Bilkent University
Department of Computer Engineering

Senior Design Project

Gymtor

Analysis Report

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This report is submitted to the Department of Computer Engineering of Bilkent University in partial fulfillment of the requirements of the Senior Design Project course CS491/2.

1. Introduction

Exercising regularly is one of the key ingredients of a healthy lifestyle. However, due to various reasons such as not having enough time and motivation due to heavy work loads or not having enough money to spend money on fitness clubs, most people do not exercise at all. These reasons suggest that the accessibility aspect of exercising poses a significant problem, which led to the main idea of our project.

In order to make exercising accessible to more people, our team came up with the idea of a sport assistant, which is powered by cutting edge deep learning techniques to analyze the body pose of a person and provide relevant real-time feedback to the user about what can be improved about a certain exercise in order to help the users in making the most out of their workouts.

In the remaining sections of this report, the system will be described in detail. First, the functional, non-functional, and pseudo requirements will be explained. Then, the use-case scenarios, the class diagram, and the dynamic models, and the user interfaces will be presented. Finally, the analysis of various elements such as general factors involving the project, risks and alternatives, the project management plan, and ethical and professional responsibilities will be provided.

2. Current System

There are other sport assistant apps in the play store and apple app store such as Freeletics, Runtastic, and several apps of the company Leap Fitness Group. These applications give visual and auditory instructions for exercises, save the statistics of the user where the user enters the data and allow users to follow different exercise plans. However, their instructions and feedback are predetermined and there is no real time user-specific analysis or feedback for the exercises.

3. Proposed System
3.1. Overview

Gymtor is a mobile application that will assist users to do exercises using visual processing and machine learning techniques. The app will analyze the user with the mobile camera while exercising and it will give feedback accordingly. Also, it will track the exercise routines and progress over time.

There are several sport assistant applications in the market, but these applications generally consist of preset instructions that users follow and there is no chance for the users to know whether he or she is doing the exercise properly. However, Gymtor will be able to give user-specific real-time feedback so that the users will gain more benefit from their exercises.

When the user first opens the application, he or she must sign up and accept the license and privacy agreement to protect both the user and Gymtor team. Then, the user can login and start using the application. In the application, the user can see the preset exercises and can create new exercise plans by choosing exercises to add to that set. Then, the user can start an exercise or schedule it for a date and a notification will be sent to the user when the exercise time comes. When the user starts the exercises, the application will ask the user to place the phone in a proper location for that exercise. After that, the application will ask the user to start the exercise and it will give some information such as the number of repeats, exercise name, etc. via voice or text on the screen. After the user starts, it will watch the user and give real-time feedback about the exercise, and it will count the repeats. This process will be repeated until all the exercises are done. Then, the application will show the overall statistics to the user and save them.

Users will be able to see their progress and share them on social media. Optionally, users can join the leaderboard of the week among all the users, which is created by the amount of time they spent on exercise.

If the user has a smartwatch, he or she will be able to connect it to the application so that the application will also record pulse rate information.

Gymtor will be a free mobile application. Its purpose is to help people who cannot afford to go to the gym or who do not have enough time. It will meet the state-of-the-art machine learning and visual processing techniques with the end-users in such a crucial domain of daily human life, sports.

3.2. Functional Requirements

User Requirements:

- The users will be able to sign up, login and logout using an email and a password.
- The users will be able to login using a Google account.
- The users will be able to change its password.
- The users will be able to see exercise plans, create new ones and modify them.
- The users will be able to schedule an exercise for a future date.
- The users will be able to see scheduled exercises and modify or delete them.
- The users will be able to start an exercise plan.
- In an exercise plan, the users will be able to pause the exercise, quit from the exercise plan or skip to the next exercise.
- The users will be able to enter weight, sex, height, and age information and update them.
- The users will be able to enter the information of any exercise tool (such as dumbbell) if the current exercise requires one.
- After the exercise plan, the users will be able to see the statistics.
- The users will be able to see the old exercises and statistics.
- The users will be able to connect or disconnect a smart watch before the exercise plan.
- The users will be able to change the settings of the application.
- The users will be able to activate or disable notifications.
- The users will be able to delete its account.
- The users will be able to upload profile pictures.
- The user will be able to search for other users and exercise plans.

- The users will be able to add other users as friends.
- The users will be able to report other users.

Application Requirements:
- The application will send notifications for scheduled exercises.
- The application will watch and analyze the users' exercises.
- The application will give real time auditory or textual feedback based on the visual analysis of the exercise.
- The application will create statistics after the exercise plan and display it to the user.
- The application will warn users not to do exercises without break and not to do overtraining.
- The application will be able to create overall statistics with all the exercise data of the users and it must be able to display them to the user when asked.
- If the user activates the notifications, the application will send notifications to motivate the user to exercise.

3.3. Nonfunctional Requirements

Efficiency Requirements:
- System response time must not exceed 30 seconds.
- Neural network must generate the feedback for the exercise with a maximum of 5 seconds delay.

Usability Requirements:
- Buttons and menus must be seen easily.
- Button and menu names must be clear and understandable.

Reliability Requirements:
- The application must be able to detect the angle of the body parts in exercise analysis with at most 5° of error acceptable.
- The application must be able to count the repeats of an exercise with 90% accuracy. In other words it can only miss at most one of the 10 repeats.

- The application must be able to roll-back to a safe state in case of any crashes and the user data must not stay in an unstable condition.
- The application must be available to 10,000 active users at a given time.

Security Requirements:
- User data cannot be accessed by a third party application or a person.
- The servers that hold data must use RSA-256[1] encryption keys.

Supportability:
- The application must run on any android device with Android 6.0 or higher.
- The application must be able to connect to Samsung Galaxy Sport and Watch series, Xiaomi Mi Band series smart watches and it must be able to retrieve pulse rate data from them.

3.4. Pseudo Requirements

- Java programming language will be used to develop the majority of the project.
- Android Studio will be used to build the application.
- The program will be delivered as an .apk executable.
- Python Deep Learning libraries will be used to develop the Neural Network for 3D skeleton modeling from images implementation.
- Firebase[2] will be used to manage all database functionalities.
- Git platform will be used to keep track of application's development.
- Gymtor will be available on Google Play Store for free.
- The application will require internet connection to access the pre-modeled ground truth of the correct motions of the exercise.
- If an user chooses to download the movement sets that are frequently used, no internet connection will be needed.
- A video recording device (camera) will be needed for exercise movement accuracy analysis.

3.5. System Models
3.5.1. Scenarios

Use Case Name:	Create Exercise Plan
Participating Actors:	User
Flow of Events:	1) After opening the Gymtor, the user presses the exercise button. 2) Gymtor presents the exercise plans that the user follows. If a user does not have any exercise plan, Gymtor will simply open a page that has written "you have no exercise plans". 3) User presses the "+" button to create a new exercise plan. 4) User fills the form with the exercise plan information with the exercises he/she wants to follow. 5) The Gymtor creates the exercise plan and puts it to Database.
Entry Condition:	The user has logged in Gymtor and has a proper internet connection.
Exit Condition:	The user receives a success/ error message.
Special Requirements:	None

Use Case Name:	See Exercise Plans
Participating Actors:	User
Flow of Events:	1) After opening the Gymtor, the user presses the exercise button. 2) Gymtor presents the exercise plans that the user follows. If a user does not have any exercise plan, Gymtor will simply open a page that has written "you have no exercise plans". 3) The user can select an exercise plan to see by simply pressing on them. 4) The exercises on the selected plan and the days for them that planned to do will be shown to the user.
Entry Condition:	The user has logged in Gymtor and has a proper internet connection.
Exit Condition:	The user closes the tab or the user receives an error message.
Special Requirements:	None

Use Case Name:	Start Exercise Plan
Participating Actors:	User
Flow of Events:	1) After opening the Gymtor, the user presses the exercise button. 2) Gymtor presents the exercise plans that the user follows. If a user does not have any exercise plan, Gymtor will simply open a page that has written "you have no exercise plans". 3) User picks an exercise plan that he/she wants to start. 4) The user presses the "clock" button to schedule the exercise plan to their week. 5) User picks the days he/she will do the specified exercise plan. 6) Gymtor puts the exercise plan to scheduled exercises tab on "Exercises"
Entry Condition:	The user has logged in Gymtor and has a proper internet connection, the user has an Exercise plan.
Exit Condition:	The user receives a success/ error message.
Special Requirements:	The user has the selected exercise plan.

Use Case Name:	Enter Personal Information
Participating Actors:	User
Flow of Events:	1) After the user opens the Gymtor, the user presses the "profile" button. 2) User presses the "modify profile button" on the top right. 3) User can modify the age, height, sex, weight information from here.
Entry Condition:	The user has logged in Gymtor and has proper internet connection.
Exit Condition:	The user receives a success/ error message.
Special Requirements:	None

Use Case Name:	Search Exercise Plans
Participating Actors:	User
Flow of Events:	1) After the user opens the Gymtor, the user presses the "search" button. 2) The user picks the plans tab. 3) User types the keywords to search bar like "arm workout" 4) Gymtor shows the related exercise plans to the user.
Entry Condition:	The user has logged in Gymtor and has a proper internet connection and has an exercise scheduled or the user has an exercise plan that includes an exercise tool.
Exit Condition:	The user closes the tab or the user receives an error message.
Special Requirements:	None

Use Case Name:	See Exercise Statistics
Participating Actors:	User
Flow of Events:	1) After the user opens the Gymtor, the user presses the "stats" button 2) Gymtor will show the total activity information, recent routines and summary information. 3) If the user presses "Show All Past Exercises" Gymtor shows the exercises plans that are being done by the user with the last date that is done. Gymtor shows following statistics: Total time spent doing that exercise plan, the total calories burnt with doing that exercise plan. 4) If the user presses "Show Activity History" button the Gymtor shows the graphics of the total time that user has followed an exercise plan, total calories the user has been burnt, total weight that the user has lost.
Entry Condition:	The user has logged in Gymtor and has a proper internet connection.

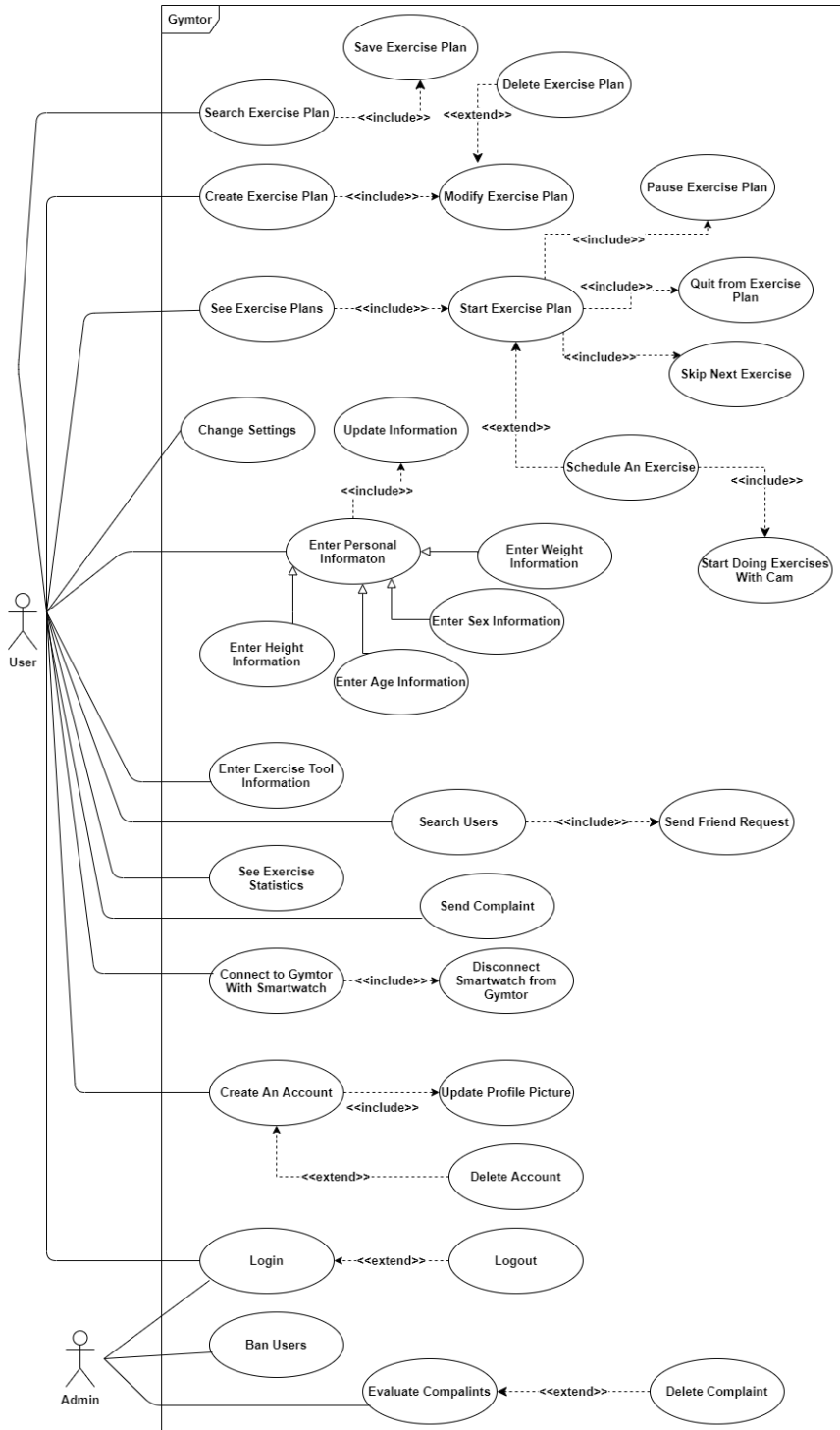| Exit Condition:	The user closes the tab or the user receives an error message.
Special Requirements:	The user has followed at least one exercise plan.

3.5.2. Use Case Model

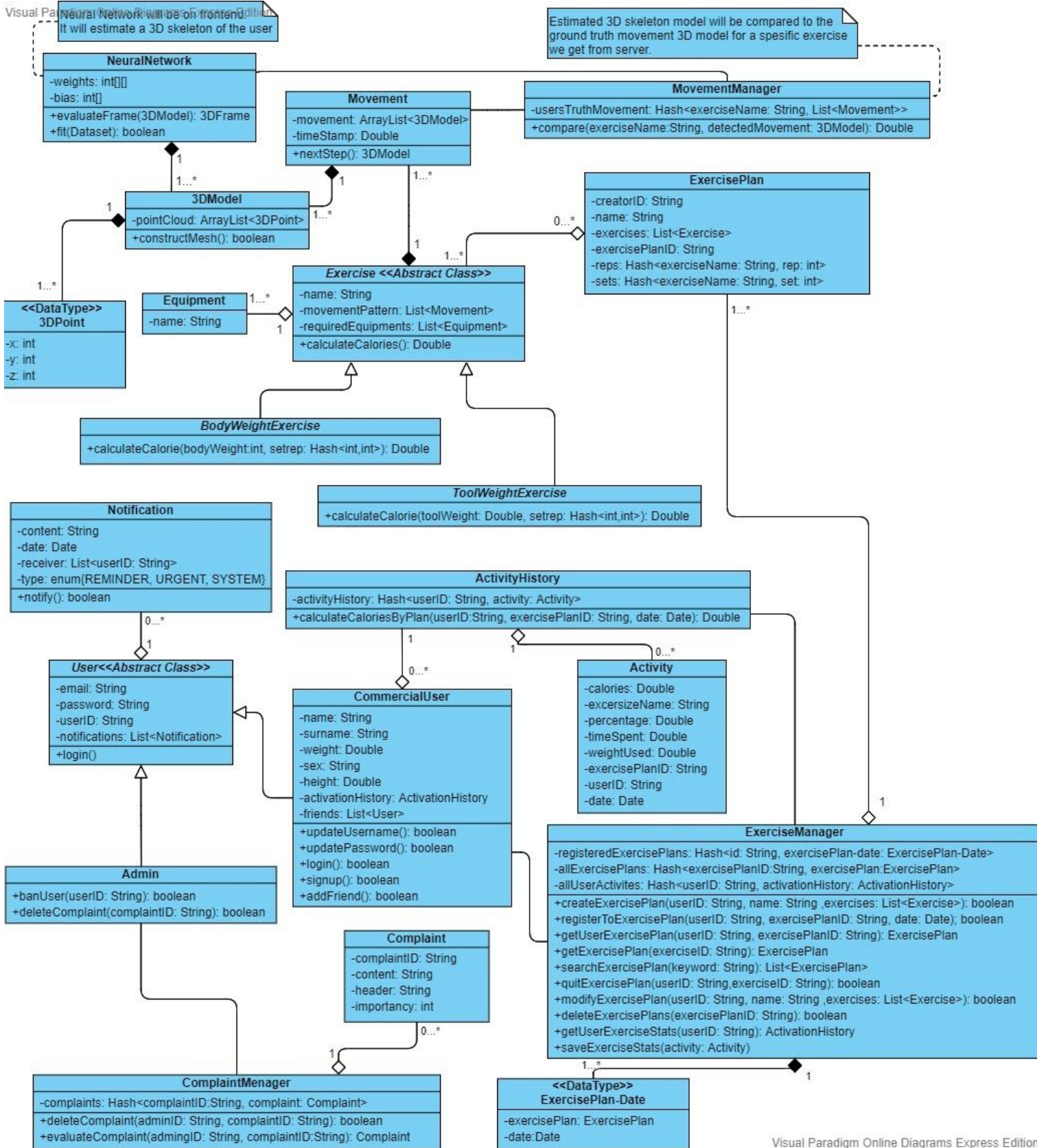Figure1 : Use Case Diagram

3.5.3. Object and Class Model

Figure 2 : Class Diagram

3.5.4. Dynamic Models
3.5.4.1. Sequence Models

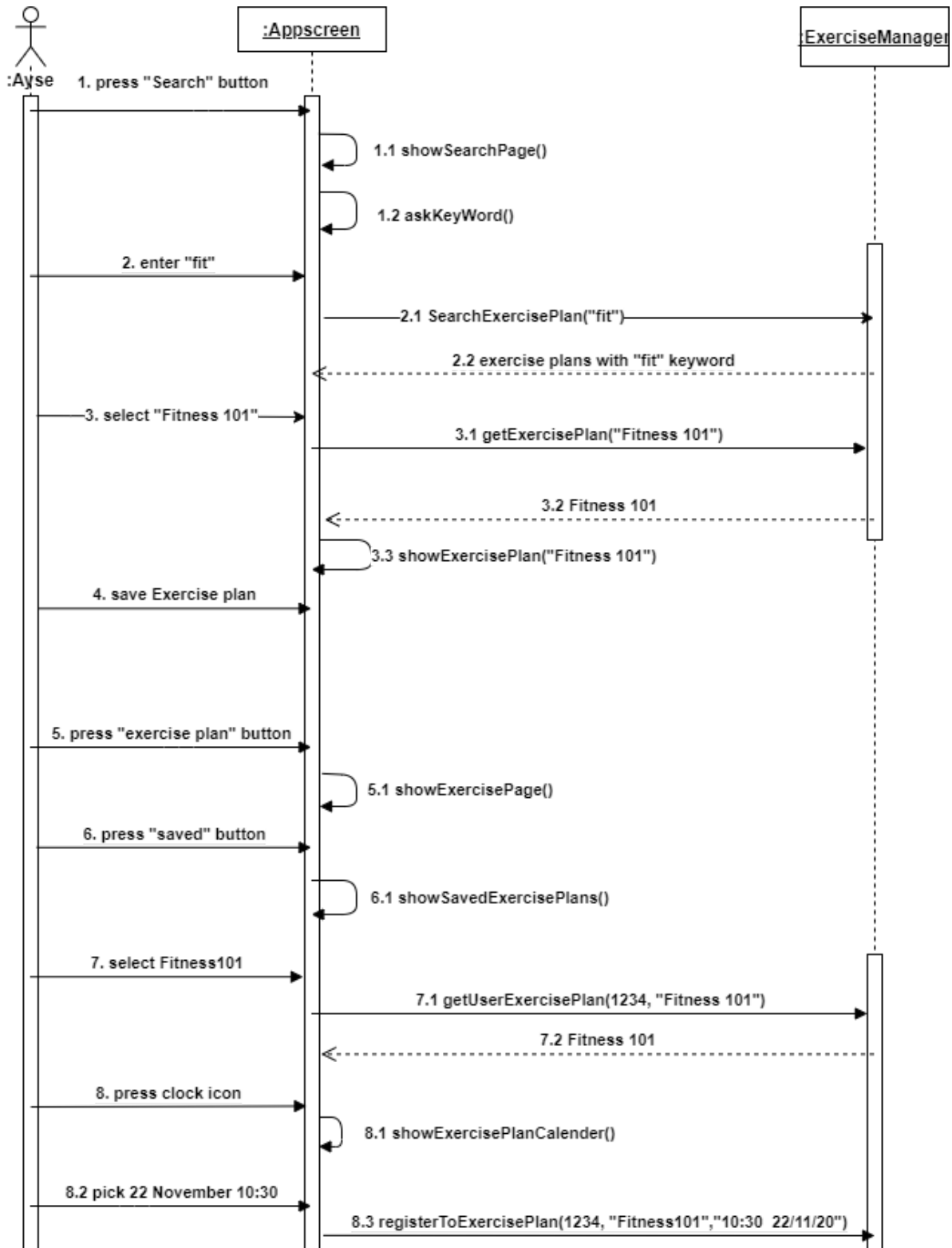Sequence Model: User searches for exercise plans with "fit" keyword, saves the exercise plan "Fitness101", schedules "Fitness101" to 22/11/20 10:30

Figure 3 : Sequence Diagram 1

Sequence Model: User looks at her exercise statistics
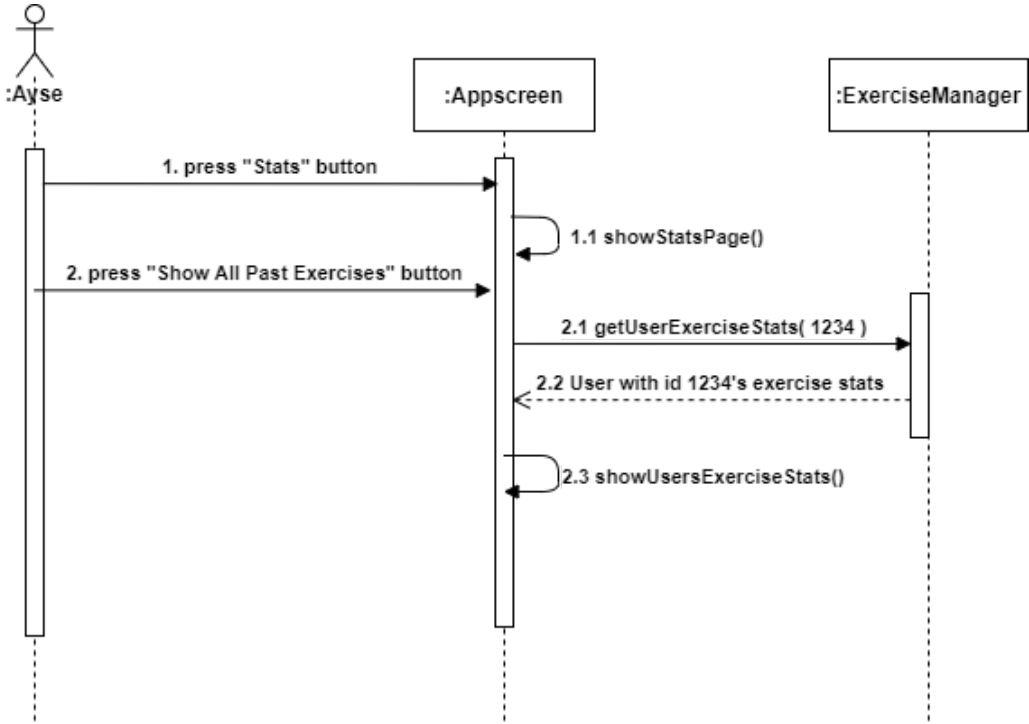
Figure 4 : Sequence Diagram 2

Sequence Model: User creates a new exercise plan
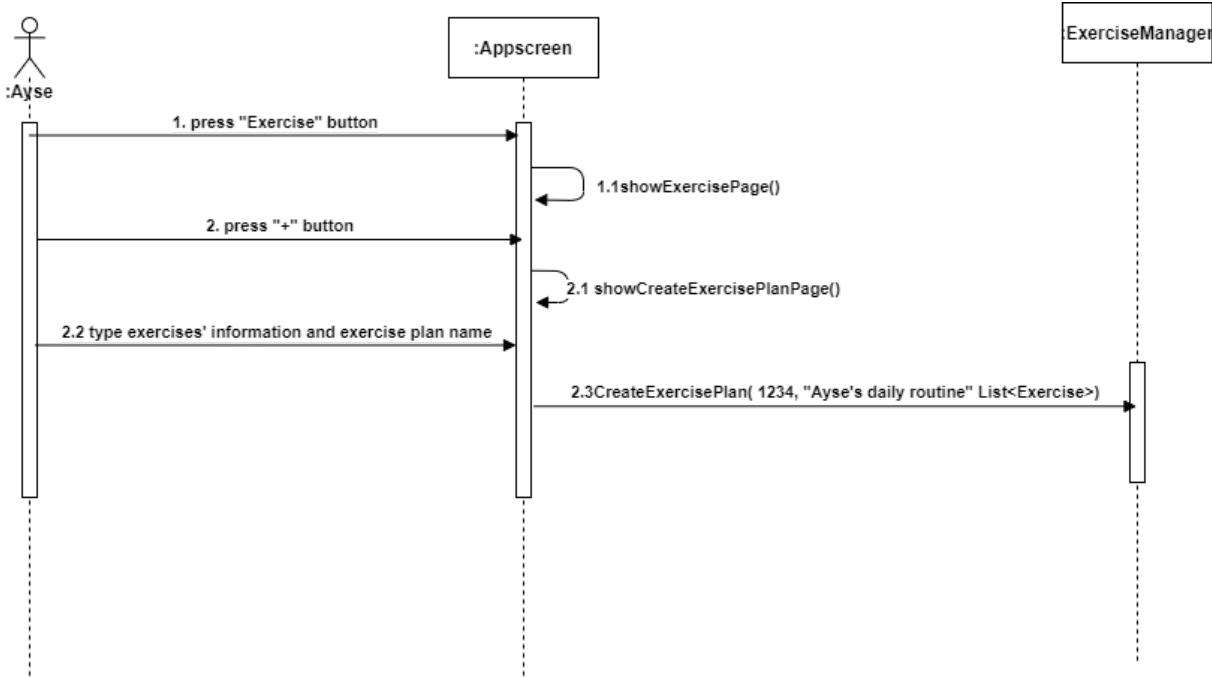
Figure 5 : Sequence Diagram 3

Sequence Model: User looks at her exercise plans, picks "Arda's Magic" exercise plan, starts exercise plan.
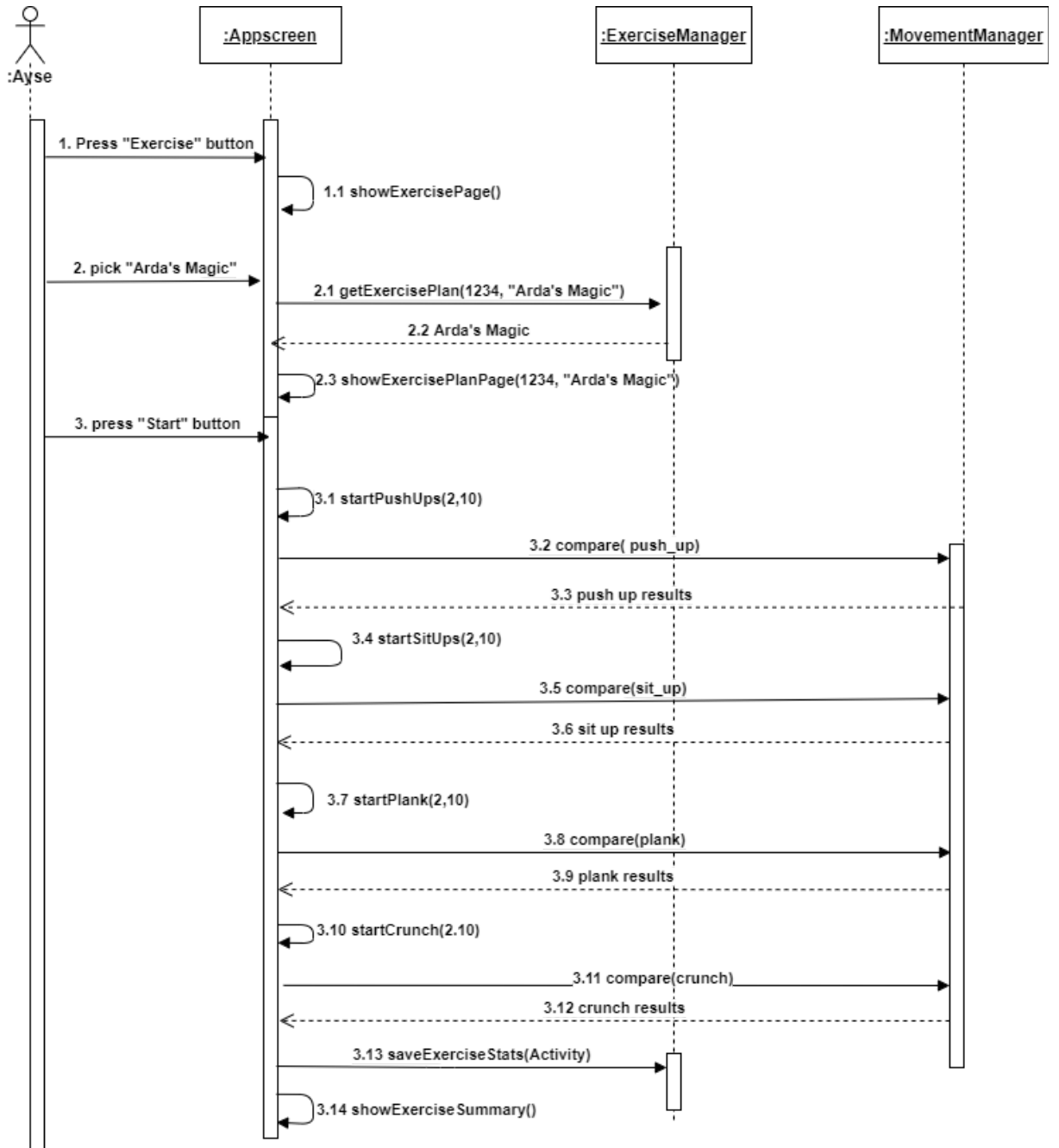
Figure 6 : Sequence Diagram 4

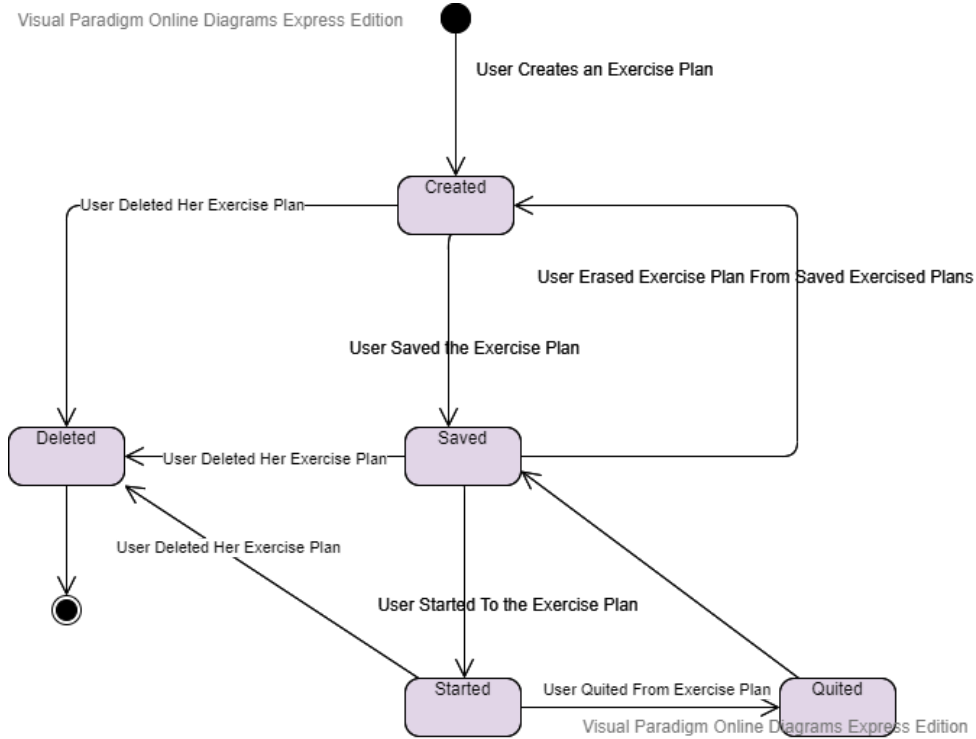## 3.5.4.2. State Diagrams

State Diagram for Exercise Plan

Figure 7 : State Diagram

3.5.4.3. Activity Diagrams
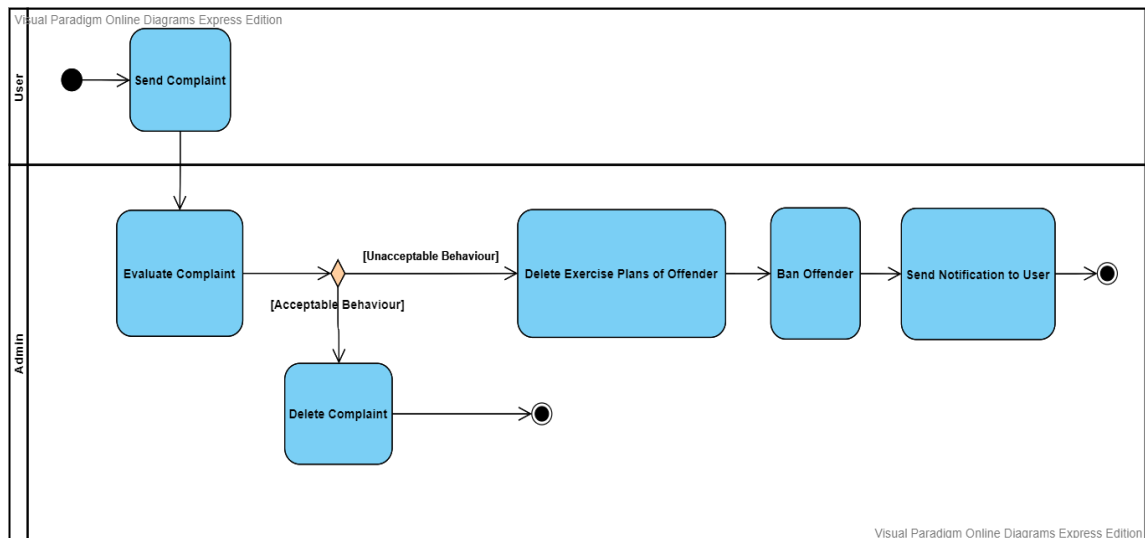
Activity Diagram for Sending Complaint About Other Users

Figure 8 : Activity Diagram 1

Activity Diagram for Searching and Adding Friend

Open Search Page

Open People Tab

Type Friend's Name

[Friend's Name Is Not Found]

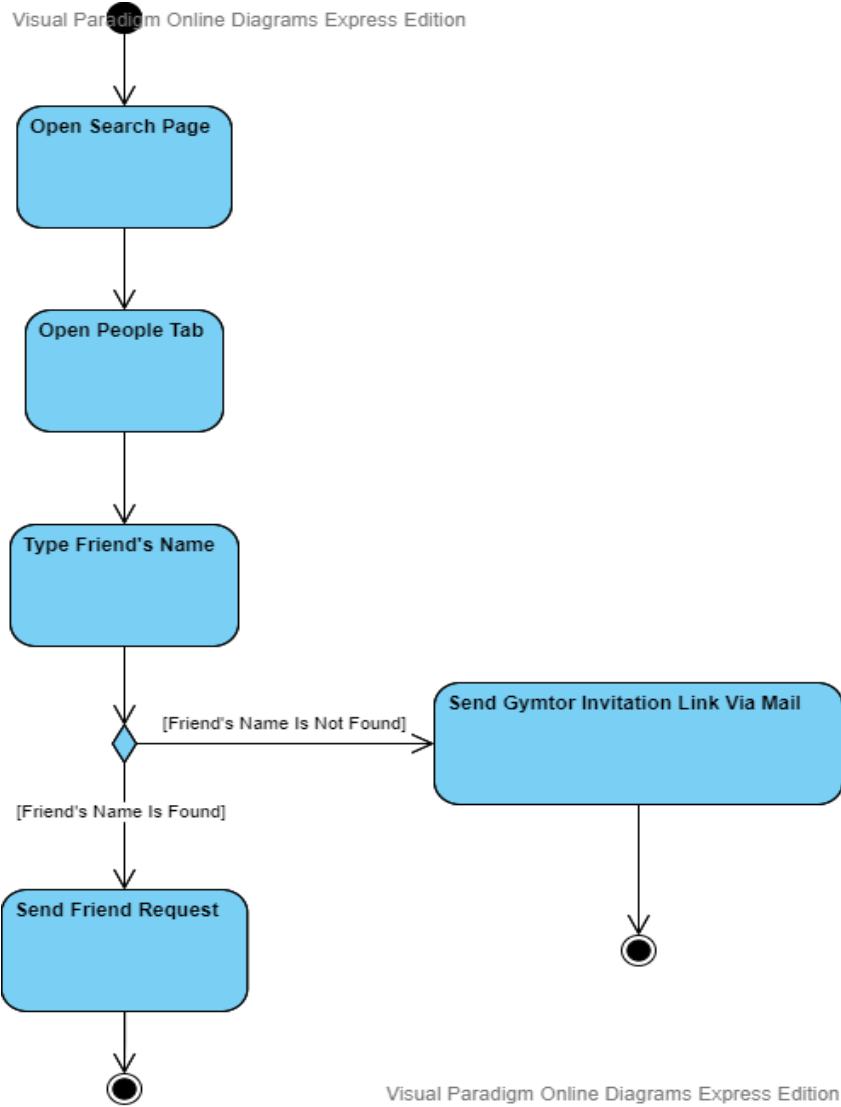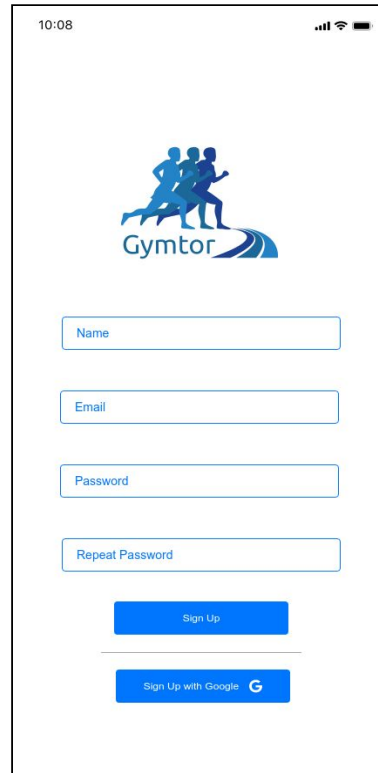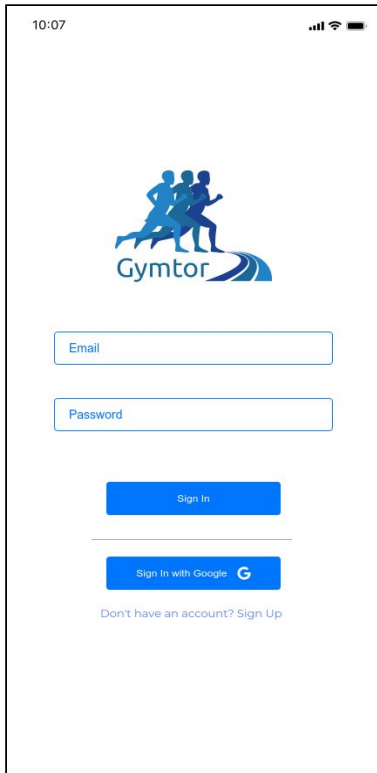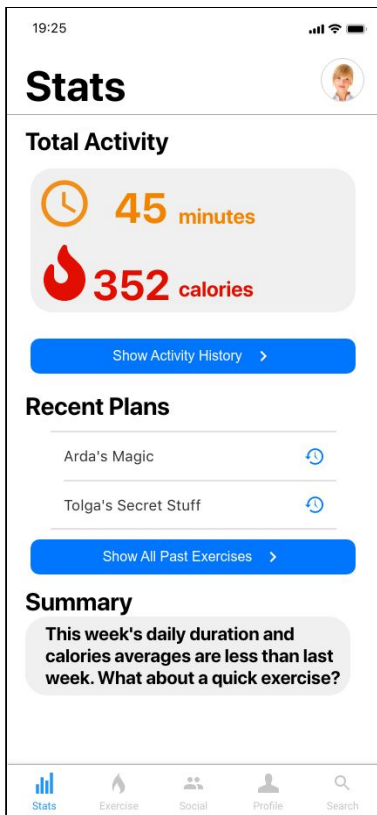Send Gymtor Invitation Link Via Mail

[Friend's Name Is Found]
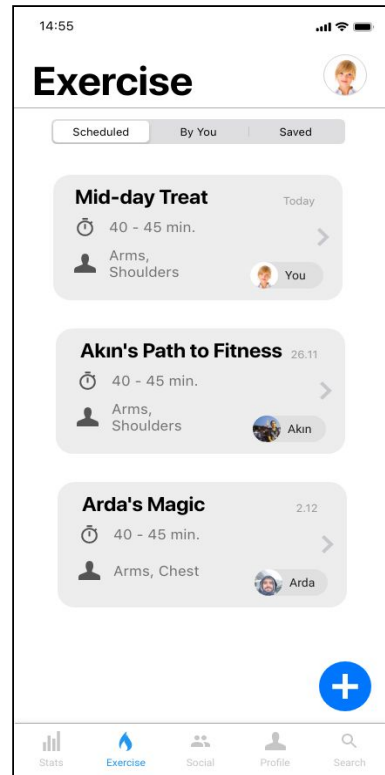
Send Friend Request

Figure 9 : Activity Diagram 2
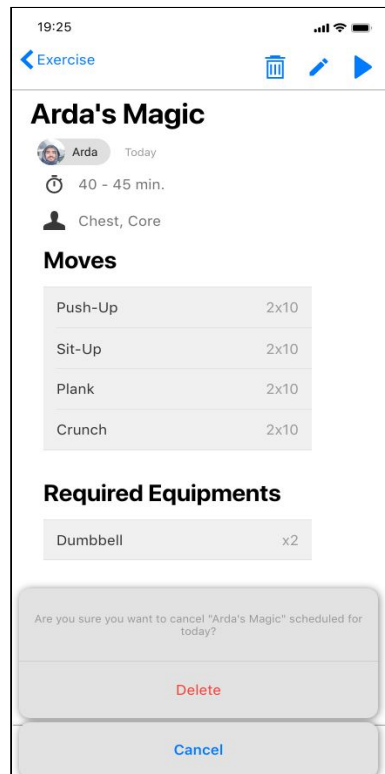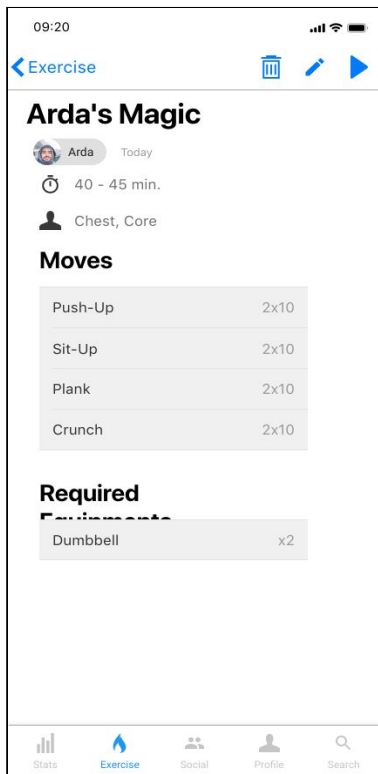
3.5.5. User Interface - Navigational Paths and Screen Mock-ups

Log In and Sign Up Screens

Stats and Visualized Stats

Screen 1 (top left)

19:25

‹ Stats

All Exercises

Arda's Magic	Today	37m	230cal
Tolga's Secret Stuff	17.11.2020	32m.	435cal
Full Body	15.11.2020	45m	324cal
Fat Burner	13.11.2020	1h13m	763cal
Akın's Path to Fitness	13.11.2020	57m	564cal
Ömer's Anti-Fat Way	12.11.2020	43m	356cal
Umur's Two Way Approach	10.11.2020	36m	319cal
Full Body	9.11.2020	42m	340cal
Full Body	8.11.2020	31m	308cal

Stats   Exercise   Social   Profile   Search

Screen 2 (top right)

14:55

Exercise

Scheduled | By You | Saved

Mid-day Treat   Today
⏱ 40 - 45 min.
👤 Arms, Shoulders   You

Akın's Path to Fitness   26.11
⏱ 40 - 45 min.
👤 Arms, Shoulders   Akın

Arda's Magic   2.12
⏱ 40 - 45 min.
👤 Arms, Chest   Arda

Stats   Exercise   Social   Profile   Search
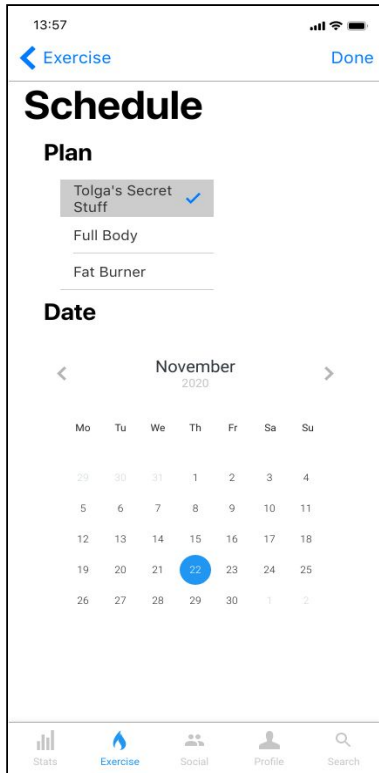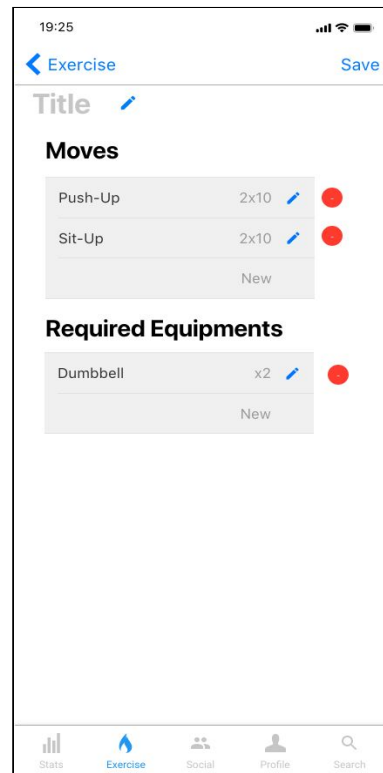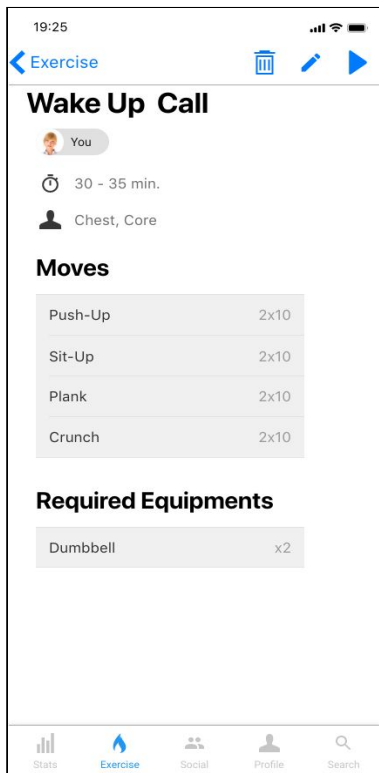
Past Exercises and Scheduled Exercises

Screen 3 (bottom left)

09:20

‹ Exercise   🗑 ✎ ▶

Arda's Magic

Arda   Today
⏱ 40 - 45 min.
👤 Chest, Core

Moves

Push-Up	2x10
Sit-Up	2x10
Plank	2x10
Crunch	2x10

Required Equipments

Dumbbell	x2

Stats   Exercise   Social   Profile   Search

Screen 4 (bottom right)

19:25

‹ Exercise   🗑 ✎ ▶

Arda's Magic

Arda   Today
⏱ 40 - 45 min.
👤 Chest, Core

Moves

Push-Up	2x10
Sit-Up	2x10
Plank	2x10
Crunch	2x10

Required Equipments

Dumbbell	x2

Are you sure you want to cancel "Arda's Magic" scheduled for today?
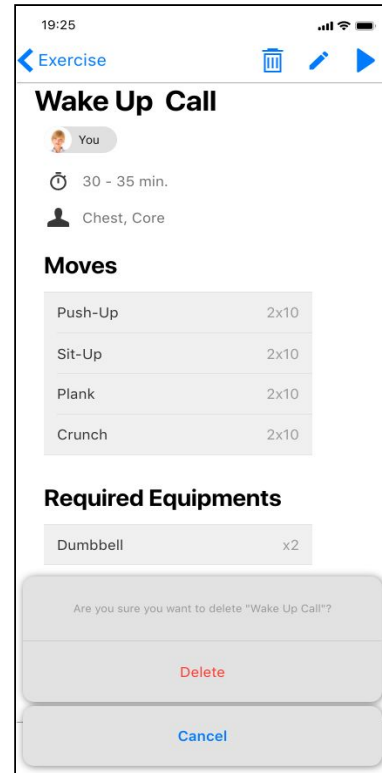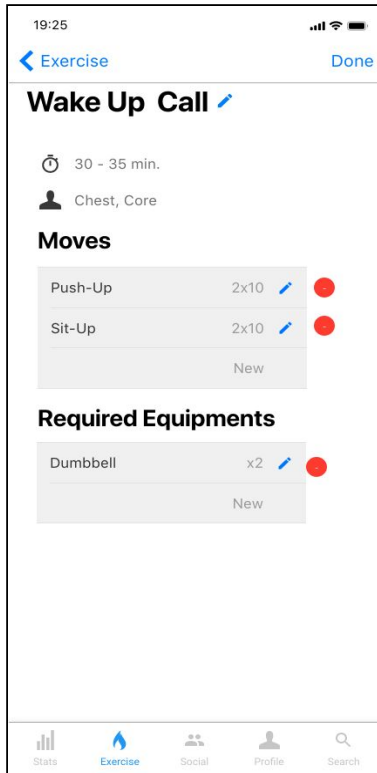
Delete

Cancel

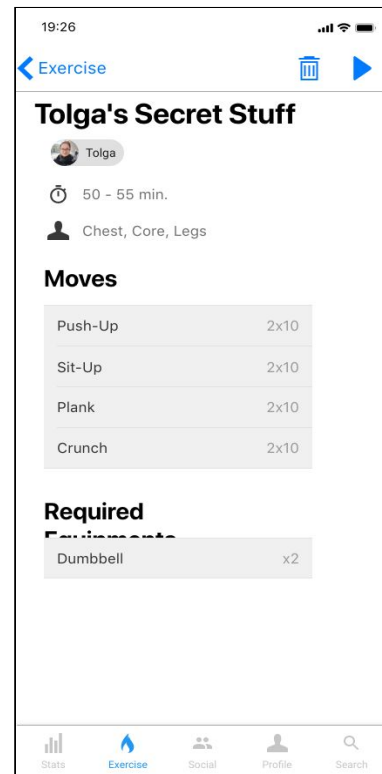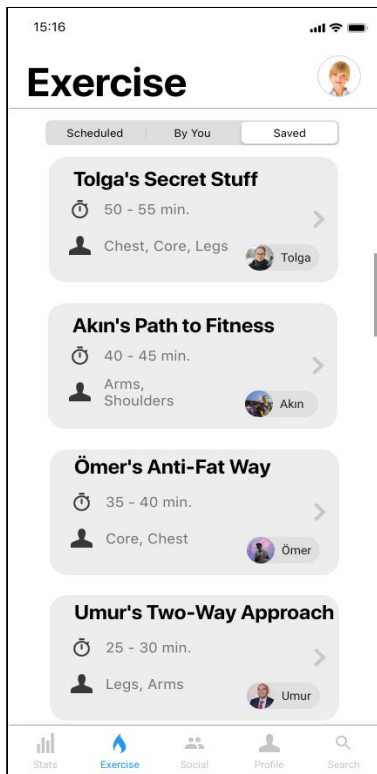Scheduled Exercise in Detail and Cancelling a Scheduled Exercise
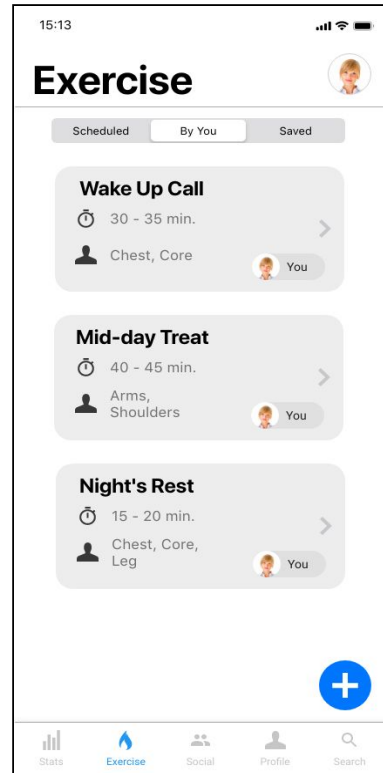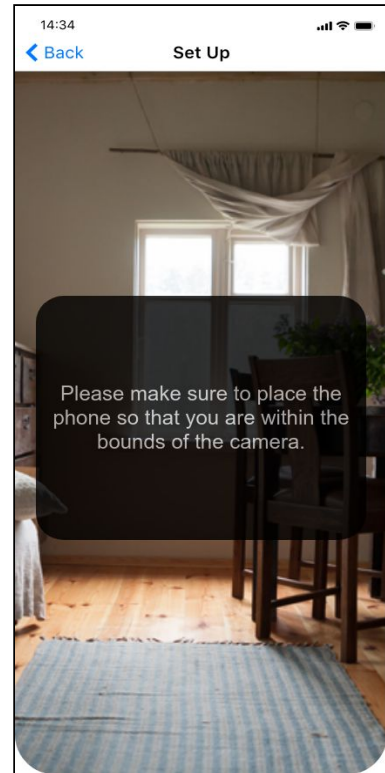
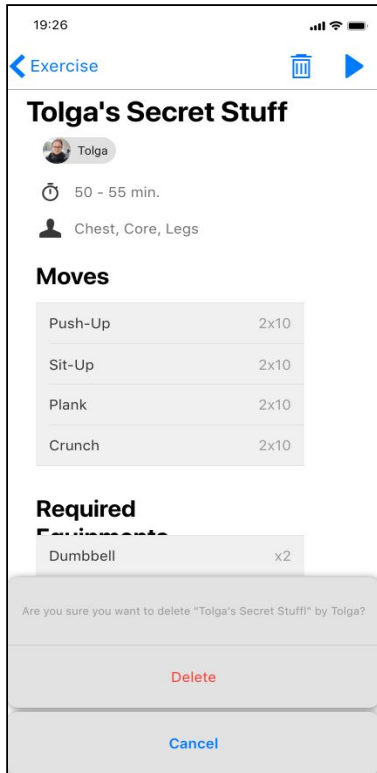Exercise Scheduling and Own Exercise Plans

Own Exercise Plan in Detail and Exercise Plan Creation

Editing Own Exercise Plan and Deleting Own Exercise Plan

Saved Exercises and Saved Exercise in Detail

Deleting a Saved Exercise and Exercise Set Up
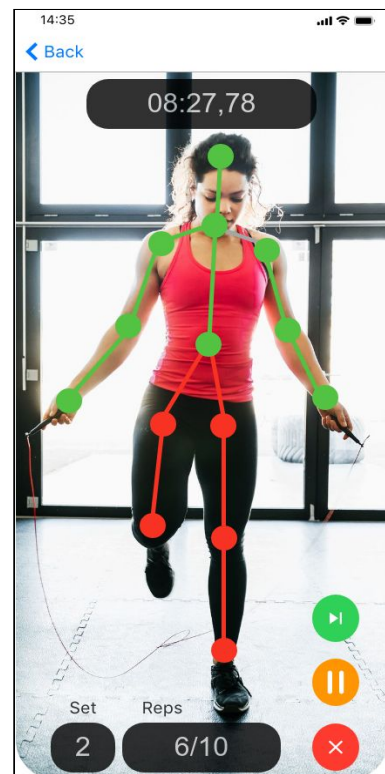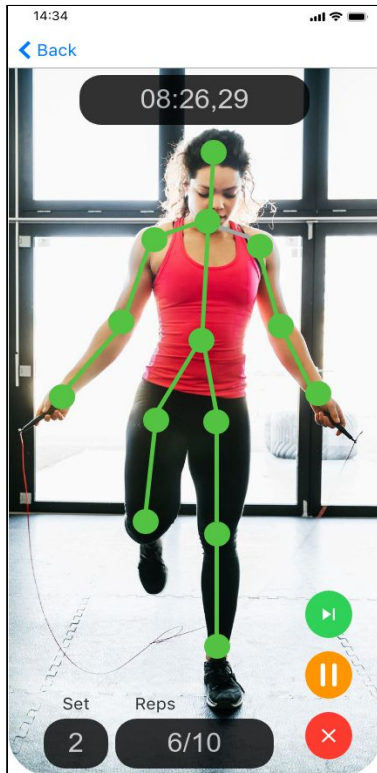
Visual Feedback on Correct Exercise and Incorrect Exercise

Exercise Pause and Exercise Summary

Social Screen and Friend Profile

Friend's Exercise Plan and Friend's Connections

Profile & Settings and Changing Password
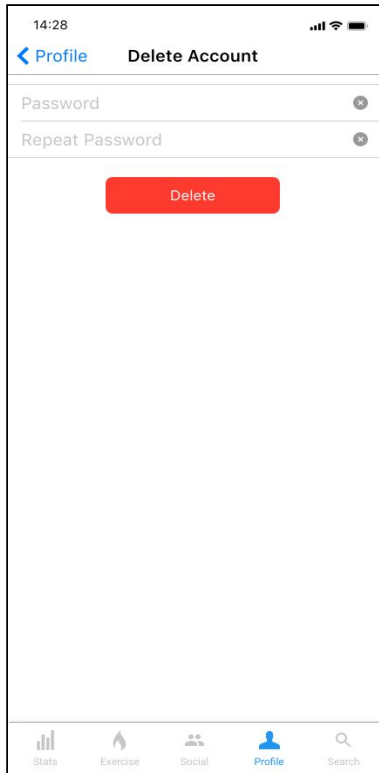
Deleting Account and Searching Page
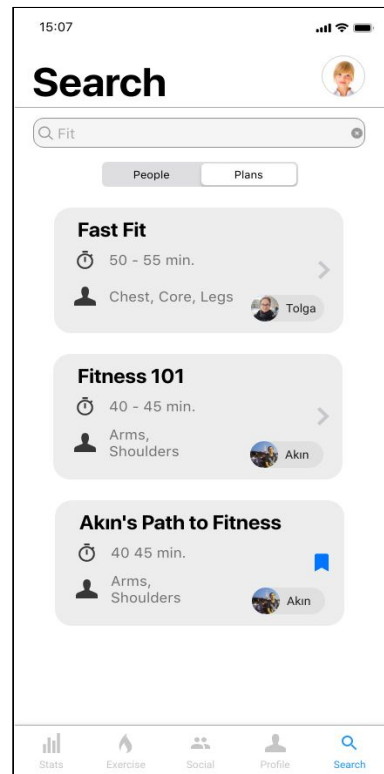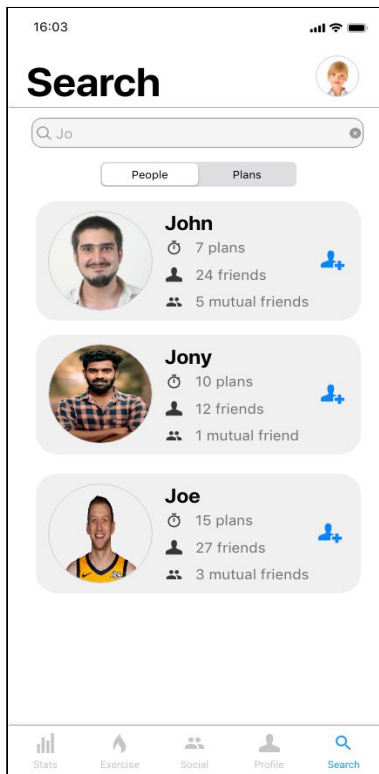
Searching People and Searching Exercise Plans

4. Other Analysis Elements
4.1. Consideration of Various Factors in Engineering Design

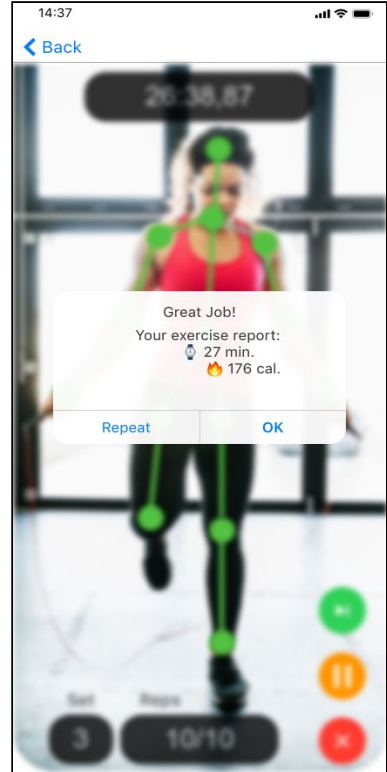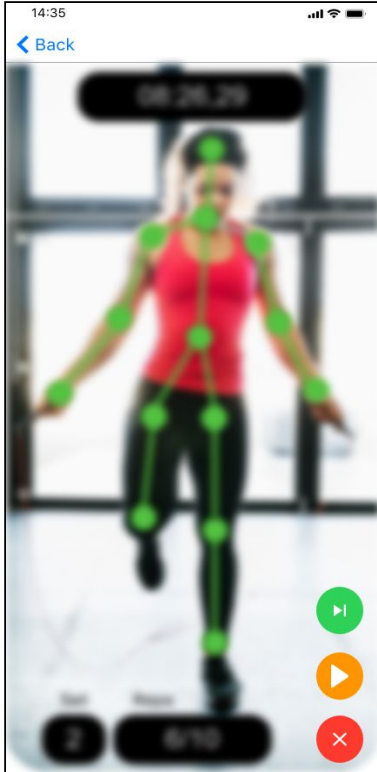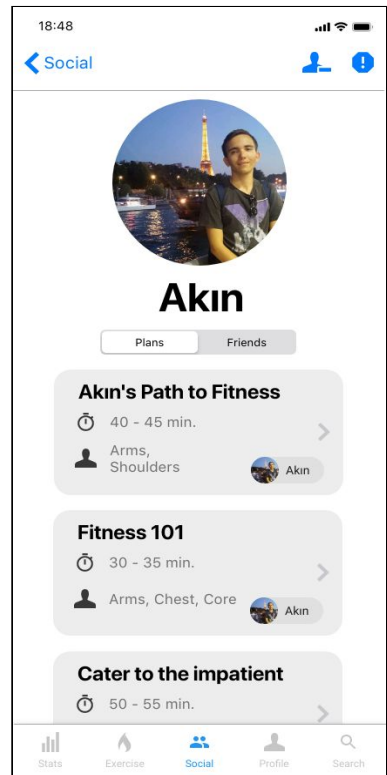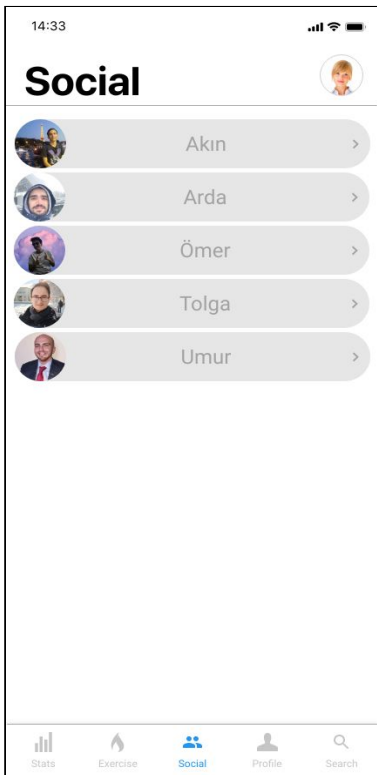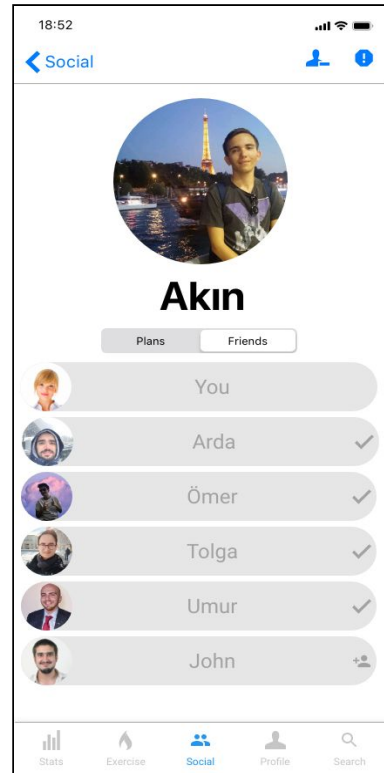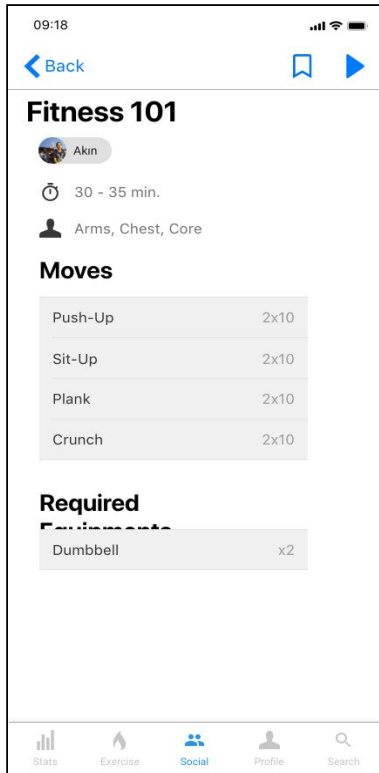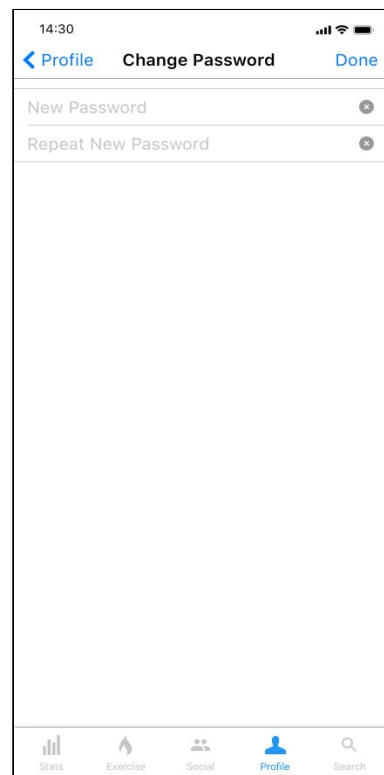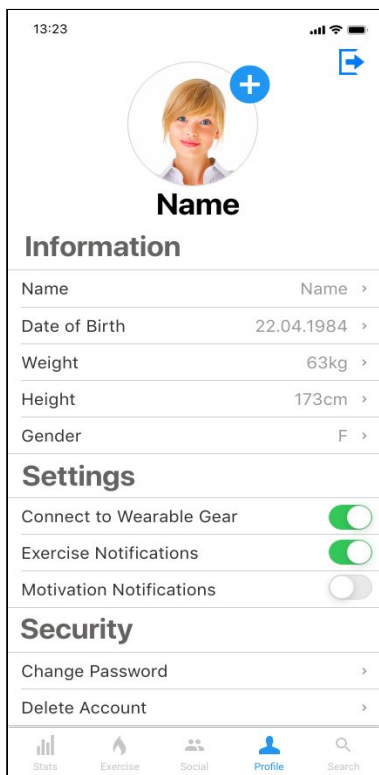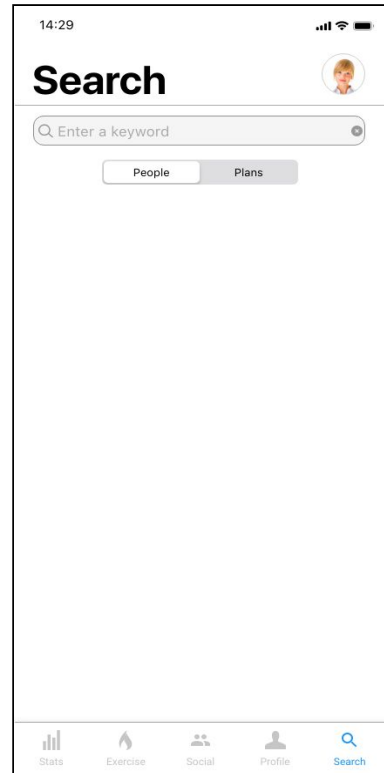- **Public Health:** Gymtor is a sports assistant app that is directly connected to the body's health. Gymtor must not force users to do exercises that might be harmful to them. Furthermore, it must not motivate them to try harder exercises or to increase the repeats of exercises up to a limit that they cannot handle. Besides, properly doing the exercises also affects user health. Thus, Gymtor must be able to give accurate instructions to the user and must not drive them to do the exercises in the wrong way which may harm them.

- **Public Safety:** Gymtor will use image processing technologies that require users to allow camera access to the application. The visual materials of the users will be processed by the application and these materials may contain private information such as inappropriate visuals of a person, any material that might reveal the location of the person such as a specific building or banner in the background, or any personal information. In a situation where these materials are accessed from a third party person or organization without permission, this might create a potential safety problem for the users.

- **Public Welfare:** Gymtor will be a free sports assistant application and its motivation is to help people to do exercise at home or wherever they want without paying any money or without going to the gym. Thus, Gymtor may satisfy some users' exercise needs without enrolling in a gym, which eventually benefits their welfare.

- **Cultural Factors:** Gymtor has no major relationship with cultural factors. However, Using a mobile application with machine learning technologies, and getting instructions from it may make some people feel uncomfortable or unusual.

- **Social Factors:** Sports activities are not only a body health matter but also it is a socializing tool for many people. Gymtor's motivation is to allow people to do sports at home, however, this might hinder users from socializing by going to the gym or attending outdoor sports. Thus, it is planned to add a friendship and following mechanism between users so that they will be connected to each other via the application.

- **Economical Factors:** Gymtor will be a free application. However, using a server for the application for the database and for the computational power (if necessary) have a cost. Still, this cost will be minimal at the beginning of the application with fewer users and can be afforded easily. However, in the future, these fees can be afforded with sponsors and possible in-app purchases. Still, this future issue currently is not one of our primary discussions.

- **Environmental Factors:** Gymtor has no major relationship with environmental factors.

Factor	LVL	Effect
Public Health	9	Gymtor is a sports assistant app, which is directly related with health.
Public Safety	7	Gymtor uses visual material of users which may contain private data or any data that is a possible threat to users' safety.
Public Welfare	6	Gymtor is a free app that may hinder users from spending money at the gym and motivate them to do exercises at home.
Cultural Factors	2	Only cultural factor of Gymtor for the users is to be assisted by an artificial intelligence which may make them feel unusual.
Social Factors	4	Sports is a way of socializing and this is not possible while doing sports at home, which Gymtor exists for. Thus, the social features of Gymtor will handle social factors.
Economical	3	Gymtor will be free, and any fee in the future are planned to be afforded using possible sponsorships.

Environmental	0	There is no major relationship between Gymtor and environmental factors.

4.2. Risks and Alternatives

Failure to Give Accurate Feedback: Visual detection with machine learning applications is not an easy task. Additionally, our team has a lack of knowledge and experience in this area. Thus, it is a risk that our machine learning models may not be sufficient to give accurate feedback. Also, the feedback it gives may not be true because of a lack of knowledge in sports. This situation not only affects the user experience, it also threatens the health of the users. To deal with these risks, it is planned to contact professionals about exercise plans and possible problems. In the case that the accuracy of the feedback is inadequate, we are planning to add some feedback constraints that are created by personal trainers to limit the machine learning model to give better instructions.

Leak of User Data: When technology and the user data are on the table, it is inevitable to have the risk of a data leak. Even big companies like Google, Facebook, or Amazon are facing this problem. Besides the fact that any data leak mens the violation of the laws, it threatens the safety of the user. Thus, the risk of a data leak is one of our top-level considerations. We are planning to use the standard data encryption techniques with secure data servers, and to follow the sector standards for ensuring security. However, in the case that the security of our data is questionable in the end-product, then we are planning to modify the app so that no highly private data will be saved, rather, they will be all saved to the device of the user.

Insufficient Project Management: Creating a product in the domain that we do not have experience may cause that we may not finish the product before the deadline. To ensure that everything is on schedule, we are planning to make periodic meetings to evaluate our situation and discuss whether there is a risk of missing the deadline. If this is the case, this situation will be detected as soon as possible with these meetings and precautions will be applied.

Insufficient Technical Knowledge: In the development phase, it is possible that our technical knowledge is inadequate to create the end product. To ensure that this will not be a problem, we are planning to do a comprehensive literature search systematically and periodically. We are planning to make a meeting every two weeks and in this period,

everyone will be assigned with two or three articles. Then, these papers will be explained to the others in these meetings. In this way, we will ensure that insufficient technical knowledge will not be a problem. In case of any serious knowledge issues that we still could not handle, we are planning to ask for advice from our supervisors and instructors.

Problem	Likelihood	Effect on the Project	B Plan Summary
Failure to give accurate feedback.	3	Inaccurate exercise feedback may cause injuries or health problems.	Adding some feedback constraints that are created by personal trainers.
Leak of user data.	1	Violation of the law, and threatens the safety and the privacy of the user.	Using standard security protocols and not storing any important data on the servers.
Insufficient Project Management	1	Missing the deadlines.	Early detection of the problem with regular meetings and taking immediate precautions.
Insufficient technical knowledge.	2	Insufficient product functionality.	doing comprehensive literature search regularly, asking for advice from our supervisors and instructors.

4.3. Project Plan
4.3.1. Gymtor Gantt Chart

4.3.2. Work Packages and Plannings

WP	Work Package Title	Leader	Members Involved
WP1	Documentation	Emre Tolga Ayan	All Members
WP2	Frontend Development	Umur Göğebakan	Ömer Faruk Kürklü

WP3	Backend Development	Ömer Faruk Kürklü	Akın Parkan, Emre Tolga Ayan
WP4	Machine Learning Development	Cemal Arda Kızılkaya	All Members
WP5	Testing	Akın Parkan	Cemal Arda Kızılkaya

WP1: Documentation

Start Date: 01-10-2020 **End Date:** 31-04-2021

Leader: Emre Tolga Ayan
Members Involved: All Members

Objectives: Preparing necessary reports and product documentations in order to keep the project under control and design the project beforehand. The documentations such as high-level and low-level design reports will be the source documentation while working on the end product.

Tasks:
Task 1.1: Writing High-level design report
Task 1.2: Writing Low-level design report
Task 1.3: Writing Final Report
Task 1.4: Preparing necessary presentation documents and slide shows.

Deliverables
D1.1: High-level design report
D1.2: Low-level design report
D1.3: Final report
D1.4: Final report presentation

WP2: Frontend Development

Start Date: 21-11-2020 **End Date:** 20.01.2020

Leader: Umur Göğebakan
Members Involved: Ömer Faruk Kürklü

Objectives: Implementing the UI design of Gymtor with user-friendly animations and effects.

Tasks
Task 2.1: Researching user behaviors and best practises for UX/UI implementation.
Task 2.2: Implementation of main page, signin/signup page. exercises page, statistics page and settings page.
Task 2.3: Implementation of exercise session page.

Deliverables
D2.1: Main page, signin/signup page. exercises page, statistics page and settings page
D2.2: Exercise session page

WP3: Backend Development
Start Date: 21-11-2020 **End Date:** 20-02-2021
Leader: Ömer Faruk Kürklü **Members Involved:** Akın Parkan, Emre Tolga Ayan
Objectives: Implementing the connections between the machine learning system, database system and the frontend system. Implementing the UI based backend functionalities of Gymtor.
Tasks **Task 3.1:** Implementing the frontend based functionalities of Gymtor. **Task 3.2:** Implementing database system. **Task 3.3:** Implementing the connection between machine learning system, database system and the frontend system
Deliverables **D3.1:** Database System **D3.2:** Frontend Functionality **D3.3:** Connections between different systems

WP4: Machine Learning Development
Start Date: 01-01-2021 **End Date:** 01-04-2021
Leader: Cemal Arda Kızılkaya **Members Involved:** All members
Objectives: Implementing the product for detecting body gestures, human actions and movements and generating feedback accordingly.
Tasks: **Task 4.1:** Implementing the machine learning based feedback system. **Task 4.2:** Integration of machine learning system into mobile platform.
Deliverables **D4.1:** ML based feedback system that generates real time feedback based on the visual input. **D4.2:** Mobile integration of ML system.

WP5: Testing
Start Date: 01-04-2021 **End Date:** 31-04-2021
Leader: Akın Parkan **Members Involved:** Cemal Arda Kızılkaya
Objectives: Testing the UI functionality, connections between different systems and feedback accuracy of the machine learning model.
Tasks

Task 5.1: Testing UI/UX design for usability **Task 5.2:** Testing UI functionality. **Task 5.3:** Testing connections between different systems. **Task 5.4:** Testing machine learning accuracy in different conditions.
Deliverables **D5.1:** Comprehensive testing results report.

4.4. Ensuring Proper Teamwork

In order to ensure proper teamwork, we have been using third party applications: Jira for tracing the job done by each member and their job status; Discord for synchronous communication between team members; Google Docs for working on reports concurrently; Github for working on code concurrently and easily. Every monday after CS491 class, we organise our meetings and we share the beneficial articles to our project related to Computer Vision and Deep Learning.

4.5. Ethics and Professional Responsibilities

Gymtor collects data from users such as images or videos, personal information and preferences which are private and needs to be stored or used carefully. Any information that had been captured in that manner must be used without breaking the agreement between user and the application. A detailed and explicit User's Agreement to the Terms and Policies must be proposed to users before using the application and only the users who have accepted the policies should be subject to storage of private information. Our application requires analyzing videos and capturing the most of the information that is possible. Some personal information like weight, sex, age or other physically related information must be tracked. So we must ensure that users trust the application and do not try to give false information.

4.6. Planning for New Knowledge and Learning Strategies

Since Gymtor is a mobile application, first we need to learn how to create a mobile application for android phones. To do that, besides the lots of rich online courses and material, Google has its android development courses and we are planning to follow them.

For the machine learning side, we are planning to do a comprehensive literature review about machine learning, real-time image processing, and body mapping. Also, we are planning to investigate the open-source tools for body, movement, and action analysis. Additionally, we must find a way to use the machine learning features on the mobile side. For this purpose, we are planning to follow courses from Coursera and to read official documentations for machine learning and android development tools.

5. References

[1] D. Bider, "Use of RSA Keys with SHA-2 256 and 512 in Secure Shell (SSH)," Nov. 2015, Accessed: Nov. 21, 2020. [Online]. Available: https://tools.ietf.org/html/draft-rsa-dsa-sha2-256-02.

[2] "Firebase." https://firebase.google.com/ (accessed Nov. 21, 2020).