul Rahman, Bachelor of Computer Science (Hons)

PLAGIARISM CHECK RESULT



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Virtual Physical Therapist Application with Human Pose Detection

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Programme / Course	COMPUTER SCIENCE (CS)
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Date: 21st April 2022 Date: 21st April 2022

FYP 1I CHECKLIST

FYPII CHECKLIST

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Supervisor Name	Dr Ng Hui Fuang

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