CS3483 Multimodal Interface Design
Project Design Report
Group 21
Project Name: Sport Postures Instructor

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1. A detailed analysis of the user community of the interface

During the COVID-19 pandemic, many places for doing sports like gym rooms and sports grounds were closed due to government policies. People can only work out on their own at home. Without any supervision from gym instructors, it is common for people to execute the wrong exercise posture. It may decrease the effectiveness of the action. What is more, performing the wrong postures may cause health problems and injuries. To improve the effectiveness and safety of doing sports at home, we would like to design a web application to help track the correctness of the actions when the users are doing sports.

The user community of the application would be the public in all age groups who would like to exercise at home. Here are the characteristics of the community and the points that have to be noticed when designing the application in order to provide a smooth and convenient experience for the users of the application.

Speed and Accurarcy

The sport pose detection process should be quick and accurate. The users keep moving in front of the device to do the sport. If the tracking speed fails to follow the movement of the users, the users may feel they are being interrupted. They may have to slow down. Besides, if the devices cannot track whether the users are doing the exercise accurately, the users may keep doing the sports wrong. Injuries may be caused. Therefore the recognition process has to be speedy and accurate.

Intuitive Interaction

The target user of the application is the public. The learning skills and speed of different people vary. Therefore, the structure of the application and ways of interacting with it should be similar to that of the other common applications in the market. The users should know how to use the application the first time they open it. The adaptation time has to be short.

Convenience

When the user is using the application for pose detection, they usually keep a distance from the device. It is inconvenient to move back and forth to change the setting. Thus, there should be a way for users to interact with the application with speed and handily. For example, hand and pose recognition for changing some basic settings or stopping the detection.

Performance Evaluation System

Some of our target users would like to learn how to perform the sports correctly by using the application. Hence, a performance evaluation system and a feedback system should be designed to assist them to improve.

Motivation of Keep exercising

A part of the user would like to keep fit and do sports on a regular basis. To retain their motivation and interest, we would like to track the user's progress and improvement to keep them motivated.

2. Description of the final structure of the interface and the relationships between the individual interface screens

Navigation Bar

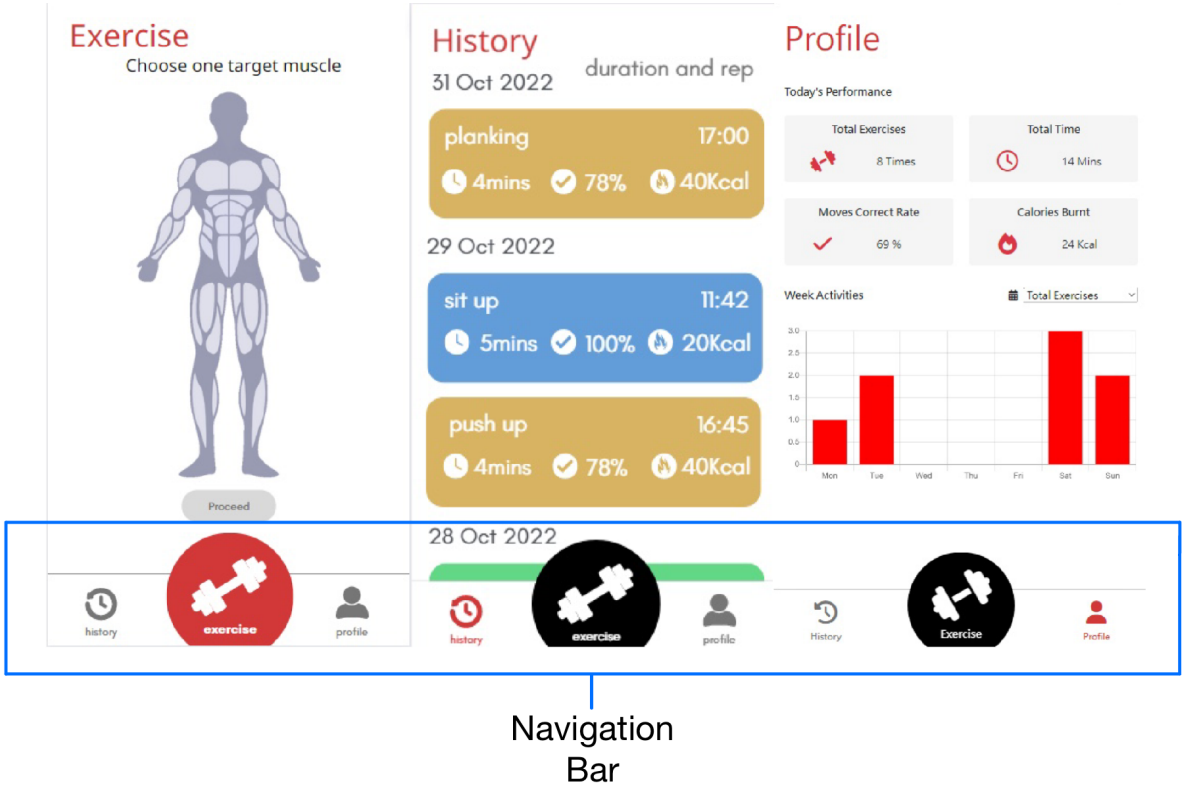


Figure 2.1 Navigation bar located at the bottom of the interface

The navigation bar is located at the bottom of the interface. It will exist in our main function pages. This bar is designed for the users to access our three main functions - ‘Exercise’, ‘History’ and ‘Profile’ of the application.

Profile

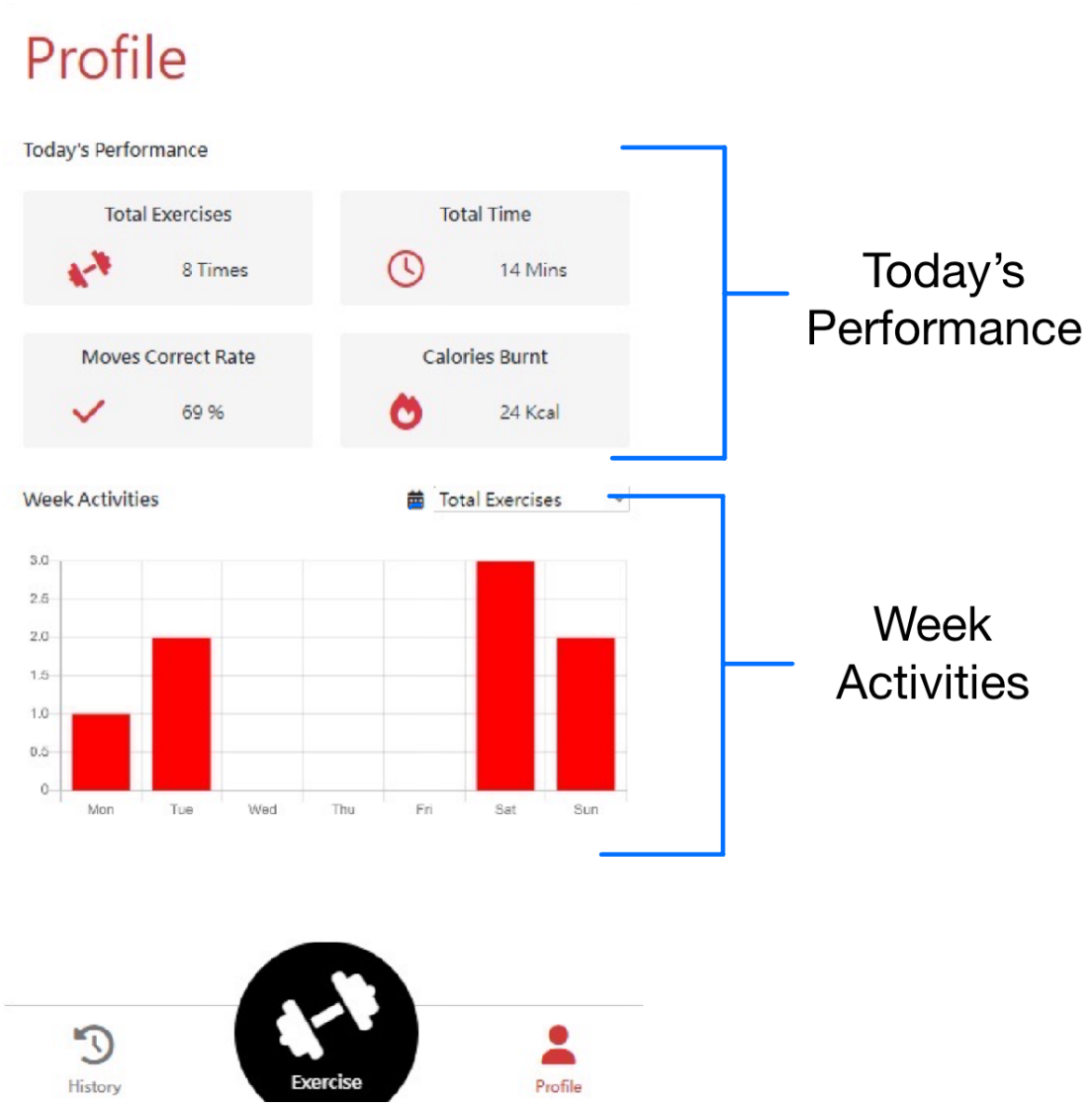


Figure 2.2 Profile Consists of 2 Parts, “Today’s Performance” on top, “Week Activities” at bottom

The Profile page shows the exercise statistics overview of the user. It can be accessed by clicking the profile button in the navigation bar.

At the top of the page, we can see the function name. In the middle we can see this page mainly consists of two sections: “Today’s Performance” and “Week Activities”. The “Today’s Performance” section grouped the daily statistics of the user. The “Week Activities” is the weekly statistics bar chart which is below the “Today’s Performance”.

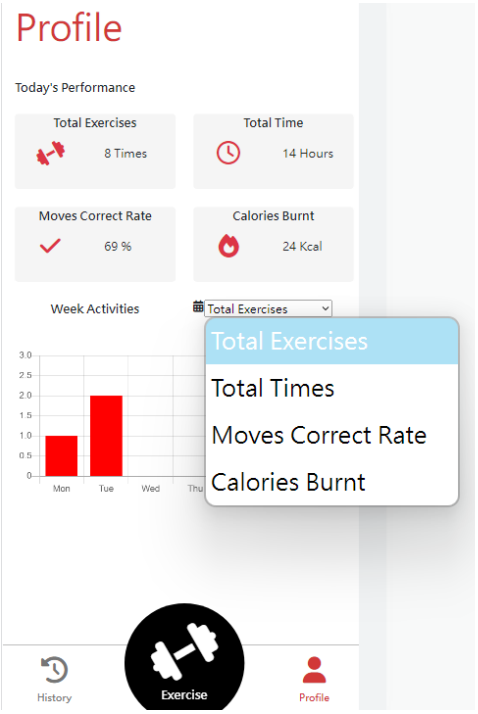


Figure 2.3 Different Kinds of Week Activities

In both “Today’s Performance” and “Week Activities”, we can see the daily and weekly exercise times, duration, move correct rate and calories burn statistics.

History

Figure 2.4 History in Single Page Design,
Record Sorted by Dates from the Most Recent to the Oldest

When the history button is clicked from the navigation bar, past exercise records will be shown.
Similar to the profile page, we can see the function name at the top of the page. In the middle, a list of exercise records sorted from the most recent date to the oldest date are shown in a single page. Users can scroll down for older records. In each record, the type of exercise, duration, correctness, calories burnt and time of doing the exercise is displayed.

Exercise

a. Muscle and exercise selection

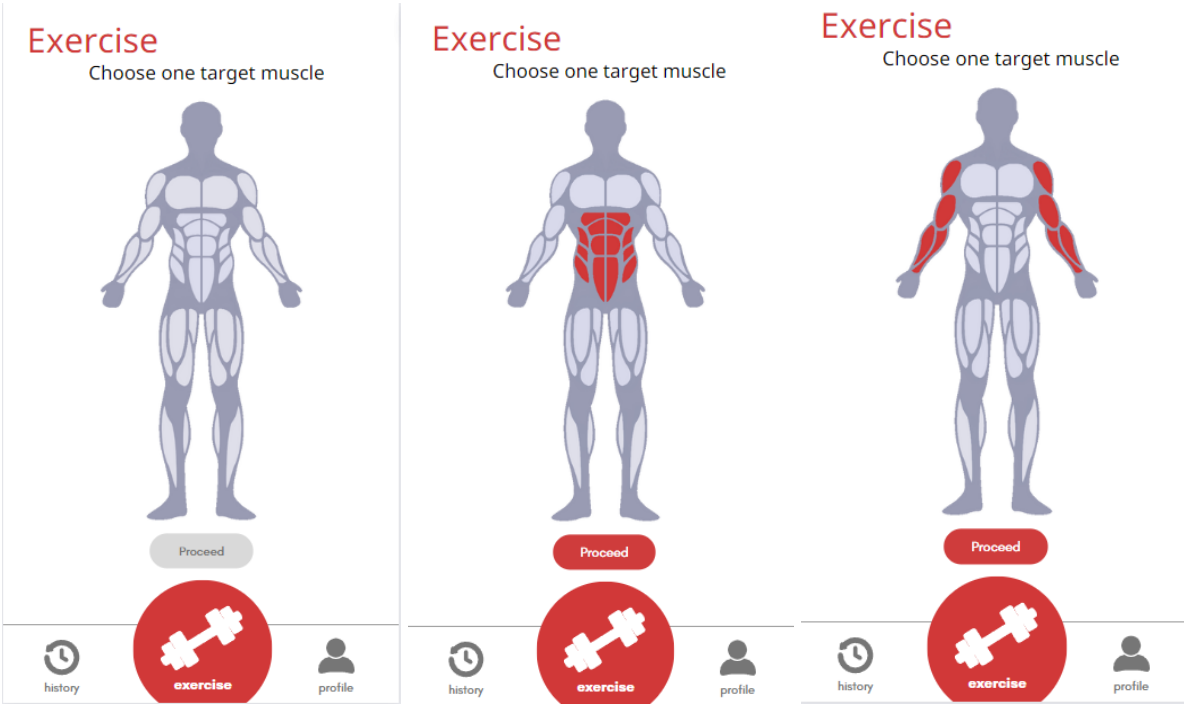


Figure 2.5 Muscle Selection, Chosen Muscle Indicated with Red Color

After clicking the ‘Exercise’ button in the navigation bar, the user can reach the exercise function.
We can see the function name at the top of the page. In the center of the page, a virtual human body with different muscle parts is shown. The user can click the muscle part that they would like to train. The chosen muscle will be indicated with a red color. Then the “Proceed” button will be available for the user to click.

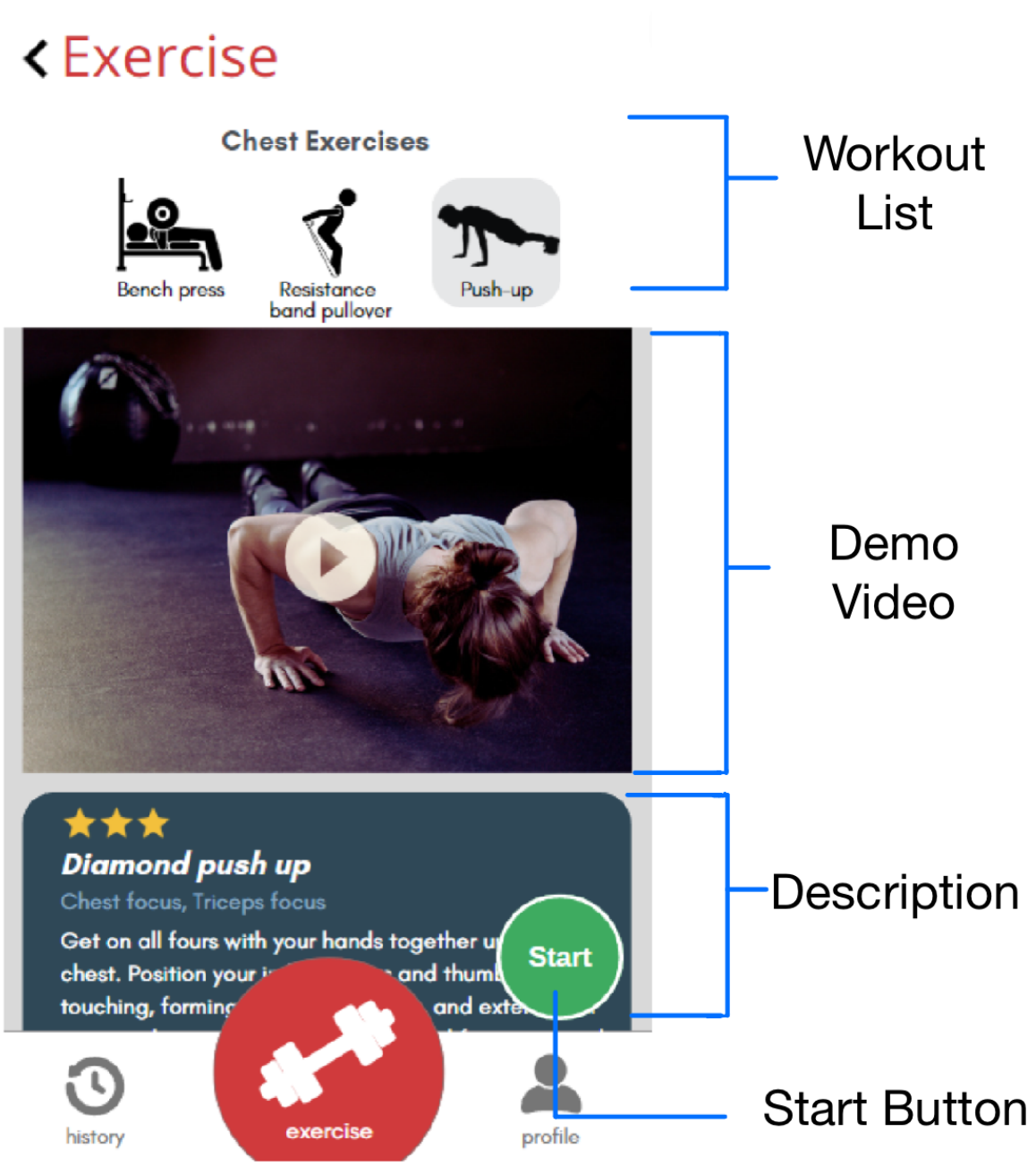


Figure 2.6 Exercise Selection

After clicking “Proceed”, the user will be directed to the page with different exercise items regarding the body parts the user has chosen. At the upper part of the page, there is an exercise list containing all the workout items. When one of the workout items is clicked, a demonstration video, detailed description and instructions of the chosen exercise will be provided. On the bottom-right of the exercise page, there is a green ‘Start’ button available if an exercise is chosen. The user can start the exercise by clicking it.

b. Exercise Movement Tracking

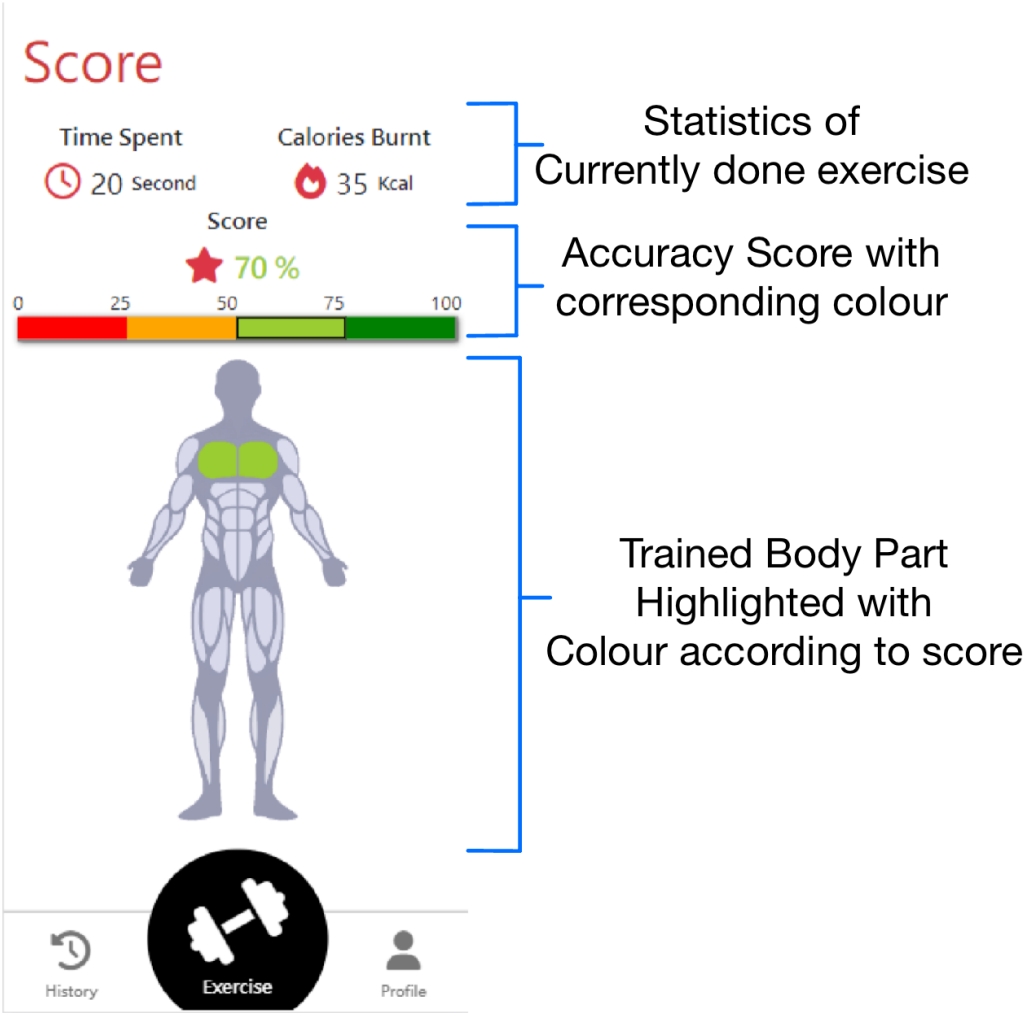
Figure 2.7 Movement Tracking Interface, Function Buttons at the Corners

Figure 2.8 Trigger Exit Buttons by Gestures

The exercise movement tracking interface will display after the users click the start button. The interface will change to landscape mode. The view finder for users to capture their exercise movement would be in full screen. The counter of doing the correct posture will be shown on top of the screen. The functions buttons pause, more options and exit would be at different corners of the screen. The pause button can pause the detection and time counter. The exit button will direct the user to the performance evaluation page and the options button is for more camera and exercise settings. To perform these functions, the user can either directly click the button or hover over the button for a certain amount of time.

The application will also keep track of the movement and the posture of the user. A skeleton generated by PoseNet will be shown on the user body for motion tracking. When the user performs the action correctly, a notification sound will be played to notify the user and increases the counter by one.

c. Performance Evaluation



.Figure 2.9 Performance Evaluation

When the user finishes their exercise and exits the movement tracking page, a performance evaluation page will be displayed. The system will give a score to the user based on the accuracy rate of the exercise posture in the previous phase. Time spent and the calories burned on the exercise will also be shown. The related muscles are also colored according to the score. The lower the accuracy, the color will be closer to red and vice versa. The chest muscle of the virtual human body becomes light green in color, indicating the posture of the exercise is mostly correct.

3. Presentation of the layout of the important interface screens and their associated features in the form of screenshots

In this section, the important interface and their features will be displayed.

Navigation Bar

In the navigation bar, The “exercise” button is significantly larger than the “profile” and “history” buttons. Moreover, it is located at the center of the navigation bar. Exercise is the core function of the application which users will frequently interact with. By using this design, the finger moving distance will not vary much even if the finger is located somewhere else on the screen according to Fitts’ Law . Thus, users can access the most frequently used “exercise” button in a shorter time.

History

We use a single page menu to list out the records and the performance. Since some basic and key information of the records from different dates are listed out on a single page, users are not required to switch between pages to view and compare their performance on different dates. Moreover, if they want to find records from specific dates far away from the present day, they just have to scroll down in the history page to find the desired records. The pages are easy to view and search by using this design. Also, the user can compare the performance easily to see their progress and understand the points they need to improve. The design can motivate the users to do sports frequently.

Profile

In the design, the daily and weekly statistics are explicitly grouped. For instance, the daily statistic is grouped at the upper part of the screen and titled with a larger bold font “Today’s Performance”. Each of the daily statistics also share a similar design which consists of a red colored icon and the actual number statistic. And the weekly statistic is placed below the daily statistic as “Week Activities”. Users can read the statistics smoothly and easily relate those statistics together at first glance. It is because it fits the law of Proximity of the Gestalt Law that humans tend to relate close objects together rather than far objects. The user could quickly understand the difference of weekly and daily statistics without explicitly reading the wording of the statistic.

Exercise

Muscle selection

In the design, the muscle selection process is intuitive. A body image with all the muscle parts is shown. To select the target muscle, only a single click on the specific muscle image is needed. The muscle parts chosen are highlighted in red which is a sharp color and acts as a more significant indication to the users. Then the proceed button is enabled for the user to proceed to choose the exercise that can train their target muscle. It is an interactive, modern and intuitive design.

Exercise selection

If a new beginner trainer wants to do sports at home, they may be unfamiliar with various kinds of exercises. Therefore in the exercise list, there are icons of the workout on top of the sports' name which can provide a glimpse for the rookies to understand a particular exercise by the picture of the exercises' posture. Besides, video demonstrations, instructions and descriptions of the exercises are provided for better understanding. These components also help achieve our goal to prevent users from making wrong exercise postures.

Movement Capture Interface

In the interface, the buttons are at different corners of the display. Therefore, the capturing area can be in full screen so that the users can capture their whole body easily.
As the users will keep their distance from their devices, we allow users to use hand gestures to control the camera and exercise setting when they are doing exercise. The function buttons are at the four corners of the viewfinder. Although it consumes more time to press the separated buttons by touching the screen, it is easier for the users to point to different corners of the display to press the button from a distance. It avoids pointing and activating the undesired functions as the buttons are not close to each other. Plus, pointing to the desired buttons for controlling it is more direct and the user would need less time to learn the different gestures.

Movement Tracking

When the user does the posture correctly, the application will play out a notification sound. By using this design, the user can know that their posture is right by hearing the sound from a distance when they are doing the exercise.

Performance Evaluation

There is immediate feedback pop up right after the exercise. No extra searching is needed. The color of the body part and the score will be different according to the performance of the user. The colors used are very direct. Red is for poor performance and green is good. The user can know how well they have done and the performance of each body part by just a quick look which provides convenience for the user.

4. A detailed justification of your design based on the theories, principles and guidelines you have learnt from the course

Gestalt Principles of Perception

Gestalt principles are originated in a school of thought in psychology Gestalt, in Austria and Germany in the early 20th century, which describes the foundation of visual design and explain how we can organize and interpret visual input. In our project, some of its principles are adopted.

Similarity

The similarity principle states that objects in similar visual characteristics such as size, shape and color, will be regarded as a group and have a close relation. In the design of exercise selection, after the selection of muscle, different exercise items based on the selected muscles will be displayed. These items have the same visual characteristics that they are black in color, similar in size and icons, which shows the users that they are the group of exercises can be selected and are all under the same muscle category.

Continuity

The continuity principle states that humans tend to see changes in smooth and continuous representations. In the History page, past exercise records are ordered from the latest workout and displayed in a one-page list. This design allows users to scroll up and down the page for record checking instead of abrupt changes such as switching between pages back and forth to check the activities on different dates or clicking on a specific date, which meets the continuity principle for smooth representations.

Proximity

The proximity principle states that objects in close directions are seen as belonging together rather than far objects. In the Profile page, the daily statistics are clustered together at the upper part of the page, followed by the week statistics. The clustering allows users relate the daily statistics together at first glance, and it helps distinguish the difference between weekly and daily statistics clearly without users explicitly reading the titles of the statistics. The exercise items mentioned above can also be considered adopting the proximity principles and users can relate the items somehow related to each other and understand these items can help training their desired muscles.

Fitts' law

The Fitts' law refers to the model that predicts the time required for the user to locate a certain target. Below shows the formula of this prediction model.

$t = a + b \log_2 (\frac{D}{S} + 1)$

t : The time needed to move the current position to the target in minesecond.
D :The distance between the user's current position and target position.
S : The size of the target.
a,b : Two constants in the formula.

In short, a larger target requires less time for the user to locate, and vice versa. When a user interacts with a small target, more time is needed to precisely locate the target to avoid wrong interaction, such as pressing the other target. A larger target could reduce the precision requirement when the user is locating it as there is more area for the user to interact with the target. Hence, lesser time would be needed for precise movement

In the navigation bar, the “Exercise” button is designed to be significantly larger than the “History” and “Profile” button. The “Exercise” button has a large circle area that allows users to quickly locate and interact with it as a larger area provides . Since the exercise function is the main function of this application, it will be a frequent action for users. Reducing the time for users to locate this frequent action can increase the efficiency when the user is using the application. According to the prediction model in Fitts’ law, it is chosen to increase the parameter “*S*” , which is the size of the target, to reduce the time required to locate the target.

In addition to the design principles mentioned, different design guidelines are followed.

Task analysis

The task analysis guidelines allow designers to think about the task sequences. In the design, we have chosen suitable atomic actions for users. After starting an exercise, the interface automatically enters the movement tracking interface and allows users to perform exercise. Users can also choose when to end by hovering their fingertip to the exit button, then a performance evaluation page will be shown to users. A large number of actions is not needed for the users as some of the steps/interfaces are automatically triggered. There is also flexibility provided for users to let them choose when to end their workout.

Performing task analysis can also allow developers to create designs based on the action frequencies of tasks. Frequent actions will be performed by single special keys, while the less frequent actions will be performed by sequence of menu or form fill-in. In our design, the most frequent actions, which is clicking on the exercise button, is surrounded by a circular outline, filled with color and it is larger in size to emphasize its importance and frequency. Intermediately frequent actions such as checking the workout history and viewing the profile, the key to trigger these functions is relatively smaller. Less frequent actions such as viewing the weekly statistics, it needs to take a further step in the profile page to choose different exercise statistics (4 less common statistics) in a drop-down menu. Therefore, we have made our design based on the frequencies of actions.

Cater to universal usability

In the workout selection page, we can see the workout name, description, and a demonstration video when we select any one of the exercises in the list. Some of the beginners may not be familiar with all the exercises only by the name of them. The design helps them to understand what they are going to do once they start the current selected exercise.

Linear sequence of menus

In exercise selections, we break down the complex decision-making process by providing one choice at a time. We first let the user choose the muscle part they want to train. After that we proceed to choose the workout according to the previously chosen muscle part. This sequence helps users to decide the workout which can train their target muscles.

Cyclic network

In our design, the majority of the pages can access all the other pages of the application. For example, we can go back to the muscle selection page, profile page and history page when we are in the workout selection page. The users can repeat the previous menu.

5. Description of the alternative modality of interaction that has been implemented in the design

In the application, the user exercise postures will be detected to check the accuracy of their poses. In order to identify whether their movements are correct, gesture recognition will be used. After the user chooses a workout item and press start, the application will enter exercise movement tracking mode and turn on the front facing camera of the device to check the movement of the user. When the user is exercising, they will keep a distance from the device to track the whole body. It is inconvenient to move back and forth to change the camera and exercise settings. Therefore, gesture recognition would not be only applied in sports movement tracking. Users can also change the camera and exercise setting by either directly pressing the button on the interface or their gesture.

Method of implementation

As there are no built in methods for detecting postures and their accuracy by videos. Thus, we have to import some libraries and models to track the body movement and design some algorithms to calculate and determine the user's activities.

a. Exercise Movement Tracking

The exercise movement tracking can be divided into two parts:

<u>Body Detection</u>
The body detection part is done by PoseNet. PoseNet is a pre-trained machine model that estimates human posture in real-time. As the model can be used to detect both single or multiple poses at a time, it can be used to track the pose by either photos or video for one person or multiple people.

In the application, PoseNet is used to detect if there is a human body. Then, the skeleton structure of the bodies and the coordinates of the point of joint is detected and recorded for later calculations.

<u>Movement Evaluation</u>

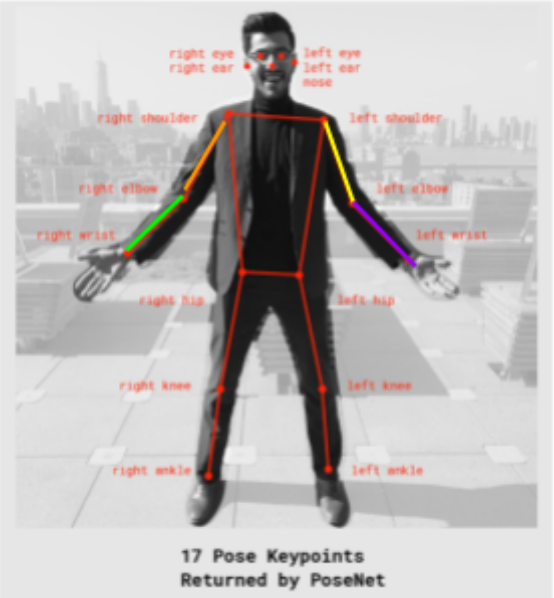


Figure 5.1 PoseNet Keypoints and Lines for Evaluating the Accuracy of Push-ups

The data of the skeleton structure detected are processed by our algorithms and to evaluate the accuracy of the poses. The accuracy is determined by the angles between the skeleton parts. Take push up as an example. To see the accuracy of a push up action, we will calculate the angle between upper arm and lower arm (angle between orange and green lines or the angle between yellow and purple lines from figure 5.1). If that angle is first under 110 degree, then greater than 160 degree, we will take this as one successful push up. A notification sound will be given. If not, the action will be treated as inaccurate and the counter will not increase. The accuracy mark will be deducted according to the successful rate of the action.

b. Gesture recognitions for controlling settings

This part is for users to change the camera and exercise settings a distance away from the device by using gestures.

Body Detection

PoseNet is also used in the body detection in this part. In the application, PoseNet is used to check if there is a body in front of the device. If yes, it will track and record the skeleton structures and joint coordinates for later steps.

Remote Control Application Interface

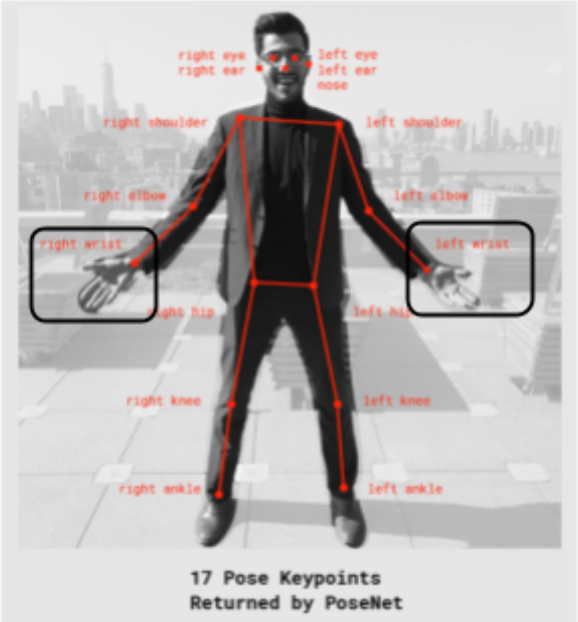


Figure 5.2 PoseNet Keypoints for Controlling the Setting

To determine the functions the user is trying to call, the coordinates of the joints are checked. If the coordinates of the wrist (Keypoints circled in Figure 5.2) are detected overlapping with the position of one of the buttons, the application will treat the user as trying to call the function he or she is pointing at. For example, if the user lifts up his or her hand that the coordinates of the wrist captured by the viewfinder is overlapping with the exit button, the application will exit from movement tracking mode.

6. Possible future extensions of the current design

Muscle Selection
Currently, there are only four muscle categories, which are arm, chest, core and leg, to be chosen. There are more muscle parts that can be trained in reality. The muscle part can be precisely trained. For example, in many types of training, we can train only the biceps, triceps or forearms instead of the whole arm. Therefore, we will expand the muscle categories in the future system development.

Exercise Selection
Similar to muscle selection, there are many kinds of muscle training exercises. However, we only demonstrated two kinds of exercises in our application due to time constraints. Adding more workout in the exercise list would also be the possible future extensions of the design.

Human Body Detection Model
When we were developing the application, we found that PoseNet was not stable enough for our application. For example, PoseNet sometimes fails to build an accurate skeleton from camera capture when the whole body of the user is not shown or the user moves fast. For the future extensions, we may further modify the program for better detection by PoseNet or search for a better model or library for detecting the human body.

Performance Evaluation
We understand that we cannot simply determine the accuracy of the pose or movement by the angle between the skeleton part. Many factors have to be considered to see the accuracy of a posture. We will further design the algorithms to calculate the correctness of user movement. For example, we will collect many exercise video samples to develop a machine learning model for determination.

Remote Control
When doing the exercise, the remote control is done by checking if the hands are overlapping the buttons. However, this might be difficult if there is environmental obstruction. The user may find it hard to reach the button using their hands. A better way is to use a beam pointer to control the buttons when performing a certain gesture. For instance, when the system detects the user pointing out an index finger, a beam would be extended from the index finger as a pointer to let the user control the button without much movement of their whole body.

7. Updated responsibility of each group member

Name	Student ID	Responsibility
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