Bilkent University

Senior Design Project

Project short-name: GymFeat - AI Training Coach

Final Report

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1. Introduction

Given the importance of healthy life, sports itself play a prominent role to develop a healthy body. Not only it helps people to develop the muscle mass, but it also improves the health of one's mind [1]. According to the researches about how sport affects the health of mind, it is shown that doing exercises "positively impacts the level of serotonin, a chemical that helps regulate mental health", reduces the level of stress, improves mood, and distracts people from negative thoughts [2, 3]. In addition to these impacts of sport on mind, it also boosts the immune system [4]. Therefore, we should always prioritize doing exercises in our lives.

In normal circumstances, some people would prefer to go to the gym, and some people would prefer to do exercises at home and there used to be a trade-off between them. However, since the beginning of the pandemic, people are seeking new means to stay active inside the house, because many parts of our lives remain restricted. At this moment "maintaining an exercise routine at home can seem more like a 'should' than a 'want to'" says Shannon Collins, an Integrative Manual Physical Therapist [4]. We, as a team, would like to encourage people to be more active at home.

Nevertheless, when people work out at home without the guidance of an expert, there is a risk of getting injured. Imagine yourself, trying to preserve your healthy body and mind, and while doing so, getting injured. Our project idea started out with the question, how we can prevent people suffering from exercise-related injuries, i.e. sprains, muscle strains, tendinitis, and so on. According to an article from Harvard Health Publishing, people should choose their workout carefully, learn the proper technique in order to prevent injuries and drink water to stay hydrated [5]. Hence, we would like to address these issues and provide a web application, which will prepare a training program for you, check your body movement to make sure that you are applying each movement correctly, and remind you of drinking water during the training.

2. Requirements Details

2.1. Functional Requirements

In this section, the functional requirements of our system will be explained.

2.1.1. Personalized Fitness Program

- To be able to use online backup functionality the user will have to sign up and create an account.
- After creating a profile, the user will enter personal information such as weight, height, and his aim, i.e., getting fit, getting muscular, losing weight etc.
- According to the information given by the user, a fitness program will be proposed by the application.
- The fitness programs that are suggested by the app will be pre-prepared programs with the help of professional fitness trainers.
- The user can adjust the proposed program by editing the order of the movements, or by changing the training-rest days that were suggested by the app.

2.1.2. Calendar Synchronization and Progress Log

- The personalized fitness program will include a weekly fitness schedule with both active and rest days, including the movements to be done given the active days.
- A progress log within the app will keep information about which movements were made successfully daily so that users can track their progress and how much they follow their schedule.
- The suggested schedule will be editable so that users can add, remove or change active and rest days to get a schedule better suited to their life.

2.1.3. Synchronous Training with AI Fitness Trainer

- Before starting the training, the computer of the user will be set in a position so that the camera of the computer can clearly see the user. The application will guide the user to align the phone properly.
- The camera of the computer will observe the user so that the AI trainer can interact with the user by giving directions and warnings with voice.

- At the beginning of the training, the AI trainer will show how the movement should be made correctly, then the user will be able to observe himself while doing the movement to learn the correct way of making the move.

- While the user is doing each movement, the AI trainer will be tracking 16 points on the user's body to analyze how the user applies the move.

- If the user is not applying the movement correctly, the AI trainer will intervene to highlight how the movement should be adjusted to do it properly.

- The AI trainer counts the repetitions of the movements, and once the count reaches the predetermined set limit, training is set to be completed and the AI trainer scores your movement.

2.1.4. Additional User Interaction with the AI Fitness Trainer

- The AI trainer will determine the rest period between sets, and will remind the user to drink water between the movements and to engage in active recovery because according to the studies, practicing active recovery between sets helps clearing the lactate in the body faster than engaging in passive recovery, i.e. sitting [6]. Our application will give directions to the user in order to stay active during the rest period, by walking, or doing dynamic stretches, hence, the body will stay warm and it will keep the muscle and the tendon pliability [7].

- Users can skip the introduction of the movement at the beginning of the set and deactivate the warnings if he feels he is performing the movement properly.

- The rest period between sets can be shortened or extended according to the desire of users.

2.2. Non-Functional Requirements

In this section, the non-functional requirements of our system will be explained.

2.2.1. Usability

- The user should be able to use the application without logging in, or to keep logged in, to ease usability.

- There should be at most two pages before starting the training, and those pages should be the enrolment page and the initial setup page to generate a special training program.

- After the program is created, the user should be able to start training with only one click. To see the progress log, he should click at most two buttons.
- The user should be able to learn the use of UI with a tutorial video of at most thirty seconds.
- The user should be able to memorize the UI, in average, after fifth usage of the application.
- The user should be able to observe the fitness program along with the other activities within the same calendar, and to start training by clicking on the calendar event.

2.2.2. Reliability

- Real-time movement analysis should be done in high precision, hence, the users should be able to count on the application that they are performing the movement correctly, if it does not show any warning about the enhancement of the movement.

2.2.3. Accessibility

- The system is available online for free.

2.2.4. Portability and Compatibility

- React.js is used for the frontend of our application and is chosen for its portability and compatibility across multiple browsers.

2.2.5. Performance

- Screen loading and response times from the server side shouldn't take more than one second.
- The AI trainer will analyze the movements in real-time to give instant feedback.
- Creation of personalized fitness program, and Google Calendar Synchronization should not take longer than three seconds.

2.2.6. Security

- The user is able to register and use the application from multiple devices, therefore, the information about the user will also be stored in a database. Therefore, the system should provide a secure environment in order to keep the data about the user safe. The data that will be stored in the database are the progress log, e-mail, username, and password. This data should not be shared by anyone and should be kept according to General Data Protection (GDPR) [8].

2.2.7. Maintainability

- The network has a modular structure, so modules are not strongly bounded and they are not affected by changes in other modules.
- In addition to the automated checks about the new code changes, there is a specified code standard throughout the codebase. Each pull request has been checked by the reviewer to increase the maintainability of the code in future changes.

2.2.8. Legal and Regulatory Requirements

- Each user will need to accept the terms and privacy policies, to be able to use the application.

3. Final Architecture and Design Details

GymFeat's software final architecture is composed of multiple subsystems. We made the choice of using React and Redux with Javascript for web development. React js is particularly chosen because of the flexibility, performance and ease of use in implementation [9]. Additionally, the components architecture of React makes the front-end easier to write. As for Redux js, it helps the application to behave consistently across client and server [10] .

3.1 Overview

First a general overview of the design must be presented. As shown in Figure 1, GymFeat's design consists of a client-server architecture which consists of a client and a server layer. The server has an application layer and a data layer. Application layer is where the logic happens and the data layer is where the information is stored. The client consists of two layers as well, view layer and image processing layer. As it is self-explanatory, the view layer is responsible for showing what the client is supposed to see. Image processing layer is responsible for processing the current image of the user's body position and responsible for deciding if the user's current body position is correct. Below, you can find the current system components.
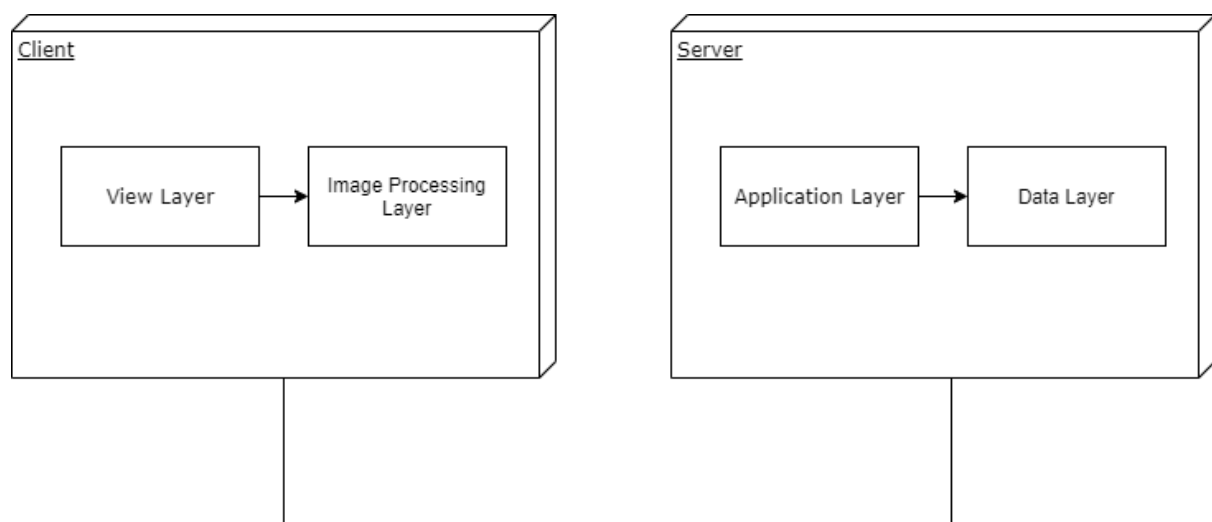
Figure 1: Overview of the Architecture

3.1.1. Client

Client side of the software consists of view and image processing subsystems. In the view subsystem the front-end logic and the user interfaces of all of the application will be present. This subsystem works as the communication channel between the back-end logic, such as authentication, and the user. The main concern of this subsystem is to make the application as user-friendly as possible.

The second subsystem under the client is the image processing subsystem, in which the user is observed in real-time via camera while working out. The pose estimation algorithm detects

the body points continuously. The analysis algorithm interprets the user's movements from extracted body lines to give real-time feedback and count repetitions during the whole workout. Furthermore, the exercise is rated after finished according to cumulative body points information. For this purpose, the following APIs are used:

- PoseNet [11]
- React-Speech [12]
- React-Speech-Recognition [13]

3.1.2. Server

The server side consists of two subsystems, which are the application subsystem and database subsystem. The application subsystem is responsible for authentication, performing user-related functionalities and workout related functionalities. While doing so, it also communicates with the database subsystem. In the database system, the authentication information is stored and encrypted for security. Also, user information and workout data are stored here. This part is implemented by using AWS DynamoDB [14]. As for storing workouts, local storage is used to store the detailed information.

3.2. Client Architecture & Design Choices

Earlier, it was mentioned that React js has a component-based structure. These components in React helps developers reusability of the code and build higher-level components from small components. Hence, implementing web applications with React.js creates consistency, maintainability, and ease of development.

One of the essential aspects of web development with high user interaction is to have a good performance. Although current engines are good at executing Javascript fast, they still lack being fast when updating DOM. As one can say, DOM manipulations are the bottleneck of web application performance. However, with React js, the updates are conducted by taking the difference between the current DOM and the virtual DOM, and it finds the most efficient way to update the DOM [9].

Another crucial aspect of web development is consistency. To achieve this, Redux.js is used. In its state containers, the current state of the application is kept, and any component can access this information at any time. By keeping all the application information in one place,

the application becomes more predictable and traceable. Moreover, it increases its maintainability [10].

The analysis of the body movements is done on the client-side to increase the performance. It is vital to have good interaction between the user's movements and the personal AI trainer during the workout. The following APIs are used for the AI trainer.

- **PoseNet:**

  In PoseNet, it is possible to have a real-time human pose estimation for a single person, which is what was needed to analyze the body movements. This API is built in collaboration with Google Lab and it can be easily imported and utilized in Javascript [15].

- **React-Speech:**

  React Speech API is a React component for Web Speech API, which provides text to speech output [12]. This API is used for enabling AI Trainer to talk.

- **React-Speech-Recognition:**

  React Speech Recognition API is a React hook for converting speech from the microphone to text that can be interpreted by the software [13]. It is used for the interaction during the workout to collect responses from the user.

3.3. Server Architecture & Design Choices

Before diving deep into how the architecture looks like, design choices and generally what was the goal will be mentioned. First of all, the team wanted a decoupled architecture, i.e. a monolith which keeps everything together inside was not at all what the team wanted. Therefore, the design choices started with planning for having a decoupled system where there would be several subsystems with different purposes. When it came to thinking about the services themselves and how they would be implemented, the priority was to delegate the operational work, reliability and security as much as possible to the 3rd party services, the reason behind it is to have the team write code for the application instead of letting them waste time with anything other than the application logic. When looking at the 3rd party services for such purpose, there weren't many options (AWS, Azure, Google Cloud) and since the team was familiar with AWS and it offered free-tier usage, choosing AWS was a no-brainer. Then, the team inspected the AWS services and looked for which services could be used to make the implementation easy. Therefore, the result was to use AWS Cognito,

AppSync and DynamoDB [14]. However, there was not a service that directly handled how the GymFeat needed to analyze the body posture of the user, therefore, the team decided to implement a service called 'Pose Analyze' which would not be an AWS service. Below, the report will have the details of each subsystem.
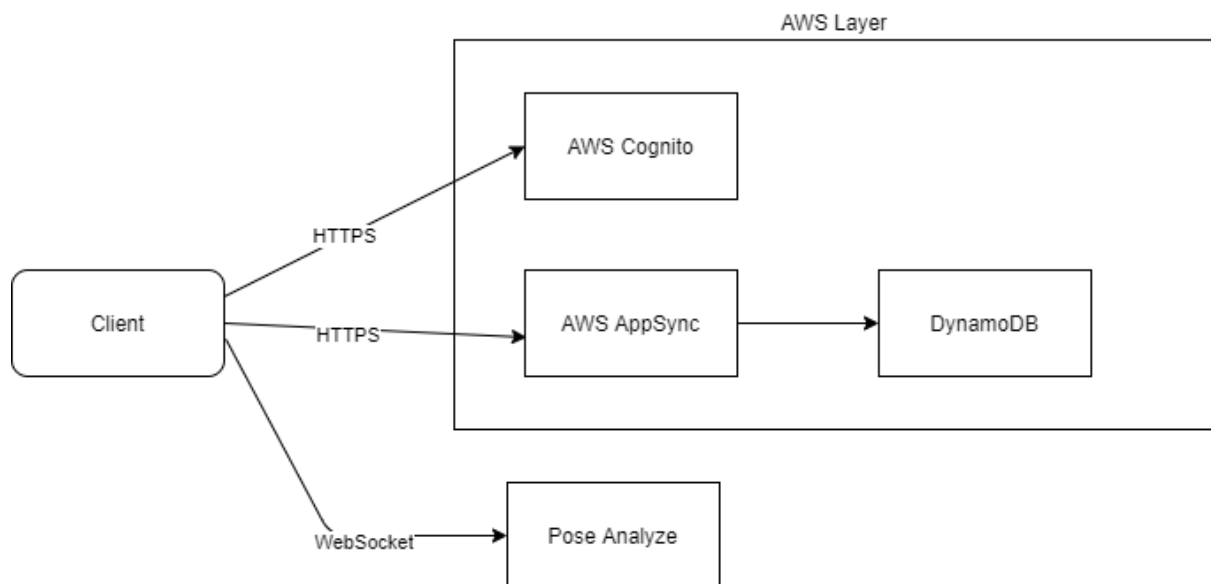
Figure 2: Detailed Architecture

3.3.1 AWS Cognito

AWS Cognito has a simple purpose, to provide authentication and authorization workflow. GymFeat uses the cognito to let the users; sign up and sign in. Details of how cognito is implemented is abstracted away by the AWS but as long as it is configured correctly, its usage is simple. The client interacts with Cognito through an HTTPS connection.

3.3.2 AWS AppSync and DynamoDB

DynamoDB is simply a key value store by AWS. GymFeat uses DynamoDB for all its database needs. What AppSync does is, it provides a language called GraphQL which acts

like an ORM (Object Relational Mapper) that provides a query language of its own and a data modelling structure of its own and abstracts away the usage of DynamoDB (like a wrapper around DynamoDB). So, with this design, the client can just ask for what it wants from the AppSync instead of specifying how it should be queried, modelled, mapped etc from the DynamoDB.

3.3.3 Pose Analyze

Be wary that this Pose Analyze service is not part of any AWS service. The purpose of this service is to analyze the posture of the user through their webcam and give them feedback. This service utilizes math heavy libraries for the analyzing. Since the user should send their posture data regularly and needs a fast response, this service will be connected via websocket to the client.

4. Development/Implementation Details

4.1 Client

Client side is implemented using React.js which is a Javascript library built by Facebook for building user interfaces [16]. This method is used to be able to achieve the best and fastest result for the end product. Since React.js supports asynchronous application features, we were able to achieve an event driven application.

To ensure global state between different components, Redux.js was used. This way the global state was able to hold in the currently authenticated user information, as well as the exercise/ workout lists.

With the aid of component libraries like ant design, we were able to develop a responsive UI as well as a user friendly one.

Analysis of the body movements were done using PoseNet for javascript to make the analysis as swift as possible for the ease of use and also to diminish the chance of lagging from the server side. React Speech and React Speech Recognition libraries were also used to enable the interaction of the user with the application through speech rather than having to move close to the screen for actions like starting or stopping the exercise.

Amplify framework for JavaScript from AWS is used on the client to talk to the AWS Cognito (for authentication purposes, i.e. signing in and signing up) and to the AWS AppSync to do database operations on the AWS DynamoDB. The client makes simplified database operations to the AppSync which are translated to the real database operations in the AppSync and then later sent to the DynamoDB. For the authentication, after the client successfully signs in, it receives an authentication token from the Cognito. The token is stored in the LocalStorage of browsers and it is refreshed regularly. When the user signs out, the relevant token is invalidated (via Cognito) and deleted from the local storage.

4.2 Server

On the server side, there are the AWS Cognito, AppSync, DynamoDB and the Pose Analyze service. However, Cognito, AppSync and DynamoDB are not implemented by us since they are offered by AWS, but they are configured by us for our needs. Also, since Amplify framework is used on the client, the database operations are done on client, although, since we use the GraphQL language for the database operations, it is more of just requesting the data instead of writing queries for it (AppSync works as a middle layer between the client and DynamoDB that creates the actual database operations from the simplified GraphQL operations). Therefore, the only implementation that can be explained here is the Pose Analyze server.
Pose Analyze server is implemented with Python to utilize the use of heavy math libraries of Python for pose analyzing. It communicates with the client via websocket since the client needs a 2 way communication between the server, i.e. constantly sending their pose data received from their webcam to the Pose Analyze and then constantly receiving the analyze result from the server.

5. Testing Details

Testing is an important part of the development process of the application. Since we adopted agile strategy for implementation, we tested our application packages along the way.

5.1 Automated Code Review

We wanted to ensure that we are writing a readable and understandable code so we employed conventions of variable and function naming which increase the understandability of the code by observers.

Also, it was really important for us to be able to write and incorporate only working and clean codes into our project's master branch. To achieve this, we forced peer reviewing in our commits and merges to the master branch and ensured at least one other project member has seen and understood the new commit.

5.2 UI Usability Testing

We employed some of our friends and family that can be in our audience to try out our application and share their thoughts with us. This way we were able to get customer feedback and adapt our UI with respect to that.

5.3 Server Testing

On the server side, GymFeat uses AWS Cognito, DynamoDB, AppSync and our Pose Analyze server. However, since Cognito, DynamoDB and AppSync are already developed and tested by AWS, testing the AWS services are meaningless. Therefore, we only test the Pose Analyze server on the server side. To test it, we keep pre-recorded videos of exercises that we feed into the Pose Analyze server where it expects a certain amount of correctness.

6. Maintenance Plan and Details

A maintenance plan must be followed to keep the website up-to-date. Moreover, the web platform should be adjusted according to the user's needs and bugs, found later, should be fixed. The maintenance plan's aim is to fulfill these needs.

6.1. Issue Tracking

Our website will be served as an Open-Source Software (OSS), which means our code will be available for other users' attention under a license, allowing other people to modify or

download the code. Once we make our Github repository public, users will be available to write new issues and we will track them to improve our software.

6.2. Updates

We would like to keep our software high quality, therefore, we will try to add new features to enhance user experience and fix bugs, when necessary. Hence, the website will be updated regularly.

6.3. Backups

For personal training programs, we highly depend on the user's past workout data. Therefore, we need to perform back-up to avoid any undesired information loss. Fortunately the GymFeat uses DynamoDB because DynamoDB offers incremental database back-ups and it can be restored to any of the incremental back-ups at any time.

6.4. Site Monitoring

Site monitoring is used for tracking any speed issues, 404 errors, and broken links. By using site monitoring, we can improve the quality of the software at all times. There is a popular site monitoring tool called, Uptrends, which costs 45$ per month and monitors the activity of the website [17]. It will be used to track issues after the release.

6.5. Analytics

Google Analytics will be used to analyze site traffic and offer suggestions for content and design of the website [18].

7. Other Project Elements

7.1. Consideration of Various Factors in Engineering Design

There are various limiting factors that must be addressed in the GymFeat. This section of the report aims to address these limiting factors in detail.

7.1.1 Public Health

Main use case of the GymFeat is to help people exercise more often and more safely. Therefore, public health is aimed to be increased by GymFeat as people using the app will be exercising more and without any dangers.

7.1.2 Public Safety

One of the main points of the GymFeat is helping people do exercises safely. While not directly related to public safety, with the help of GymFeat, people can do exercises more safely than otherwise they would be doing on their own without the help of GymFeat.

7.1.3 Global Factors

GymFeat is in English and the application will be the same for everyone. Thus, it can be said that it is a global application which can be used by anyone who knows English. Also, GymFeat collects user's data only to some extent, thus, it is made sure that GymFeat complies with certain data regulations of countries.

7.1.4 Cultural Factors

People from different cultures may want to have different exercises that are unknown to other cultures or to us. Hence, GymFeat tries to have a diverse set of exercises to target people from different cultures.

7.1.5 Social Factors

In GymFeat, users can only directly communicate with the AI trainer. Therefore, GymFeat can be said to have no effect in terms of social factors.

	Level	Effect
Public Health	9	Increasing public health by helping people exercise
Public Safety	4	Having people exercise safely
Public Welfare	1	People need smartphone and internet connection to use the GymFeat
Global Factors	1	GymFeat complies with data regulations

Cultural Factors	1	Different cultures are considered for exercises
Social Factors	0	Not affected

7.2.Ethics and Professional Responsibilities

- Keeping the piracy issues in the sector in mind, the source code of the project is kept private.
- To be able to keep up with the tight schedule, our team met at least twice a week at the beginning of the project phase. Later, based on the project schedule, the meetings transformed into weekly Scrum meetings [19].
- The decisions regarding this project were made democratically within the team.
- Team members have all separate roles per divide and conquer development strategy [20]. The roles of the group members are as follows:
  - Gonca Yılmaz, Mustafa Çağrı Güngör: Machine Learning Engineer
  - Ayşe Ezgi Yavuz: Front-end Developer
  - Talha Burak Çuhadar: Backend Developer

Ethical:

- In this project, we apply General Data Protection Regulation (GDPR) and the Code of Ethics [8, 21, 21].

7.3.Judgements and Impacts to Various Contexts

The numbers in the table below are out of 10:

	Level	Effect
Impact in Global Context	6	GymFeat attempted doing exercise at home more efficiently and enjoyable.
Impact in Economic Context	0	It is completely free, so it has no economic context.
Impact in Environmental Context	1	Server's electricity consumption when doing body point estimation and storing data is small but not insignificant.
Impact in Societal Context	3	People can share their feedback reports on

		social media or their friends which will draw attention.

7.4 Teamwork Details

In this section, the details of teamwork is discussed and how the proper teamwork will be ensured is explained.

7.4.1 Contributing and functioning effectively on the team

We assume that the key to a successful product is effective team-work and we do not want anyone to be solely responsible for a certain aspect of our project. We therefore strive to circulate duties and responsibilities so that everyone has sufficient knowledge of the sections of the project. Therefore, we first discussed the main roles of each member and how they can collaborate effectively and efficiently in the team. To do so, each member in the project group took part in certain aspects of the project. Since our project includes three main parts for the implementation, we assigned the members to each component in the following way.

- Front-End Engineer(s): Ezgi Yavuz
- Back-End Engineer: Talha Burak Cuhadar
- Machine Learning Engineer(s): Cagri Güngör and Gonca Yilmaz.

By dividing the project implementation in the aforementioned way, we have obtained an environment, in which everyone can take actions on some aspects of the project and everyone can contribute in the area that they have some prior knowledge about.

As for the reports, a similar outline is followed for the division of labor. For each report, the outline of the project report and the consistency were assigned to one specific member, which changed for each report. The sections were divided among the members equally in order to create an equal environment, which enables each member to function effectively.

7.4.2 Helping creating a collaborative and inclusive environment

To maintain proper teamwork, the key is to create an environment of collaborative creation, where every participant is involved in most aspects of the project. To ensure this, the team

needed an environment in which it was easy to address project management and documentation in a systematic way. Asana and GitHub have been explored for this reason, and because everyone already has a GitHub account, the team has agreed to use it as a project management tool for the implementation part.

For the rest of the project deliveries, Asana is used as a project management tool and the leader of the current package discussed the work that needs to be done with each member and assigned those tasks in Asana to keep track of all tasks, which are in queue, in process and completed. The leader is responsible for giving a detailed explanation of each task and each member who was assigned to a certain task was responsible for updating the status of that task.

7.4.3 Taking lead role and sharing leadership on the team

In this project every member of the team has been appointed leader of a certain job kit. Using this strategy, we will ensure that all of the team members will lead in their respective job kits and will have the chance to experience leading a part of the project.
We circulated duties and responsibilities so that everyone shares leadership and that everyone has sufficient knowledge of the sections of the project.
The work package division among the project members is as follows:
- Gonca Yılmaz was responsible for the initialization of the project. Initial planning phase and the requirements specification as well as analysis of those requirements were done under her leadership.
- Ayşe Ezgi Yavuz is responsible for the site research and the beginning of the implementation phase of the project. The implementation specifications, frameworks to be used and implementation planning is done under her leadership.
- Mustafa Çağrı Güngör as our lead ML specialist, will be responsible for the ML research and analysis by using real time data and integration of that analysis as an implemented algorithm into our application.
- Talha Burak Çuhadar will be the leader of the finalization process. Under his leadership, the final report and the final project demo along with the presentation will be distributed equally among the team members. Before the project demo, the

implemented system and the connections should be finalized and tested very thoroughly. Hence, he will also ensure that all of these steps are done properly.

7.4.4 Meeting objectives

The project met most of the expectations. All of the main functionalities are implemented. Some functionalities that we described in the specification report are not able to be implemented. One of the examples is to export a schedule to the Google Calendar. We could not do this because we decided to make this project in the browser rather than mobile. Another example is that the AI trainer does not intervene during training, it scores the movement at the end of the movement.

7.5 New Knowledge Acquired and Applied

The list of necessary software engineering and computer science concepts for this project is listed below.

- Back-end development
- Front-end development
- Web application development
- Image analysis

Our team learnt and improved the listed skills above for our project before and during the implementation process. Our team used different sources like online learning platforms, framework documentations and existing sample repositories in order to be able to satisfy these requirements. Distribution of the tasks was done according to the interests and previous experiences of each team member to get better results.

8. Conclusion and Future Work

In conclusion, we developed a browser application that is currently capable of performing the tasks specified in the requirements of the application. Even though we could not implement some of the functionalities, the application includes all main functionalities. Our main goal is to make GymFeat downloadable in certain App/Android Stores, but currently our program can be used through a browser on the web. Thus, the next step for us will be to change the app platform from browser to mobile phones. We are planning to use IONIC to run our application on mobile phones from the web.

9. Glossary

- General Data Protection Regulation (GDPR) : This is the set of regulations drafted and passed by the European Union (EU) in order to protect privacy and security in the world [8].
- AWS: Amazon Web Services. Reliable, scalable, and inexpensive cloud computing services provided by Amazon. Remote servers can be rented through this service [23].
- Scrum meetings: Scrum meeting is a kind of catch-up meeting adopted by agile development teams [19].

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