



Bilkent University
Department of Computer Engineering

Senior Design Project

Gymtor

High Level Design Report

Emre Tolga Ayan, Umur Gögebakan, Cemal Arda Kızılkaya, Ömer Faruk Kürklü, Akın Parkan

Supervisor: Selim Aksoy

Jury Members: Can Alkan, Çiğdem Gündüz Demir

High Level Design Report

December 27, 2020

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.

Contents

Introduction	3
Purpose of the System	3
Design Goals	4
Definitions, Acronyms, and Abbreviations	5
Overview	6
Current Software Architecture	7
Proposed Software Architecture	8
Overview	8
Subsystem Decomposition	8
Hardware/Software Mapping	11
Persistent Data Management	11
Access Control and Security	12
Global Software Control	13
Boundary Conditions	14
Subsystem Services	15
Presentation Tier	15
Logic Tier	16
Data Tier	17
Considerations of Various Factors in Engineering	17
Teamwork Details	17
Contributing and Functioning Effectively on the Team	18
References	18

1. Introduction

Exercising on a regular basis is essential for living a healthy life and one of the best practises that you can turn into a habit to take care of what had already been given to you: your body faced with slowly fading into mold, yet still full of energy and filled with the fresh water from the spring of youth; ready to move, willing to act; ready to prove, waiting to attack.

However, due to the way of living that most of today's society has to pursue, each day each person wastes their time on the way to work, at work and on the way back to home [1]. Unwillingly paying hundreds of dollars to fitness clubs and personal trainers just to make you sweat for 45 minutes and listening to your excuses about how difficult it is to reach out the gym after work at rush hour [2]. So we think that an inactive lifestyle, which is one of the most serious problems of the digital era [3], could and should be solved by an intelligent digital application: Gymtor, your artificially intelligent fitness mentor.

In order to make exercising accessible to more people, our team came up with the idea of a sports 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 development of this idea, we realized that most of the mobile phones that we encounter today are capable of capturing sufficiently high resolution videos and have enough computational power to perform the tasks that our idea presupposes. Furthermore, smart phones have become an integrated essential part of our lives that everybody has always access to in nearly every condition. If we take into account that newly developing smart watch industry, some additional information about the state of the body can be collected and used to extract meaningful information.

In the remaining sections of this report, the system will be described in detail. First, the Current and Proposed System Architectures will be explained. Then, the Subsystem Services and Considerations of Various Factors in Engineering section will be presented. Finally, Teamwork Details will be provided at the end of the report.

1.1. Purpose of the System

Gymtor is an artificially intelligent mobile application that its main purpose is to let users do physical exercises at their home as proper as possible while keeping information about the development process of him/her, making the process of development easier, more interactive

and more accessible. Embodying various state of the art computer vision techniques, Gymtor is aiming to control the user about how the movements are being done and give live time feedback to correct the movements of the user compared to the correct movement patterns of the shown exercise.

1.2. Design Goals

We have decided that the following design concepts should be taken into consideration while software design process:

1.2.1. Usability

Gymtor should be easy to use so that the users can operate the system effectively and make productive use of it. Therefore, the user interface should be simple and easily navigable even for the first use. It should also be compatible with other android smartphones.

1.2.2. Performance

Since Gymtor should give live feedback to the user based on the exercise that has been shown, it is important for the application to process input, make necessary calculation steps and return feedback to the user almost in real time. In order to achieve this goal, neural network based models should be optimized and computations should be done regarding their computation.

1.2.3. Robustness

The system should remain in a constant state and give meaningful responses to the user even when the backend services or any important service is temporarily unavailable. Also if there occurs an error on the mobile side, the system should still be responsive and be able to restore current state from the server side.

1.2.4. Availability

The system should be active and responsive throughout the entire live exercising process. Server should not stop working and always be in a consistent state unless there is an unpredictable emergency event affecting the server.

1.2.5. Scalability

System should be sustainable as the number of users is expected to increase with time. So it should be scalable and not lose its performance constraints after a certain point of users.

Also the design should satisfy adding new features in the future as easy as possible and extend the usage of other devices for a possible integration in the future.

1.3. Definitions, Acronyms, and Abbreviations

Abbreviations and some technical terms that have been used in the report are listed here with their brief explicit definition for a better understanding of the latter sections:

1.3.1. Cloud Storage

HTTP based request responder to retrieve information. Online and can be reached through the network.

1.3.2. Client

HTTP based request sender. Sends online requests to the backend to retrieve information as a response.

1.3.3. Movement Ground Truth

Array of 3D point cloud sparse matrices to represent the accurate movement pattern of an exercise.

1.3.4. Machine Learning Model

Trained models to produce certain outputs from a given output according to the learnt/estimated parameters during the training phase.

1.3.5. JSON

JavaScript Object Notation as a lightweight communication format to store and transfer data.

1.3.6. AWS

Amazon Web Services, a cloud platform to provide computational resources as well as remote machine instances.

1.4. Overview

Gymtor will be a mobile application that will assist users to do exercises using visual processing and machine learning techniques for the Android platform. 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.

2. Current Software Architecture

Currently in the market there are a lot of sport assistants. The main purpose of our system is to enhance the sport experience by providing machine learning components that detect user movement and give feedback to users on their movement.

Current Systems:

- **Movement Detector:**

Gymtor use image processing techniques to visually capture and detect users' movements in order to give appropriate feedback on the sport that the user has done.

Features:

- Detects the users initial posture before starting the exercise,
- During the exercise detects users movement and sends the obtained data to MachineLearningComputer Package to compute the correctness of the movement and to obtain exercise summary.

- **Sport Assistant**

Gymtor has a sport assistant that gives feedback to users using the data obtained from the MachineLearningComputer Package which is used to calculate the calories burnt and correctness of the movement. The feedback given to users is related to how they can improve their move on specific movement.

Features:

- It shows the exercise summary. (The users can see how accurate they have done the movements, how much calories they have burnt by doing that movement.)
- It shows the exercises planned. (The users can plan exercises in their schedule)

- **Social Media Manager**

In Gymtor, users can add each other as friends and see each other's exercise plans. As a result, this mechanism has to be supported by current software architecture

Features:

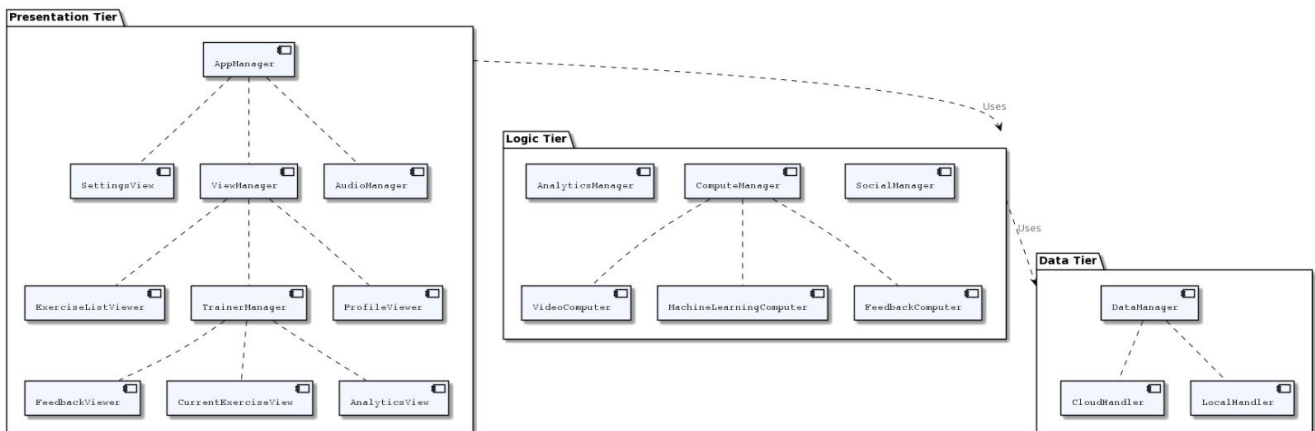
- Search for friends (it is needed to look at the Cloud if the searched user exists on the Gymtor)
- Send friend request (An user can send friendship request to another user, this feature is provided by CloudHandler since it is a database injection class)
- See friends exercise plans (A user can see his/her friends exercise plans)

3. Proposed Software Architecture

3.1. Overview

Here we introduce the architectural software design of the proposed Gymtor application. First, decomposition of the system will be presented and each identified subsystem will be explained explicitly with their functionalities and their association with other systems being emphasized. This section is followed by detailed descriptions of each subsystem service. For a better understanding of the design, visual diagrams are drawn including packages and classes. Then, hardware components and resources of the Gymtor will be clarified. Furthermore, description of how the system stores the data and how to capture persistence while doing that will be explained. Later, in the Access Control and Security section, security and access control concerns will be discussed. And finally general behaviour of the Gymtor will be discussed in relation with its boundary conditions in a detailed manner.

3.2. Subsystem Decomposition

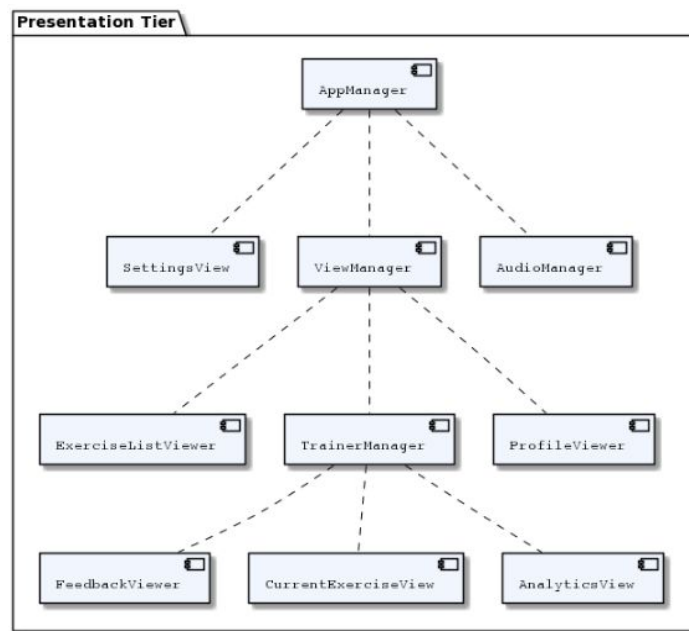


In our Application, we have designed a three-layer architecture for modularity and scalability. Since our application makes real-time visual data analysis and real-time feedback generation,

we have tried to keep our model as simple as possible to reduce the complexity of the modules and achieve a better and a faster performance.

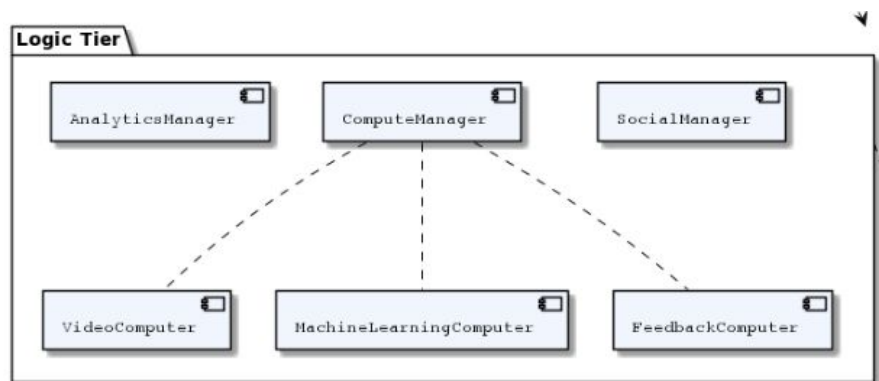
We have presentation tier, logic tier and data tier as three layers. Presentation tier is responsible for displaying all the visuals and management of them. Logic tier is responsible for computational operations including machine learning usage. Data tier is responsible for the communication of the application with the cloud data or local data.

3.2.1. Presentation Tier



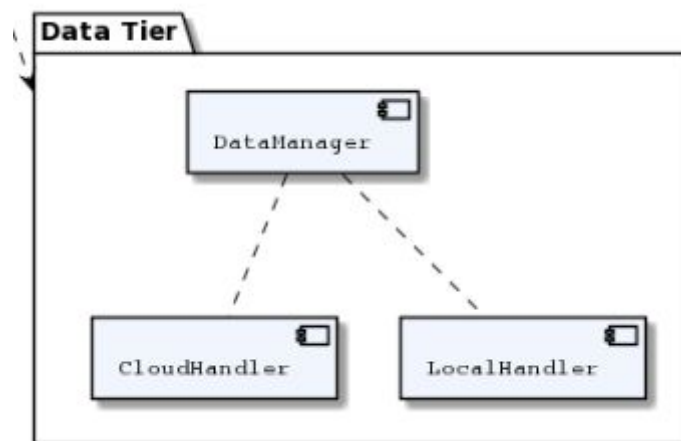
This tier is responsible for the management of visual and auditory material that is presented to the user. It includes the main package which is AppManager that handles the interaction between other packages. ViewManager is responsible for displaying the front-end content of the application. CurrentExerciseView package is responsible for displaying the video screen to the user with the generated feedback. It also captures the inputs of the user in this stage, and they are sent to the logic tier. ExerciseListViewer is responsible for retrieving the exercise plans of the user, displaying them, or scheduling them. ProfileView is responsible for retrieving and displaying the user-specific data. Other non-specific visual content is handled in the ViewManager package. AudioManager package is responsible for playing audio assets. These audio assets include sound effects such as sliding a menu, clicking on a button, etc. They also include auditory instructions in an exercise session. The SettingsView package manages the user's UI related application settings. This might be the theme of the application, colors, some UI specific personalizations, etc.

3.2.2. Logic Tier



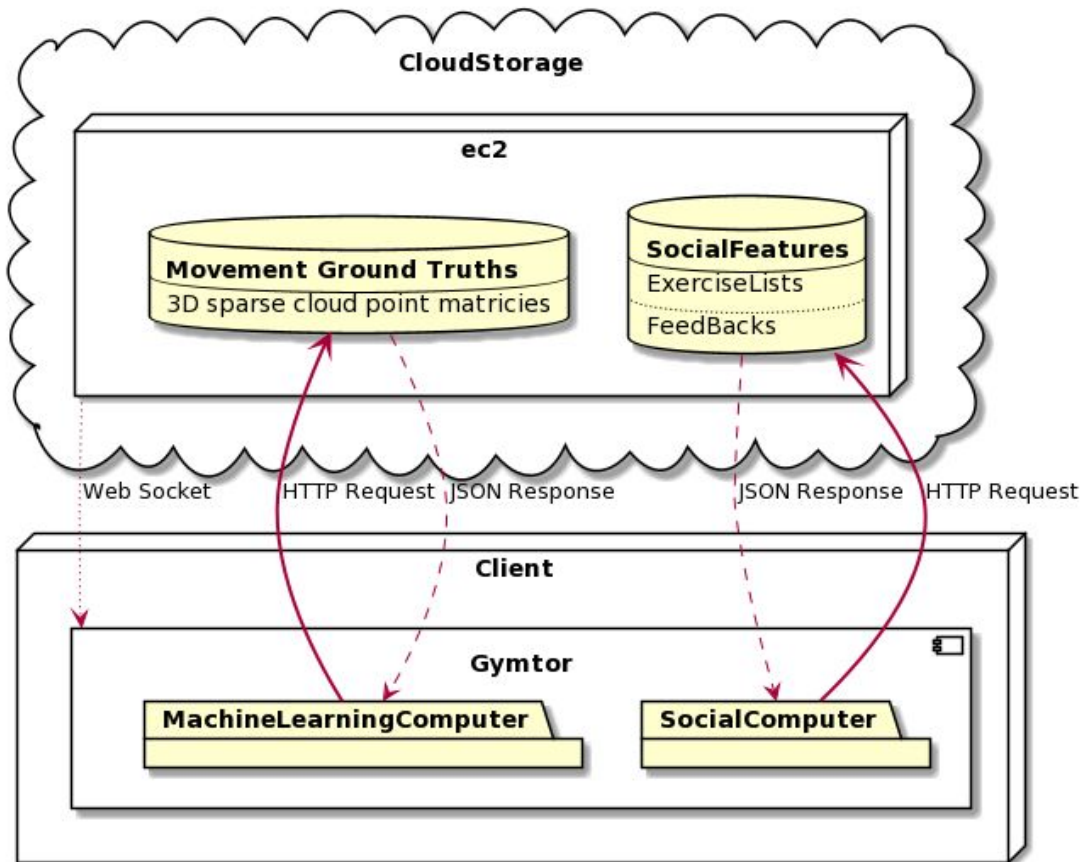
Logic tier is responsible for management of all logical operations behind the scenes. It includes a main ComputeManager which handles all the computations and also is in communication with the presentation tier. SocialManager is in control of the social activities of Gymtor such as adding personalized exercise lists, looking at friends activities etc. AnalyticManager computes the personalised feedbacks, calorie usage etc. ComputerManager handles the machine learning application of ours.

3.2.3. Data Tier



Data tier handles our cloud handler and runs on a server unlike the rest of our tiers. It contains a main DataHandler which is in contact with our logic tier and handles the database appropriately. CloudHandler handles the cloud specific packages and LocalHandler handles any logical work done in the server machine.

3.3. Hardware/Software Mapping



Our MachineLearningComputer gets the PointCloud sparse matrices as JSON responses from our cloud databases. Those are the ground truth movement paths for specific workout routines. SocialComputer gets social database features such as username, created exercise lists, feedbacks of an user etc.

3.4. Persistent Data Management

To be able to use the application, users must be able to log in, which requires a database connection. All the user credentials will be held in the Firebase database in an encrypted format. Besides, even though image processing on mobile devices requires higher specifications, video processing will be done on the client-side, which means that no visual data transfer will occur from client devices to Gymtor services for using the major functionality. Using the cloud for real-time feedback generation is problematic since the data first must be uploaded to the cloud, then be analyzed, and the feedback must be sent back to the user. This process may create a high latency. However, generating short video clips may or may not require a cloud processing operation which means that some data transfer must

occur. In that case, if the user accepts, videos will be transferred to the cloud in the background. But, the upload speed will be limited to 100Kb/s, and data will be retrieved partially if the user disconnects from the internet. This limitation is not to overwhelm the connection speed of the user.

For video processing, videos first will be preprocessed and data dimensionality reduction techniques will be applied to reduce both the required computational power and time to generate real-time feedback. In this way, interim files will not occupy huge space in the mobile phones, and computation will be easier, which is important especially for older devices.

In case of any necessary cloud computation, Amazon AWS or Google Cloud will be used.

User progress information will be held on the device as well. If the user activates synchronization, the data will also be uploaded to the cloud. These files will be stored in JSON format and they will be retrieved from the server if the user chooses to.

Some log files will be held in the devices to be examined in case of any errors. These files will be in “.log” format which is the standard for log files.

Application settings must also be kept on the client device. User settings, last status, and similar application-related information will be stored in JSON format.

3.5. Access Control and Security

Security is a critical issue for Gymtor since it is processing the visual data of the users. Besides the technical issues, all the image processing operations are planned to be done in mobile devices for security issues also. Still, there are optional features such as generating short clips from some video clips which may require cloud computation, which requires the transfer of data to the server. Also, there will be a database that holds user credentials, which again must be secure.

Other data such as exercise history, progress, and statistics of the user will be held in the device. However, if the user prefers to synchronize the data with the cloud, then, this data will be transferred to the cloud, and they will be encrypted and they will be held by following the global security standards.

For ensuring security we will follow OWASP mobile application security standards. All the data in the database and cloud servers will be encrypted and even the developers will not be

able to see their content. Source code of the application will be secured, and no one except the team members will be allowed to access.

On the user side, they will be asked to generate strong passwords while creating their account. Additionally, users will accept the terms and conditions which will be created according to the general data protection regulation(GDPR) [4], and local regulations such as KVKK [5].

3.6. Global Software Control

The most major functionality of Gymtor is processing visual data of the user and generating feedback accordingly. Thus, the major input source of the application is the data captured by the device camera. When an exercise starts, the user has to do nothing but follow exercise instructions. Gymtor will guide the user to do the exercises, rest, or finish the session. Still, the user can interrupt the natural flow of a session by clicking pause or skip buttons. Captured visual data will be processed in the logic tier's *MachineLearningComputer* package and a skeleton of the user will be generated. *FeedbackComputer* package will generate the feedback and they will be sent to the presentation layer, which will update the screen with the new feedback.

If the user schedules an exercise plan -which is done manually by the user-, the application will send a notification at the scheduled time. Then, the user will be able to click on the notification and he or she will be directed to the exercises page.

Besides the major functionality, Gymtor does not have any complicated or sophisticated mechanism to interact. There will be basic buttons for non-complicated operations such as viewing exercise statistics, changing settings, starting a new exercise, etc.

Generating real-time feedback requires low latency for a better user experience. This becomes a challenging task if the computation the application has to do in real-time is expensive. In our case, using machine learning models may become expensive even for computers. Thus, it is highly crucial to provide a consistent and healthy data flow between subsystems. Visual data must be processed as fast as possible, feedback must be generated and the presentation layer must update the screen with a low latency, which was our purpose while designing our subsystem decomposition model. The subsystems are designed to be as simple as possible to reduce the latency and computational cost.

3.7. Boundary Conditions

According to the user, Gymtor has three main main boundary conditions:

3.7.1. Initialization

Gymtor will be available on Google Play Store and could be installed from the application market willingly as it is an android application. After completion of the download and installation process, the user will be asked to login or sign up. After a successful authentication step, the user will be asked to calibrate the smartphone camera according to the surroundings with the help instruction shown on the screen. After this initialization step, the user will be directed to the main menu and the normal flow of the activities will be followed. These steps are going to be followed only when the application is going to be used for the first time or the system cache is erased manually.

3.7.2. Termination

When the user closes the application, our application will stop its all services and will not run in the background. Yet, required information for restoring the state when the user starts the application for the next time is going to be saved. This requires caching before the termination of the application. Also, some notification services for push notification will still be available for showing the necessary notification on the screen and notify the user about the upcoming events.

3.7.3. Failure

In case of a disconnection from the internet, some services may be interrupted and cannot work properly. Especially the models and accurate representations of the exercises are heavily dependent on internet connection, as it should be retrieved from the server side before the start of exercise plan as local storage is a limiting constraint for this functionality. Also, account services are in need of internet connection to work as intended and a disconnection may cause a fully dysfunctionality in that respect. So after logging in, caching will be used to restore important information about the user and activities.

4. Subsystem Services

4.1. Presentation Tier

4.1.1. AppManager

This package is used to manage the other packages(ViewManager, AudioManager and SettingView packages). With this package interaction between these packages can be handled.

4.1.2. SettingsView

This package is used for managing the settings related to the UI.

4.1.3. ViewManager

This package is used to display front end features of the application. It includes three other packages which are ExerciseListViewer, TrainerManager, and ProfileViewer. The views to be displayed are commanded by the AppManager package.

4.1.4. AudioManager

This package is used for playing audio assets such as the sound effects for general interactions within the app or auditory feedback during an exercise session.

4.1.5. ExerciseListViewer

This package is used to display the user's exercise list which is taken by the data tier. With this package users also can schedule exercises.

4.1.6. TrainerManager

This package is used for displaying the details of an exercise that the user has selected, such as the estimated duration of the exercise, the moves in the exercise, and the required equipment for the exercise.

4.1.7. ProfileViewer

This package is used to display the users' profile page whose information is fetched from the data tier.

4.1.8. FeedbackViewer

With this package users can see the exercise feedback which can be seen by the AppManager's interaction handling.

4.1.9. CurrentExerciseView

This package is used for displaying the video of the user on the screen during the exercise session. It is also used for displaying the current statistics, such as the total calories burned and the time elapsed, and for presenting control buttons to the user.

4.1.10. AnalyticsView

This package is used for displaying the data from past exercises of the user. This analytics information is taken from the AnalyticsManager package from the logic tier.

4.2. Logic Tier

4.2.1. AnalyticsManager

This package is used to fetch the data from the data tier and prepare the analytics of the exercise information which can be shown to the user after that. The analytics are related to the amount of calories burnt and amount of time spent for each exercise.

4.2.2. ComputeManager

This package is used for managing the computer packages such as MachineLearningComputer, FeedbackComputer, and VideoComputer.

4.2.3. SocialManager

This package is used for displaying the current friends of the user and retrieving the users that are most relevant to the user based on their search queries.

4.2.4. VideoComputer

This package handles video inputs, does preprocessing for easier inputs. It also controls the I/O with an external camera source.

4.2.5. MachineLearningComputer

This package is our main Machine Learning computation package. In this package, using machine learning we will make a pose estimation from a video input live.

4.2.6. FeedbackComputer

This package is used for providing the user with the appropriate feedback based on the visual data from their exercise video. This package compares the ground truth movement patterns

with the output of MachineLearningComputer pose estimation. It gets the ground truths from the database.

4.3. Data Tier

4.3.1. DataManager

This package is used for managing the operations on the database based on the user's interactions with the app.

4.3.2. CloudHandler

This package is used for handling the data in the database. In database user information like username password, number of calories burnt, amount of time has been spent on each exercise, friend information are stored.

4.3.3. LocalHandler

This package is used for handling the information obtained from VideoComputer and MachineLearningComputer. Since it can be inefficient to handle them on server side.(Cloud side)

5. Considerations of Various Factors in Engineering

As every engineering design must aim to be unbiased, secure and user friendly, we also aim to be unbiased, secure, and user friendly in the design of Gymtor. To do that, we use security measurement as explained in section 3.5 . When detecting the movement of the user, we will be constructing the skeleton based on the user's body instead of using a predefined skeleton template to fit to the user's body in order to reduce the bias that might occur in the movement detection process. Thus, the app will be suitable for all users instead of a small portion of them. In order to increase the user friendliness of Gymtor, we designed the UI in such a way that the icons used are self-explanatory to convey what they are doing. Also, when the user opens the app for the first time, there will be a short tutorial of the application which demonstrates how the app can be used.

6. Teamwork Details

In this section, we will provide the details about our team work dynamics where we explain how each member of the team is involved in the project, how we share the workload, and how we communicate with each other.

6.1. Contributing and Functioning Effectively on the Team

In order to make sure that every member of the team is effectively involved in the project, we hold weekly meetings on every Sunday to discuss our progress and how to proceed from that point. Additionally, we are using Jira for project management where we can easily see what are the tasks that should be completed and who will be working on a specific task, which makes communication easier and increases efficiency.

6.2. Helping Creating a Collaborative and Inclusive Environment

The tasks are distributed among the team members such that related tasks are assigned to the members who have similar schedules, which aims to allow the team members to work on the task together at a time suitable for all of them, hence improving the collaboration between the team members and creating an inclusive environment. Additionally, we hold short meetings when a team member asks for feedback on his work where each team member can voice his opinion and have a say in the work being done, thus creating an inclusive environment.

6.3. Taking a Lead Role and Sharing Leadership on the Team

Since there are a lot of tasks to be done, it is not optimal that every task is led by a single team member. Hence we have distributed the leader roles for every task among each member. Therefore everyone is going to take part in leading the project. We believe that it is hard to manage big scale projects, sharing the leadership tasks for each task among every member is more fair than having a single project manager. With that we think working as a team can be done more optimally.

7. References

- [1] “Where does time go? - Why and how employees are wasting time at work!,” Apr. 20, 2018. <https://www.timetac.com/en/blog/how-employees-waste-time-at-work/> (accessed Dec. 27, 2020).
- [2] Jen, “7 Tips for Finding Time to Workout,” Nov. 30, 2016. <https://www.peanutbutterranner.com/7-tips-finding-time-workout/> (accessed Dec. 27, 2020).
- [3] “Concerns about the future of people’s well-being and digital life,” Apr. 17, 2018. <https://www.pewresearch.org/internet/2018/04/17/concerns-about-the-future-of-peoples-well-being/> (accessed Dec. 27, 2020).
- [4] “General Data Protection Regulation (GDPR) – Official Legal Text.” <https://gdpr-info.eu/> (accessed Dec. 27, 2020).
- [5] “Mevzuat Bilgi Sistemi.” <https://www.mevzuat.gov.tr/mevzuat?MevzuatNo=6698&MevzuatTur=1&MevzuatTertip=5> (accessed Dec. 27, 2020).