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# Combining Deep Learning and Computer Vision techniques for football goalkeeper position recommendations

– Diploma thesis –

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**Abstract**

Two of the most important results of recent technological advancements are process automation and making knowledge more accessible. Based on that, I have created a system that has as the main aim to behave like a football goalkeeping coach. Given a football game video sequence, it is able to show what is the optimal position for the goalkeeper, helping him to understand how to position himself on the pitch.

To achieve this, the given video has to be processed by detecting the color green(the predominant color of the field), segmentation the image by separating the color white which belongs to the field's line and after having this, it detects the bottom line. The system uses Yolo v4 combined with a deep sort algorithm for tracking the players from the field and the ball. From these are selected the player who is the closest from the ball and the goalkeeper which is found by being the closest by the bottom line. A velocity vector is drawn for the player who has the ball and for the goalkeeper and the result will suggest the correct position of the keeper.

This work is the outcome of my own efforts. On this project, I have neither offered nor received unlawful help.

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# Chapter 1

# Introduction

Sports is one of the most important parts of our lives nowadays. It helps to keep people fit and healthy while also creating strong communities and raising morale. Sports are more important than ever in today's world of iPhones and computers. Competitive physical activity encourages children and adults to get outside and stay healthy while also teaching essential values.

Football, like the majority of sports, can help control weight, regulate your blood pressure, and pulse rates. It also helps to improve your mood, your cognitive abilities and can help you to relax. However, its appreciation comes from the fans that are present in the crowd all over the world to support this phenomenon. Along with popularity comes a huge amount of money that makes it one of the biggest industries of the modern world.

Nowadays we live in the technology era. It is everywhere, including in sports. For example, modern football has access to Video Assistant Referee, which helps to limit human error, correcting referees where needed. [2]

The technological progress in sports training is already present. For example, Chelsea Football academy football developed a system based on video recognition to detect players acceleration based on what position they play on the field.[5]

It is very important for each player to clearly understand his role and his responsibilities in the field. The problem I'm attempting to address in this article is one of the most crucial in a football game: the goalkeeper position.

# Chapter 2

# Scientific Problem

In 2021, the most successful sports institutions worldwide have a solid organizational system, but most important is their selection and training methods of the athletes. As an example, the South-American football national teams are visibly weaker than European ones in the last two decades due to lack of accurate training.

## 2.1 Football and what means to be a goalkeeper

Football is one of the oldest team sports, being practiced by more than 250 million players in more than 200 countries, making it the world's most popular sport. This game is played using a spherical ball on a rectangular pitch covered by grass with a goal at each end. The object of the game is to score by moving the ball beyond the goal line into the opposing goal, the winning team being the one that scores most goals [3].

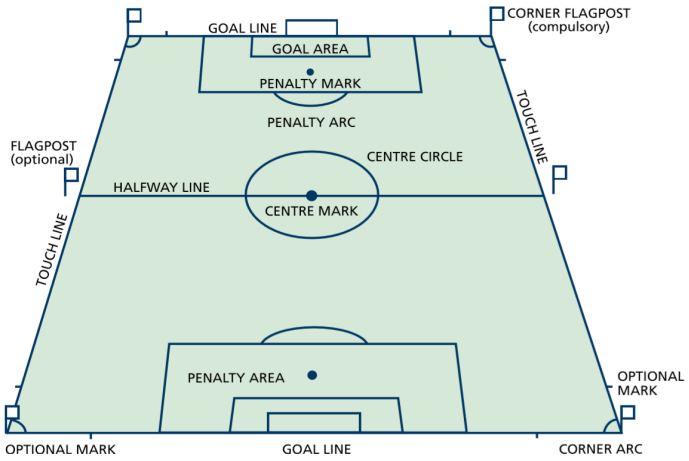


Figure 2.1: The field of play[3]

The only position required by the Laws of the Game is the goalkeeper[3] which is vital for team success. His main role is to defend his team goal, having the privilege to use his hands to handle the ball inside his own 16-meter box, being the single one who can do this without a penalty from the eleven players from the team.

From the crowd or from in front of the TV, to be a goalkeeper seems to be an easy job because he has not to run as much as any other player from the pitch, being static almost the whole game. However, the difficulty of this role consists in the power of concentration that must be maintained throughout the 90 minutes of the game, a single moment of inattention could be fatal for his team[6]. Also, a goalie must be a good coordinator for his teammates, with whom he must be in a continuously dialog for warning them about positioning or the actions of the opposing team. Height is also an important characteristic, it must be supported by physical elements trained daily together with the other elements listed above.

One of the most important components of this post is the positioning on the pitch. It must be trained and understood by the keepers since the youth period for having a solid knowledge base.

Throughout history, we had the chance to watch famous keepers a the post like Oliver Kahn, Lev Yashin or Gianluigi Buffon, which has all the elements written above and not only succeded into leading their national or club teams on the peaks of success.

## 2.2 Importance of the problem

From the beginnings of football, the people wanted to improve the performance of the football players by establishing a healthy lifestyle, having balanced nutrition, and especially regular training. The ways to train a football player have evolved over time, such as besides the collective training session, athletes started to train specifically depending on their positions.

Keepers, for example, need complex physical training which helps them to improve abilities such as reflexes, jumping, and especially the position action in the goal and pitch. The last one is a crucial element in the progress of a football game, many of the goalkeepers having serious lack of positioning coming from the youth. For avoiding situations of bad position action, the coaches need advanced training methods especially in the youth sector, where keepers must gain a level of knowledge as high as possible.

## 2.3 Technology in sports

In the last two decades, sports have evolved at an unprecedented rate with the help of technology. This evolution especially consists of athlete monitoring, which can measure data related to traveled distances, speed of movement, heart rate or the amplitude of a simple jump and all of these can be transmitted live in different parts of the globe. Using automatic detection of movements in sports, scientists found out that coaches and trainers can receive vital data about athletes performances which can help them to improve and adapt their ways of training[9]. Also, this type of monitoring can help any sports club to scout athletes which fit their needs, saving time and even money, a very important attribute nowadays(european football worth is 25.5bn euros). Having real-time information about athletes heart rate[1], hydration level, lung capacity, or any other physical parameter combined with regular medical tests can prevent injuries or worse, life-threatening accidents which terrified the world several times. In other words, using oh technology in sports can be a blessing in 21 century.

## 2.4 Research directions

### 2.4.1 Goalkeeping

Many scientists and football experts tried to study the particularities of each football post to clearly understand the needs of training and recovery after effort. One of the most important positions in the field is the goalkeeper, being directly responsible for the final result. A study made on sixty-two goalkeepers from English Premier League during one hundred nine games revealed some useful details about their activity on the pitch, referring to covered distances at different velocities. For monitoring, they used a Prozone system formed by 8 cameras and for preserving the video quality they converted it to AVI-MPJPEG format. It was not a surprise for them to conclude that the distances covered by the keepers are much less than other any player from the field, a keeper covering 5611m +- 613m the whole match and normal players covering around 5700m per half. Also, they distinguished match-analyses in 5 categories of intense motion, as you can see in figure 2.2.

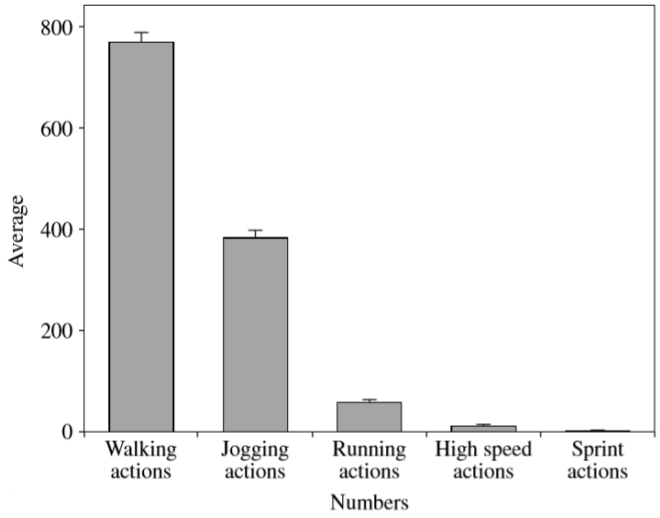


Figure 2.2: Average number of activities at different velocities in a match[14]

Due to the limited space they have to cover, goalies have a real difficulty reaching a large number of high-intensity actions, however, the most decisive moments are sprints between 0 and 5m, which means that a very important attribute to improve is an explosive movement. Other interesting conclusion of this study was that because of the physical fatigue of the field players, the second half is more difficult for any goalkeeper than the first one.[6]

Other scientists tried to provide data about execution mechanism, tactical utility, common mistakes in execution or slow movement of execution using Metaphor-Based Visualization. This application can empower team managers with the ability to evaluate, analyze and observe the performance of an individual goalkeeper between games.[14] Goalkeepers individual data should be used by managers for individual training sessions and the better the match between the training program and the needs or preferences of an individual goalkeeper, the higher the chances that he will benefit from the specific training program.[12]

Is very hard to evaluate the worth of a goalie because his performances are directly affected by the team's defense. There are some goalkeeping styles that we can remark in modern football but everyone has the same most decisive characteristic: the shot-stopping. Other important qualities that a keeper needs are claiming crosses and long balls, reaction speed, power, coordination, and positioning. For professional keepers, the position in the goal is similar for each shot but it can depend on their intuition. You can see below a figure for derivation based on known algorithm(K Nearest Neighbour), made by having the assumption that the average goalkeeper positional is most optimal.[16]

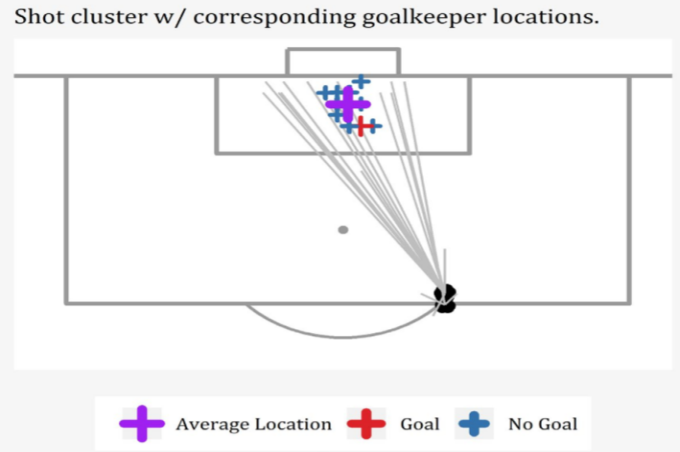


Figure 2.3: Randomly sampled shot and the cluster of similar shots from de knn algorithm[16]

### 2.4.2 Monitoring systems

One of the most used monitoring systems implies the use of GPS(Global Positioning System) devices. A study made in 2010 on Australian football players has proven that using this kind of device has an acceptable level of validity and reliability for recording movement patterns at lower speeds and for higher sampling rates over longer efforts.

They used MinimaxX, Catapult and Australia devices at 1 and 5Hz worn by the athletes on right and left scapula, approximately 25cm apart. A fact was that 5Hz's are better for monitoring long-distance runs, but have a lack of accuracy for short-distance movements(20-40m) at high intensity.[9]

A similar result was obtained in the same year in Spain where there were monitored games from second and third football divisions and one of the conclusions was that at a high intensity runs in line, GPS at 1Hz and GPS at 5Hz showed different values.[13]

In 2014, a study made on Chelsea Football Club Academy used a type of GPSs with a triaxial accelerometer incorporated to measure the acceleration in three planes and produce a composite vector. After four seasons of collecting data from 53 football players between 16 and 23 years old, was found out that are no significant differences in activity levels during training. Conversely, during matches things are completely different: several positions in the field consistently require players to perform a higher number of high-speed runs, in comparison with others(center forward in comparison with center midfield).[5]

Another way to monitorise athletes is by using automatic technology based on recognition

technology. This uses as sample data an AVI format video for detecting a moving target. Such a study was made on male and female diving competitions. The very first step was to segment the data for a better observation of the jumper. Skin color detection was then used to determine the target position in the motion region and after that was created a new binary image. This method is very efficient for detecting even the smallest movement errors and can be very efficient in solving them.[10]

All the studies presented above having the monitoring of movements as the main object have the same main conclusion: information obtained can then be used to modify the type, duration, and intensity of training, improving the specificity of these sessions, no matter the sport we are talking about. In modern sport, this became a need, and without it is very hard to perform at the highest level.

### 2.4.3 Goalkeeping systems and robots

There are some devices used in modern football which are easy to wear and can measure whatever the field position requires. Such a device is Catapult OptimEye G5 which tracks goalkeepers KPIs(Key Performance Indicators):

- Number of left dives versus the number of right dives
- Jump height
- Dive return
- Total running distance
- Maximum speed reached

However, the price of one piece is around 300 dolars. This price could be too high for small teams, especially for the teams who play at an amateur level. A cheaper reliable option could be the use of Android phones that have sensors like accelerometers, gyroscopes and magnetometers.

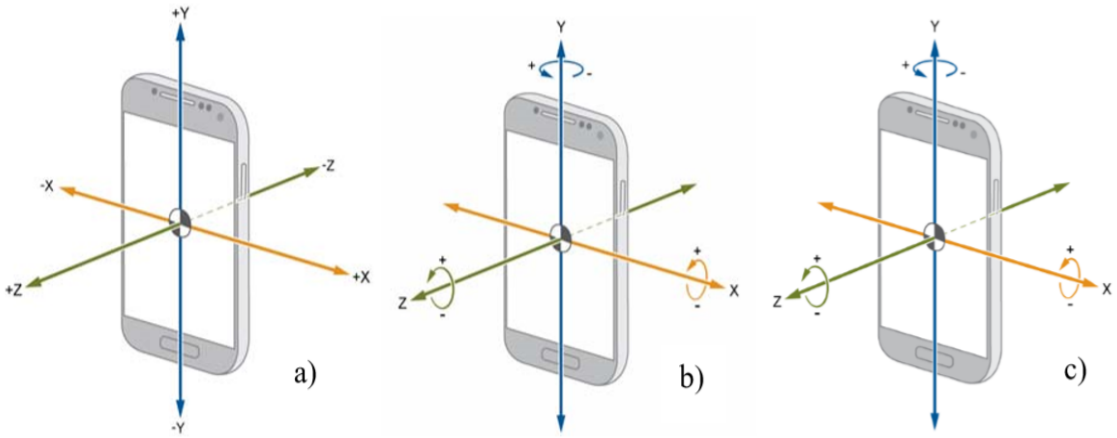


Figure 2.4: Distribution of axes for an Android phone: accelerometer (a), gyroscope (b) and magnetometer (c). [8]

In order to compute KPIs, some researchers developed a custom Android application that uses the phone's internal positioning sensors. In the testing phase, the Android phone was attached, with its screen facing the exterior, to the left arm of the goalkeeper with an armband as shown in the figure below. [8]

Figure 2.5: Goalkeeper wearing the armband with the Android phone attached [8]

One of the experiments was to identify left and right dives based on the three sensors presented above. By comparing the real measurements with the computed ones they observed a slight tendency for not counting all the left dives. This can be caused by the fact that the goalkeeper was not feeling

comfortable jumping on the phone's side (left side).

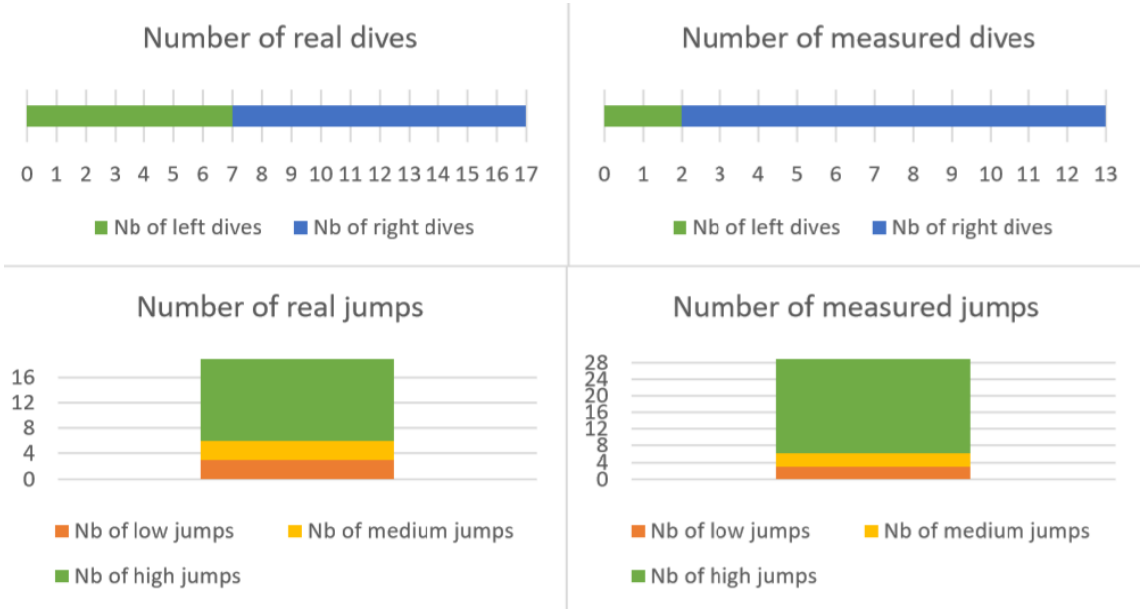


Figure 2.6: The results of diving identify test [8]

As the technology evolved, we started using robots almost every day, whether we are talking about the coffee maker, washing machine or remoted toy cars.

In sports for example, already exists a wide range of robots in fields like gymnastics, snooker or boxing. Such a robot was created to be a goalkeeper by some swedish researchers.

For its build were utilized Lego NXT bricks that use 2 NXT cameras and for target detection, they used NXTCamView software. This software is meant to configure the colormaps used for object detection. For a better detection of the ball, during the experimental part they chose a red ball to play with.

A premise from which to start developing was that the most important 3 positions are: goalkeeper's position using odometry, the target position(the red ball) using triangulation and the predicted interception point using 'Least square' algorithm. Any prevision about the ballâs trajectory was done using Simulations in Matlab.

One of the goals of its creators is to have a real football game played exclusively by robots until 2050.[17]

### 2.4.4 Artificial Intelligence in sports

Technology is already impacting football; the goal-line technology and video-assisted replays(VAR) give the third eye to the referee. AI-powered current and upcoming algorithms provide insights that can add value to the game. AI tools and techniques can analyze the playing strategy of a team by providing feedback to boost their performance. These applications use sensors in biomechanics to show footballers movements in 3D, uncovering how players play. Sports analytics is also used for comparing players' statistics and it can help by evaluating defensive or offensive athlete performance. Such a system was developed at Loughborough University. The lead director and his team created a hybrid system that uses deep learning and computer vision knowledge based on video recognition. The scientist used deep convolutional layers to understand and extract unique features(running, kicking and walking) from thousand of recordings. It helps players to access their performance and different sequences during any game that is video recorded without being human handled(which would make the process slower).

Another company that uses machine learning on big data is SciSports. They offer solutions to track footballers performances and provide scouting information. The data software can track more than half a million players which can help to find a rising talent. In the future, the company wants to implement deep learning on their system to reach the maximum potential of AI in soccer.

Machine learning and data science are also used by Data Scientists to investigate if a football player is overpaid or not. They created a computational model that can estimate a player's salary based on what are his football abilities.[11]

In football, the most important objects to be detected are players, lines and the ball. A team of chinese scientists developed a system based on video detection which can recognize each line from the field and each player, categorizing them in 4 types. This application works on wide shot videos, with the assumption that the playfield color is the dominant color. Having that, the video will be binarized with a suitable threshold using top-hat operator. The final result of field lines is obtained after the elimination of the noises caused by the players and the out of the field by using HSI color space. On the binary image is performed Hough transform for line detection(here will be detected 3 lines: mid lines, and lines and penalty lines) and for players detection and classifying they used template matching method.[15]

# Chapter 3

# Proposed approach

The main scope of the application is to help goalkeepers clearly understand where and when to position themselves on the football field based on their evolutions in training games or official ones without human handling of the events. This system will be based on videos containing each goalkeeper's evolution that will access it. In fact, every user will be able to learn how to cover the goal better week by week by seeing his previous game or training.

Another important thing is that every coach that will access the application will have a database with every keeper, helping him to make the right decision when selecting the "number one" for each football game. He will be also able to recommend to each player how to talk with his teammates (for a better defensive organization), what kind of physical training to do, or even what kind of food to eat.

## 3.1 Players detection using YOLO v4

The first important step for application development is players and ball detection. For that, I chose to use YOLO v4 on a custom data set, a real-time object recognition system that can recognize multiple objects in a single frame, creating a boundary box around every object. It is based on a single Convolutional Neural Network (CNN) which divides an image into regions and then predicts the boundary boxes and probabilities for each region.[4]

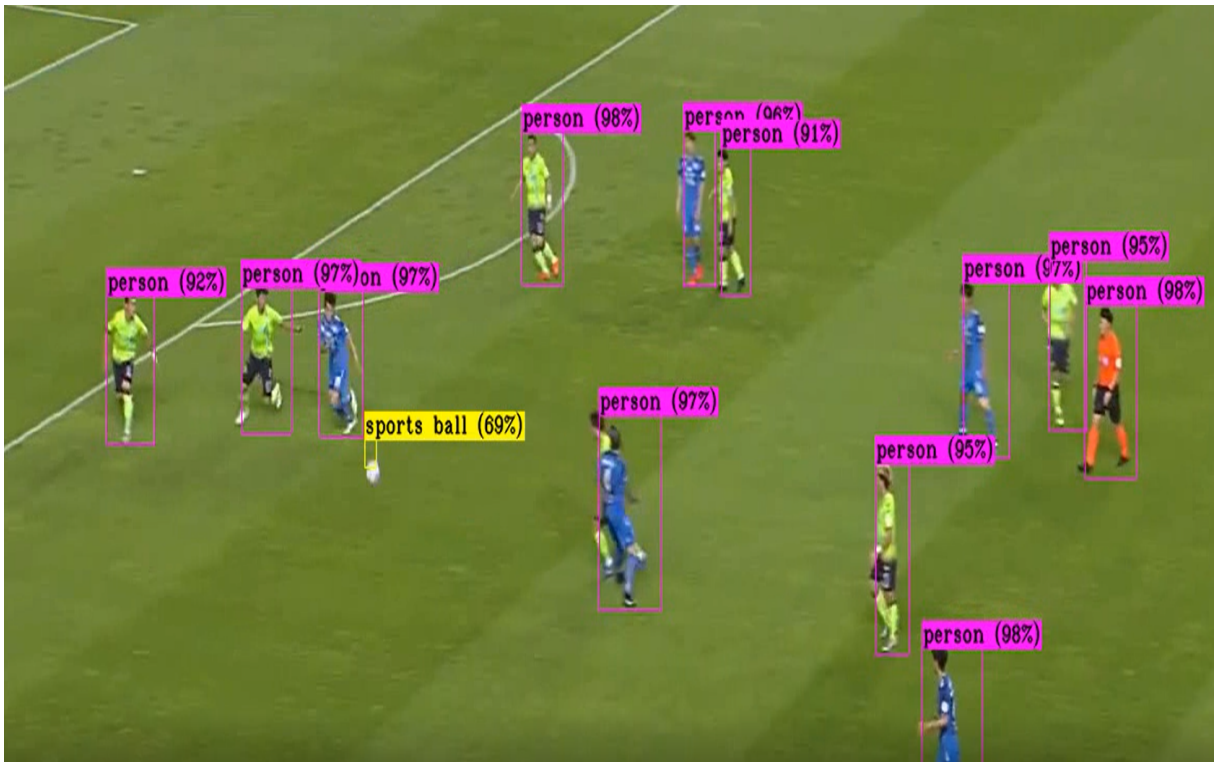


Figure 3.1: Players and ball detection using YOLO v4

A Convolutional Neural Network(CNN) is an algorithm based on Deep Learning which has as input an image and makes the difference between one and other objects. Its architecture is similar to the connectivity pattern of neurons in the human brain, being inspired by the organization of the visual cortex. Such an algorithm has the ability to learn a wide range of characteristics, filters or aspects, needing a much lower pre-processing time than other classification algorithms.

For now, CNNs are one of the best algorithms to do what the human eye can do: recognize objects, appreciate the distance between them or track their movements. However, they cannot clearly understand what an image actually means: if the context is shifted a little bit and without proper training they start to break quickly.

However, one of the challenges of using this data set was that the ball recognition was not as good as I wanted because it was not detected constantly(main tests were made on South Korea's first football league games and the recordings were made from a high spot). A limitation of Yolov4 seems to be linked to the detection of small objects moving, so it made me choose this set for person detection and another option for ball recognition.


Figure 3.2: Players detection using YOLO v4 first frame


Figure 3.3: Players detection using YOLO v4 second frame

## 3.2 Ball detection using HSL(hue, saturation, lightness) Colorspace and Hough transform

For the chosen prototype of ball detection I chose a color which stands out in a training field: yellow. For this I used the HSL Colorspace for detecting the color of the object.

Figure 3.4: Ball color selection left

For the proper detection of the ball, I used circle Hough Transformation, which provides me a better

detection of circles. It's a fundamental feature extraction technique for recognizing circles in faulty photos in digital image processing. The circle candidates are created by selecting local maxima in an accumulator matrix and then "voting" in the Hough parameter space.

Figure 3.5: Ball Hough Transform

## 3.3 Line detection using Hough transform

In order to be able to recognize what type of player is detected on the field, a very important feature for my system is line detection. For that I used Hough Transform for lines.

Hough Transform algorithm was first designed for recognizing complex lines on photographs, but it has been modified to be able to recognize all kinds of shapes. As an input, it needs to have an edge image; such an image is binarized(all of its pixels values are a 1 or a 0). The points obtained from the edge image are stored in an accumulator in Hough space and then they are interpreted as infinite length lines using thresholding. The last step of the algorithm is to transform the infinite lines into finite ones.

Detecting straight lines is the most basic application of the Hough transform. In general, the straight

line y = mx + b may be represented in the parameter space as a point (b, m). Vertical lines, on the other hand, are problematic.They would cause the slope parameter m to have unlimited values. As a result, For computational reasons, Duda and Hart recommended using the Hesse normal form:

$$r = x \cos\theta + y \sin\theta$$

Where:

- r is the distance from the origin to the closest point on the straight line
- Theta is the angle between the x axis and the line connecting the origin with that closest point

The two parameters that constitute a straight line are estimated using the linear Hough transform method. Every point in the transform space is used as an accumulator to detect or identify a line defined by algorithm wrote above. Every point along the image's recognized edges adds to the accumulators.

The accumulator's dimension is equal to the number of unknown parameters. The Hough transform method assesses if there is adequate evidence of a straight line at each pixel at (x,y) and its surroundings.

The linear Hough transform produces a two-dimensional array (matrix) that is identical to the accumulator, with one dimension being the quantized angle and the other being the quantized distance r. The total of the points or pixels that are positioned on the line indicated by quantized parameters (r, ) is the value of each matrix element. As a result, the element with the greatest value denotes the most prominent straight line in the input image.[7]

The previous sections describe the preparation that needs to be made for the actual proposed algorithm to be enforced. First of all, the dominant colour in the frames of the video needs to be established, with emphasis to the lower half on the frames which contain the football pitch in a vast majority of the video footage. The nuances of the grass are therefore detected as the range of the most frequent colours. This is important for the subsequent task of base line detection. In order to properly detect the base line of the pitch, an algorithm similar to the one in is employed.[15]

Once the baseline appears in the frame, the goalkeeper is then sought in a sweeping manner. The persons detected using the aforementioned YOLOv4 algorithm are compared with respect to their euclidean distance to the already determined baseline. The closer one to the line is deemed the goalkeeper.

On the other hand, the player attacking the goals needs to also be singled out of the detected persons on the field. This is achieved by comparing the detected persons with respect to the position of the detected ball in the frames where the ball is clearly detected. the person closest to the position of the ball is deemed the attacker.

Now that both the actors of the scenario are established their relationship on the field needs to be assessed. The goalkeeper must be situated in the goals such that the player with the ball intersects its position precisely. However, especially young inexperienced goalkeepers position themselves incorrectly and therefore automated suggestions on game footage or on training video materials are very necessary.

The proposed approach takes successive frames of the video into account. Based on the fact that the YOLOv4 detection method is combined with the deep sort method in order to uniquely identify individual persons in consecutive frames this unique identification can be used to determine and draw the velocity vector of the player with the ball. As the purpose of the attacker is to approach the goal, progressively, its vector will tend to intersect la baseline, probabilistically within the space of the goals. This is considered the ideal position for the goalkeeper. In order to suggest a better position for the goalkeeper, their position needs to know but this has already been established as the keeper has been detected in an aforementioned manner. The ultimate goal of the proposed approach is to highlight the motion vector for the goalkeeper that starts from its current position and points towards the ideal position.

First step to find the base line is converting the video in HSL colorspace to select white and yellowish white for defining the lines(just how I used it for ball detection).
For reducing the image noise I used a filter called Gaussian smooth. It also helps to consolidate the existing lines.
Next step for obtaining the base line is to process the image using Canny edge detector which is an edge detection operator that detects a wide range of edges in images using a multi-stage algorithm. In our case, the most valuable result consist in line edges.

Figure 3.6: Line detect - HSL color select

Figure 3.7: Line detect - Gaussian smooth for reducing image noise

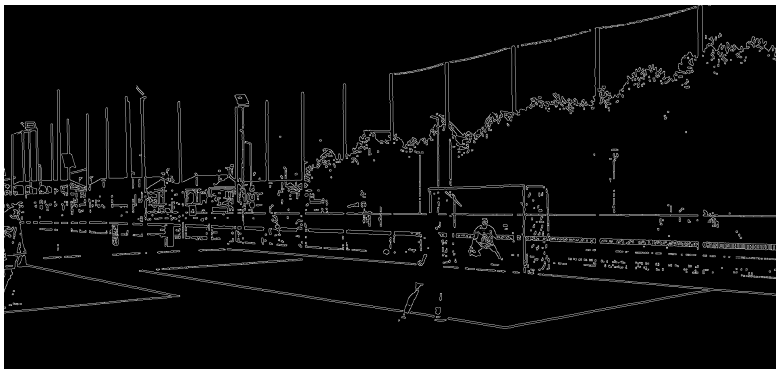

Figure 3.8: Line detect - Canny Edge

For detection of straight lines in image I used Hough transformation . Here the main target were lines close to the horizontal which defines the base line o the training field.

The end result is obtained by combining the results of all the aforementioned techniques. First the ball is detected and the coordinates of the center of the ball are stored in local variables as they will be fundamental to our further goals. Then, the white lines inside the image are detected and filtered such that their inclination is close to the horizontal thus detecting the slope of the back-field line. The players are then detected using the aforementioned machine learning techniques. Two important

Figure 3.9: Line detect final

roles need to be attributed to two of these players: the goalkeeper is deemed to be the last player swept by a line parallel to the baseline and the player with the ball would be deemed the one whose bounding box has the smallest euclidean distance to the coordinates of the ball. The direction of the player-ball ensemble is then computed from successive frames and then the line thus obtained is intersected with the baseline. As it can be seen in the picture, a red rectangle is drawn next to the goalkeeper in order to suggest the direction and the speed that should characterize his movement towards his optimal positioning.

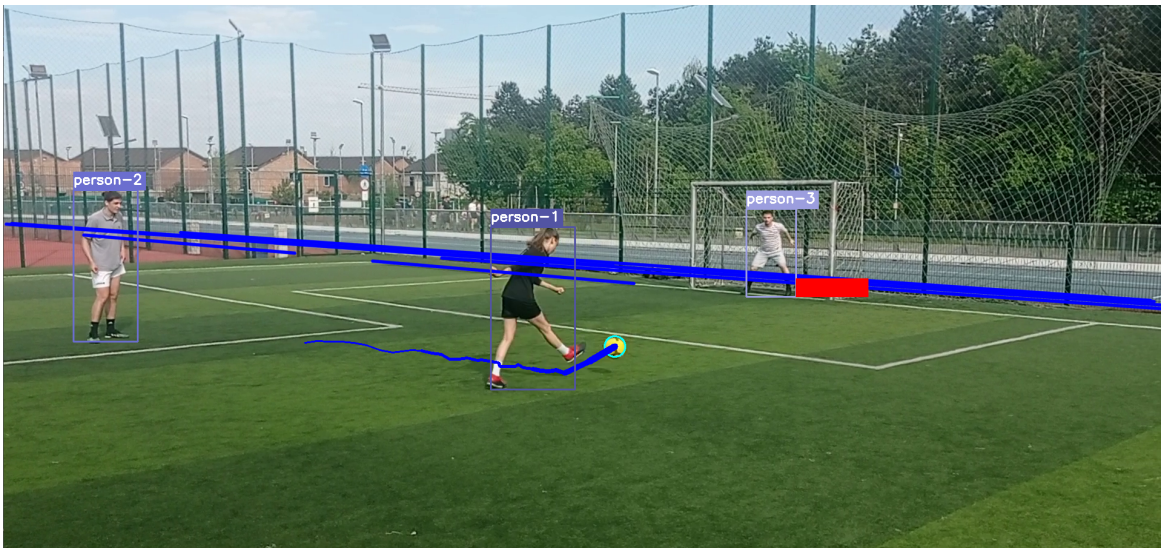


Figure 3.10: Objects detection final

# Chapter 4

# Technologies and concepts used

This chapter will explain the technologies and concepts which I used to develop my application. As a result, all of the many libraries and frameworks that will be used will be thoroughly described, with their importance clearly explained.

## 4.1 Technologies

### 4.1.1 React

React is possibly the most popular library used for the creation of user interfaces. Due to the presence of several unique and interesting concepts, the work experience generally feels engaging and dynamic.

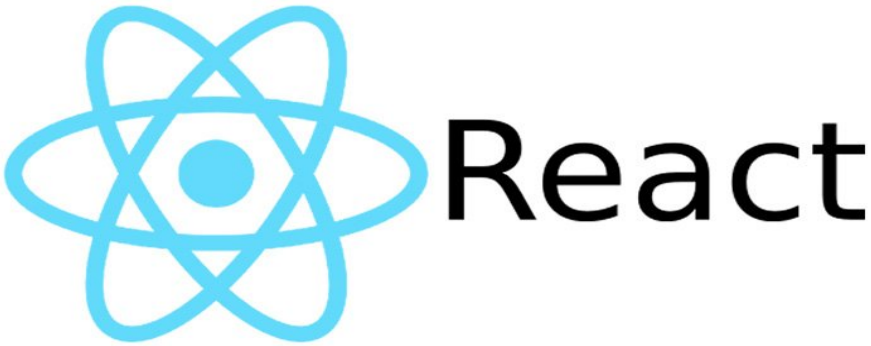


Figure 4.1: React Logo

The design of simple views for each state of the developed application is supported by its declarative nature, which also makes the code more predictable and debugging less challenging. The process of debugging is also hastened by the fact that React is a component-based library, allowing the construction of encapsulated components that can manage their states. Grouping all of these components together thus creates a more complex UI.

React also introduces Hooks, which conclusively changes the process of development. The application's memory cost is reduced, as now the creation of both stateful and stateless components is possible.

To summarize, given the React development team's perseverance in releasing new updates, and the community's constant growth, the experience of using React is sure to further improve. My own experience proved difficult until I managed to properly grasp the main concepts, but the overall experience has been positive.

### 4.1.2 Strapi

Strapi is an open-source, customizable and fully Javascript Headless Control Management System (abbreviated CMS). The aim of the software is to provide editors with a way of easily distributing and managing created content, while also allowing developers to select their favourite libraries, tools, and presets. The API can be extended through the plugin system, the initial goal of this framework being to boost API development while constructing digital experiences.

Key features:

- Custom Content Structure:

  -The generation of the admin panel is easily accomplished with a few clicks and the whole setup for the CMS is done in a matter of minutes.

- Easy Content Management:

  - Strapi's admin panel features an interface that is intuitively operated, allowing the user to create, edit and delete content. This additionally improves workflow and saves the user time.

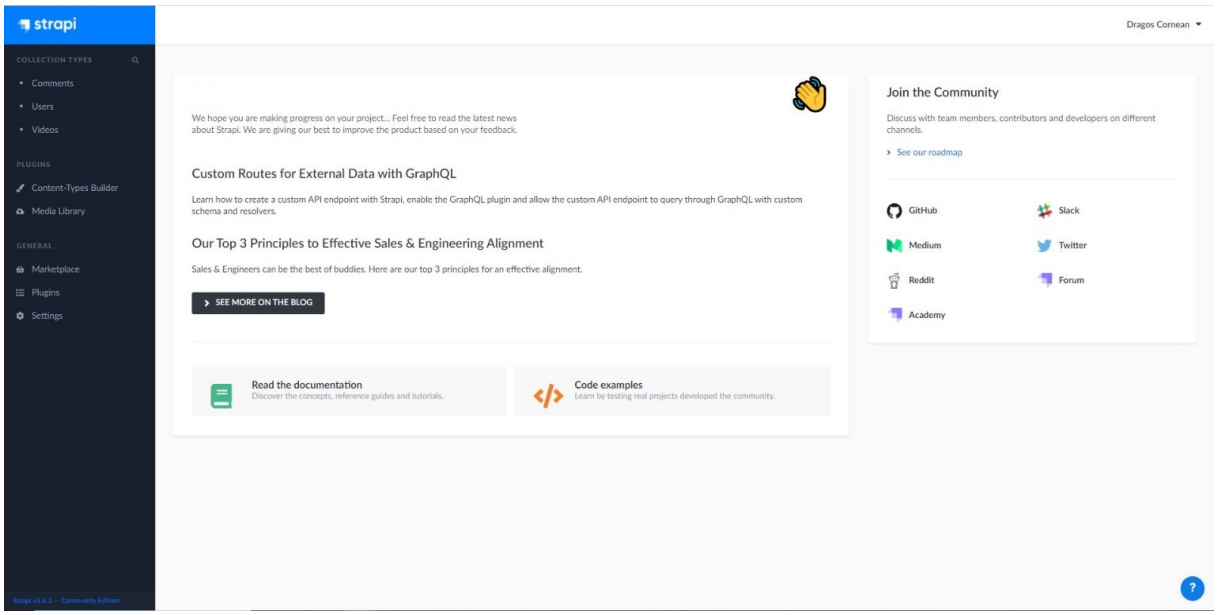


Figure 4.2: Strapi Admin Pannel

- Roles Permissions:

  - The built-in user system provided by the software permits the management of access and permissions for individual users.

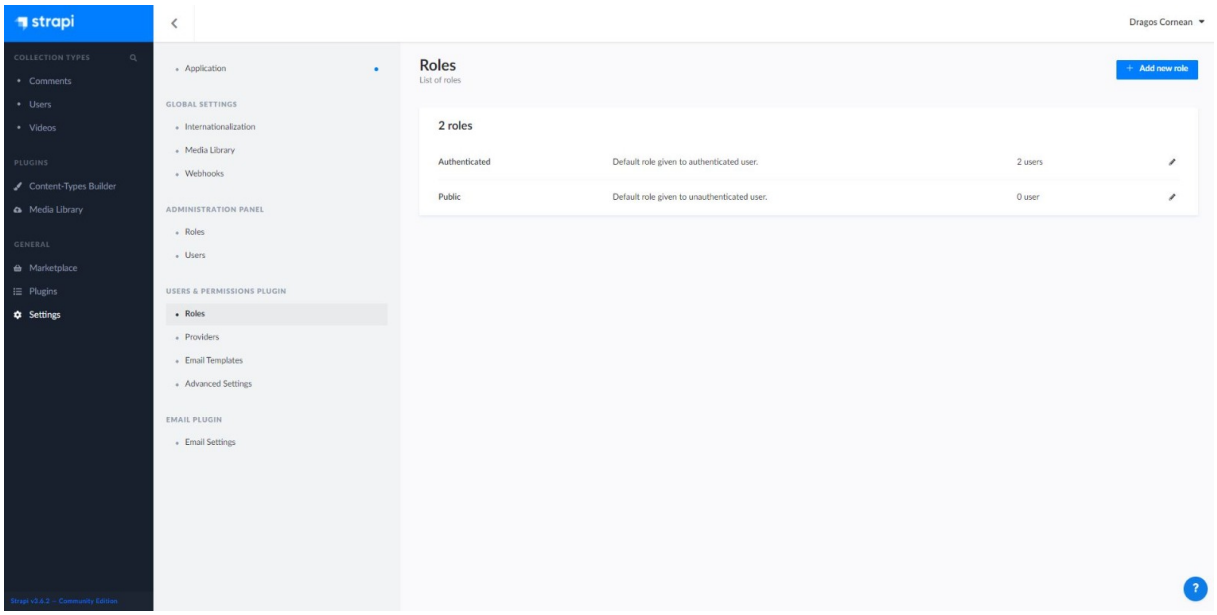


Figure 4.3: Strapi Roles

- Plugin system:

  - Various plugins may be installed from the Marketplace.

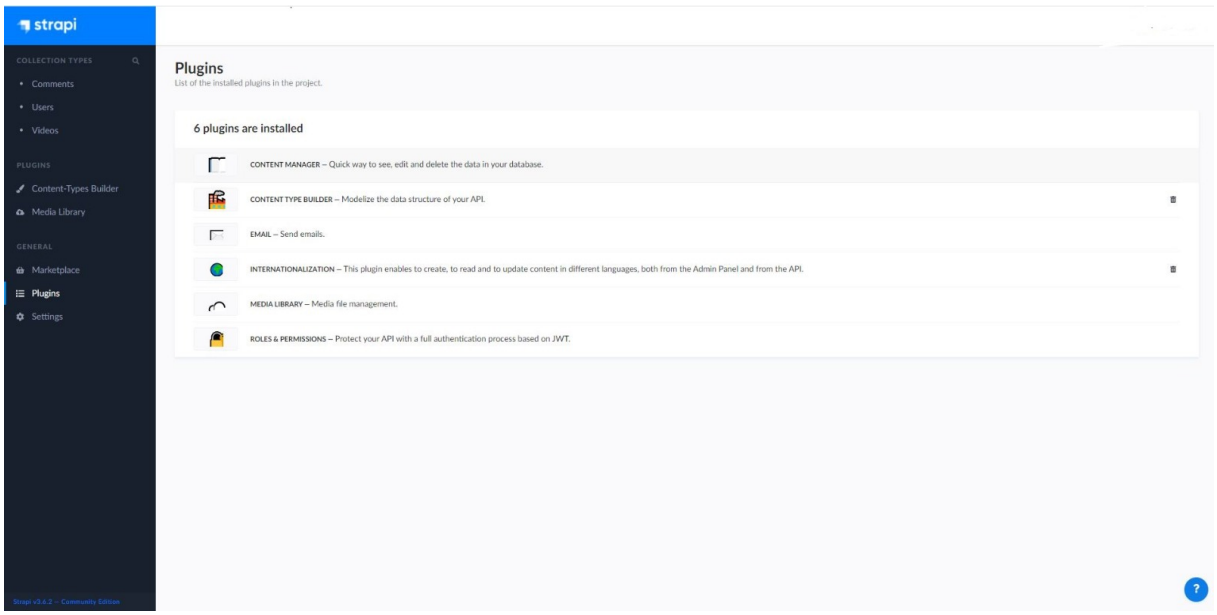


Figure 4.4: Strapi Plugins

- API Documentation:

  - Allows the documentation of the endpoints present in the application. - Restricts access to documentation.

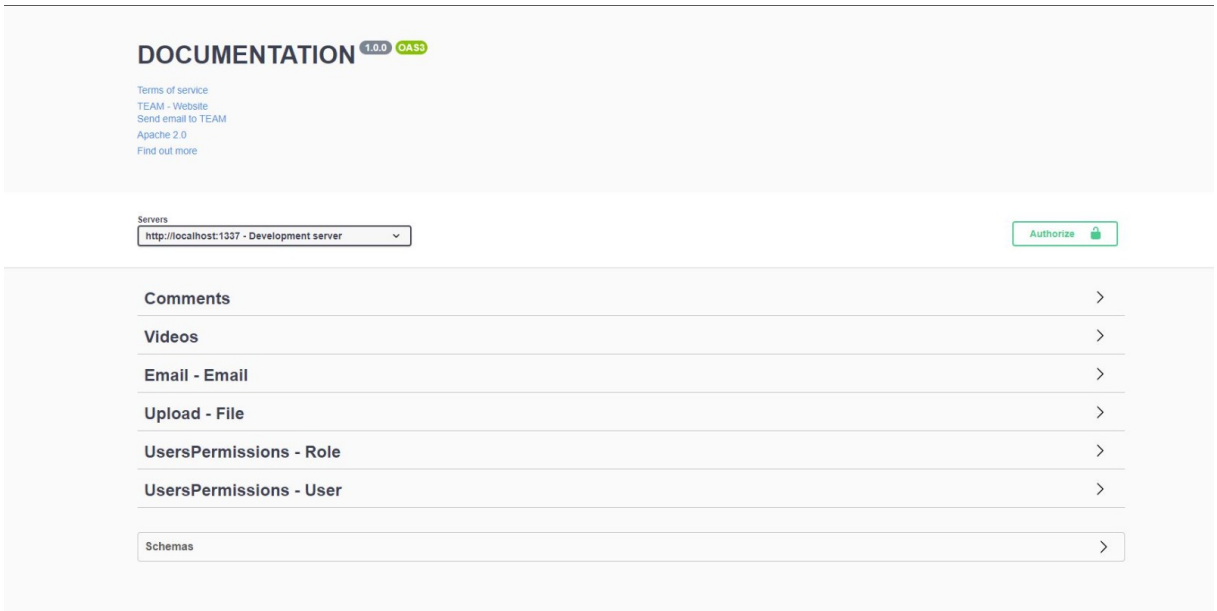


Figure 4.5: API documentation (by Swagger)

Furthermore, it is worth mentioning that when a new table (collection) in Strapi, the application defaults to creating endpoints necessary for Create, Read, Update and Delete operations (CRUD); Permissions are then set according to the individual user needs regarding these endpoints.

To conclude, I personally believe this tool can be recommended for the remarkable improvements it brings in the speed of development and general workflow. The ease of use and multitude of plugins are also considerable benefits of the application.

### 4.1.3 Redux

Redux is a state container for JavaScript applications which allows the centralization of data. The entire application state is managed and stored, reducing the time wasted calling the same endpoint for data fetching.

The workflow for this application, is not easy, taking time to get accustomed to and implement. Initially, it requires that the user defines an action for dispatch, the reducer of the component updating the store accordingly, after which the state becomes UI-accessible. The definition of a reducer for the component makes the stored data accessible to any component in the application.

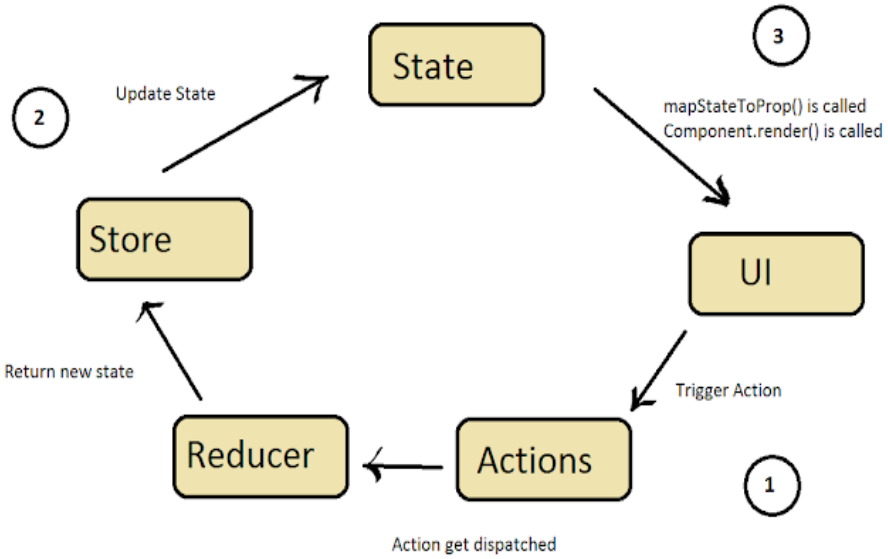


Figure 4.6: Redux Workflow

Redux provided the possibility of an enhanced architecture and helped to organize the code. As a consequence, development time increased, although this was a trade-off for the ability to further scale the project.

This approach, however, has proven overly complex, and difficult to implement. Generally, one must research extensively to determine whether Redux is indeed a superior choice for the project, as in some cases, for example with smaller applications, similar results can be achieved without using Redux. It is worth mentioning that Redux, however, is perfectly adequate for use with a large amount of data which changes over time and requires access in more components.

### 4.1.4 Axios

Axios is a promised-based HTTP client library used to make HTTP requests to the server, fetch data or perform CRUD type operations. One of the features of this library is the automatic transformation of JSON data, which reduces the wait while building requests. Installation and use are simple - simply specify the used method, server called, sent headings and, if it is necessary, also the data one wishes the server to receive.


## 4.2 Concepts

### 4.2.1 JWT Authorization

JWT, or JSON Web Token, is an open standard for securely transmitting pieces of information between parties as a JSON object. The digital signatures of this information means the data can be verified and trusted. The process of digitally signing a JWT can be achieved either by pairing a public and a private key via RSA or by using an HMAC algorithm.

The first scenario in which one uses a JWT is in the process of authorization. This grants the user access which can only be accessed with this type of token, in the form of private routes, resources and services. The second prominent scenario involves the exchange of information that needs to be seen by a single given user (whose identity can be verified) - this also entails that the user may verify whether data has been altered by an external service. JSON Web Tokens consist of 3 parts:

- Header - Incorporates the type of token (JWT) and the algorithm used for the data's signature (RSA / HMAC / SHA256) Payload - Contains the data for the exchange and other additional information such as expiration time.
- Payload - Contains the data for the exchange and other additional information such as expiration time. Signature - By taking the encoded header (and the specified algorithm), encoded payload and a secret determined by the user, the signature is applied. The result consists of a Base64-URLstring which can be passed in HTML and HTTP environments. This string is separated by three dots.
- Signature - By taking the encoded header (and the specified algorithm), encoded payload and a secret determined by the user, the signature is applied. The result consists of a Base64-URLstring which can be passed in HTML and HTTP environments. This string is separated by three dots.

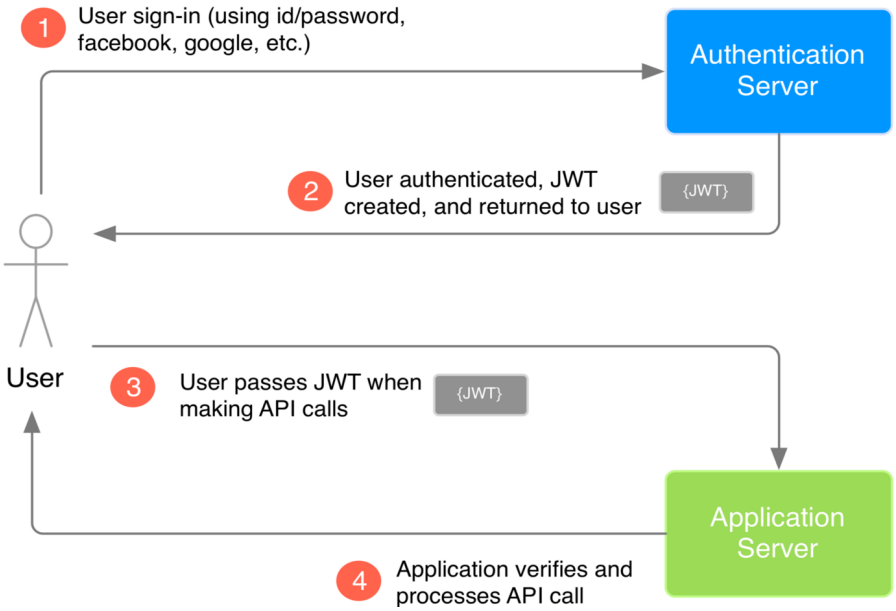


Figure 4.7: Flow of using a JWT

Example: After the user has logged in the tokens are obtained and stored in the local storage in such a manner that the application recognizes the user and thus doesn't require further logins. The data held by the token consists of data particular to the user, such as first name, contact information, etc.

When a JWT is obtained, the user may input the Header of his request, thus making specific calls to the server in order to obtain data.

To briefly summarize, JWTs represent a necessary component for every application which seeks to integrate more users, providing a good layer of security for the application as well.

### 4.2.2 HTTP

Many sites uses HTTP (abbreviated from HyperText Transfer Protocol) to allow the transfer of data between systems, presently between the server and the application. The protocol employs the concept of request-response and is a perfect fit for the REST architecture.

### 4.2.3 HTTP Request

HTTP Requests consist potentially of multiple components, one of the being the URI (Uniform Resource Identifier), which identifies the endpoint that the client chooses to access. Besides this endpoint resource, the aforementioned component may also contain Querry String Parameters, which provides the server with additional details corresponding to the requested resources (endpoints).

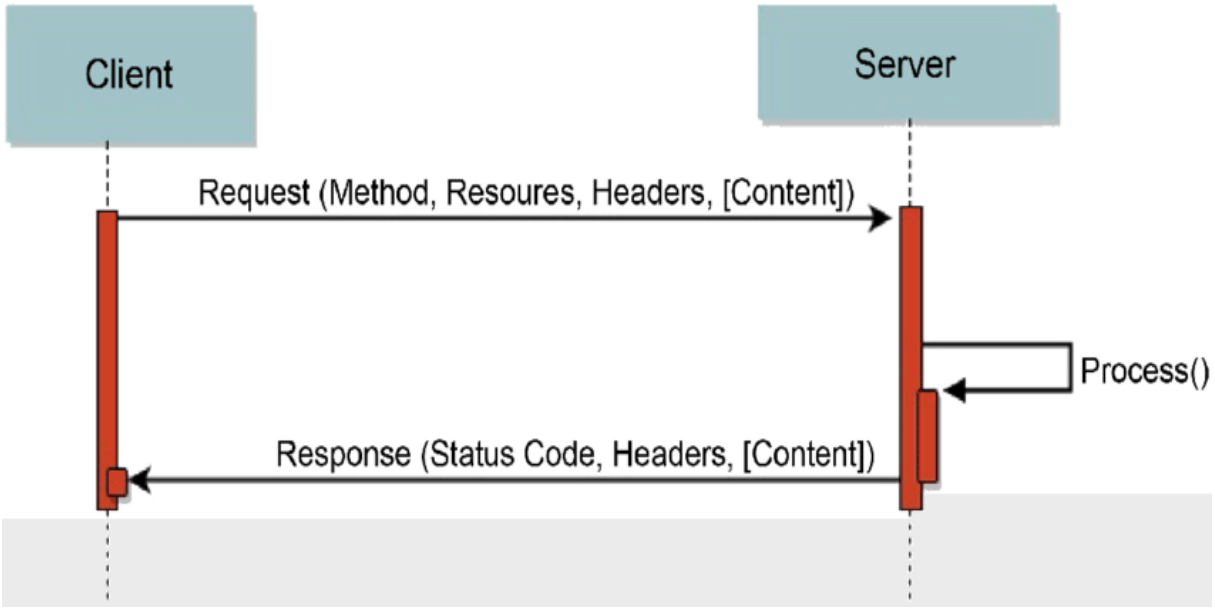


Figure 4.8: HTTP request response pattern

HTTP Requests imply an associated method, which indicates the type of action requested. The user may select from a range of methods, although the most common ones are the request methods for CRUD operations:

- GET - Retrieves data from the server.
- POST - Sends data chunks to the server, which is pushed into a table from the database.
- PUT - Updates data from a selected record in the database. This method modifies the fields from the sent record.
- DELETE - Deletes records from the table, identified via a unique identifier sent together with this method.

The role of these methods is, however, semantic, meaning that particular users may utilise them to correspond to a variety of intentions.

An HTTP Request also contains the Headers component. This takes the form of the key-value pair, specifying additional information about the request made. Information can be added which specifies the data being sent. Authorization tokens may be needed for some data requests.

Lastly, an HTTP Request contains the RequestBody, representing the data that the user is trying to send to the server. The encoding of data varies according to the user's needs, the present case utilising JSON encoding, although, in the case of uploading files, the encoding method is that of Multipart Form Data.

### 4.2.4 HTTP Response

HTTP Responses also include multiple components - the bare minimum is represented by the status code of the response, which indicates the status of the request as successful, failed or intermediate states. Examples of such status codes are:

- 100 - The client should continue with the given request.
- 200 - Tells the user the request has succeeded.
- 400 - Informs about errors - client-side.
- 500 - Informs about errors - server-side

To summarize - HTTP requests are ways of communication between the client and the server. They represent effective tools to be utilised in development, as they are easy to grasp and fairly intuitive. Caution is, however, advised in regards to their overuse, as they require a lot of time to carry out.

### 4.2.5 API - Application Programming Interface

An API is usually utilised in order to represent a list of operations that can be used by the developer, alongside descriptions guiding the developer in using the operations. APIs communicate through requests, and can also communicate with one another in their isolated states (if certain standards are respected by both).

### 4.2.6 REST

REST (REpresentational State Transfer) is an architectural style that aims to provide a common standard between systems and devices on the internet, thus making the communications between them easier. Maintaining these standards coherently means the possibility of developing such systems in isolation.

RESTful systems separate the client from the server, allowing the development of each one regardless of the knowledge of the other - this entails the ability to develop the front end at will without affecting the backend at the same time. Nevertheless, the efficiency and overall success of the communication rests upon the imposed standard, consistent between the two ends. Consequently, separating the client from the server awards higher flexibility and scalability.

The primary trait of a RESTful server is that is must be stateless, never storing context in memory. In this way, all persistent elements must be done at a database level. Communication with the server can be established through HTTP requests, as previously described.

As a short conclusion - integration of the REST concept increases the application's flexibility and scalability, constituting a solid approach to development due to the user's capacity to develop both the server and the client independently, in isolation.

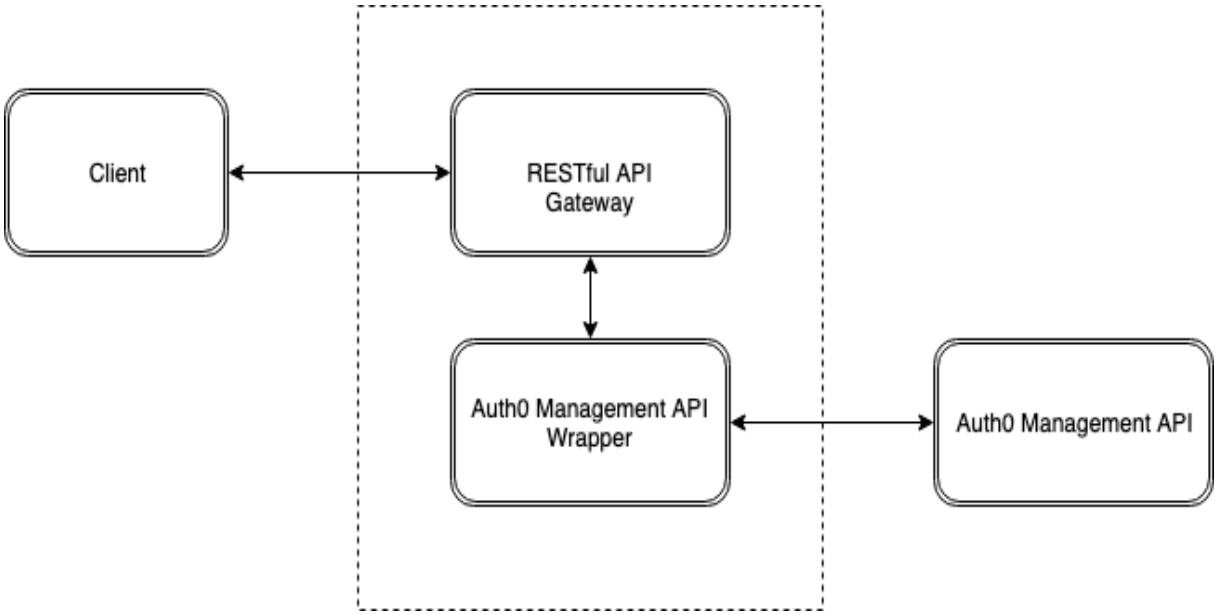


Figure 4.9: REST arhitecture

# Chapter 5

# Application: implementation details

The main idea which made me start developing this application is the need for evolution in sports training. It is crucial for a football goalkeeper to know exactly how to position himself on the field in every single minute of the game, his role being the most important. The Keeper Coach aims to help especially the keepers to understand the things presented above without a single piece of advice from his coach.

Besides the help for the goalkeepers, any manager that will use this application will be able to track the evolution of each keeper from his squad, being helped to make the best decision about selecting the best one and this thing may win games and maybe trophies.

## 5.1 Proposed application

Because the value of my technology is based on video processing, there was no need for a sophisticated application, therefore I chose a straightforward approach to demonstrating its capabilities. The web app has the following essential features:

- Login/Logout an account
- If logged as admin:
  - Add/delete a player
  - Add/delete videos for each player
  - Add/delete comments for each video

- If logged as user:
  - Add a profile photo
  - Watch videos and comments

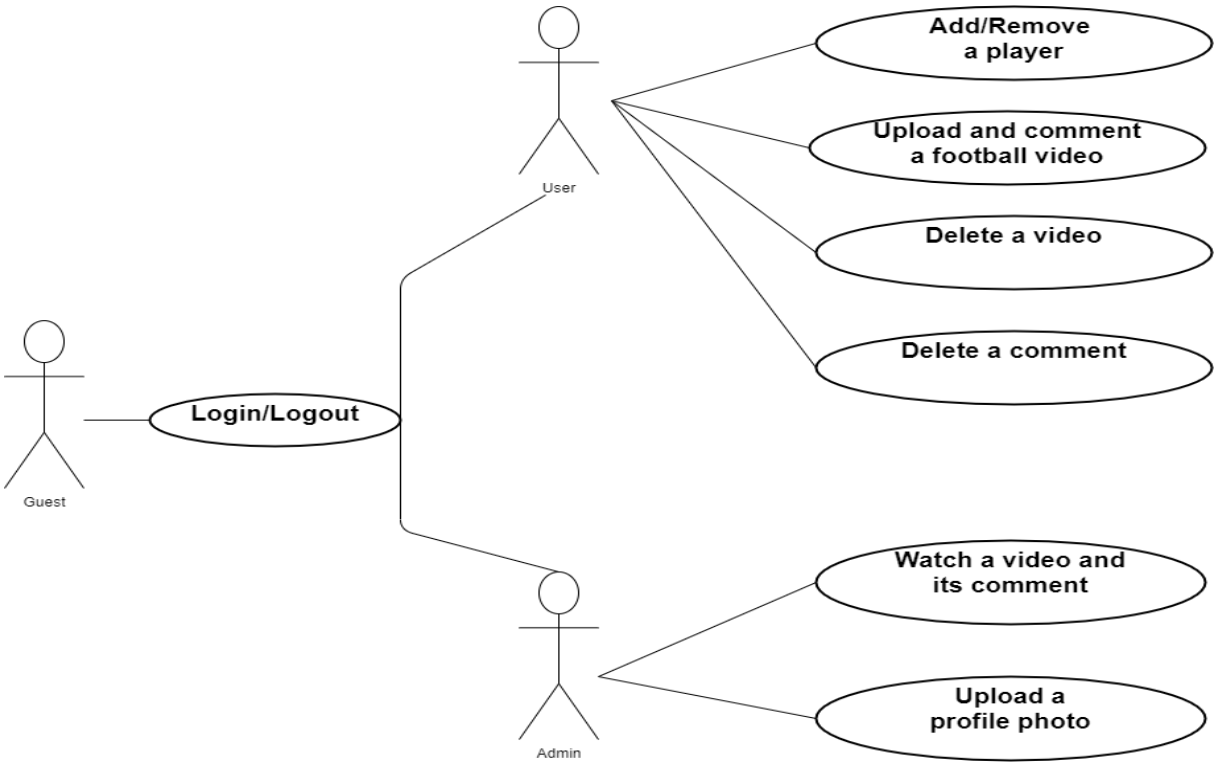


Figure 5.1: Use Case Diagram

In the next paragraph, I will describe the use-cases of my application. The table below represents the Login functionality use case.

| Name CU | Login |
|---|---|
| Participants | User |
| Events flow | The system opens the login tab, the user enters username and password and then clicks on authentication button, the system opens a new specific tab |
| Entry conditions | - |
| Exit conditions | A new tab is opened, based on what type of user has accessed the system |
| Quality conditions | New tab opens instantly |
| Exceptional scenarios | Username-Password pair doesn't exist, an error message is displayed |

Figure 5.2: Login use case table

Logout functionality works as you can see in the next table.

| Name CU | Logout |
|---|---|
| Participants | User |
| Events flow | The user clicks on logout button |
| Entry conditions | The user is already logged in the application |
| Exit conditions | The system reopens the main page where you can login |
| Quality conditions | New tab opens instantly |
| Exceptional scenarios | Miss-click the button |

Figure 5.3: Logout use case table

The next figure will represent Add Player functionality.

| Name CU | Add player |
|---|---|
| Participants | User |
| Events flow | The system opens the home page of the user, the user the button “Add player”, a new window is opened, the user fills al the fields required for player details and then the player is added in the database |
| Alternative events flow 1 | The system opens the home page of the user, the user the button “Add player”, a new window is opened, the user doesn’t fill the fields name, age and number for player details and then an error message is displayed |
| Alternative events flow 2 | The system opens the home page of the user, the user the button “Add player”, a new window is opened, the user fills the fields name with numbers for player details and then an error message is displayed |
| Entry conditions | The user is logged in the application |
| Exit conditions | The player is added in the database |
| Quality conditions | The payer is added in the list |
| Exceptional scenarios | Data is invalid |

Figure 5.4: Add player use case table

For each player, the admin can add one ore more videos, thing that can be seen table below.

| Name CU | Add video |
|---|---|
| Participants | User |
| Events flow | The system opens the home page of the user, the user taps on a player button, a new window is opened, the user clicks on add video button, selects a video from his computer and the then video is added in database |
| Alternative events flow 1 | The system opens the home page of the user, the user taps on a player button, a new window is opened, the user clicks on add video button, selects a photography from his computer and the then video is added in database |
| Entry conditions | The user is logged in the application |
| Exit conditions | The video is added in the database |
| Quality conditions | The video is added in the list |
| Exceptional scenarios | Data is invalid |

Figure 5.5: Add video use case table

When logged as a player the user can select what profile photo he will have and a use case can be seen in the next table.

| Name CU | Add photo |
|---|---|
| Participants | User |
| Events flow | The system opens the home page of the user, the user taps on the player's photo region and selects a photo from his computer and then the photo is added in database |
| Alternative events flow 1 | The system opens the home page of the user, the user taps on the player's photo region and selects a video from his computer and then an error message is displayed |
| Entry conditions | The user is logged in the application |
| Exit conditions | The photo is added in the database |
| Quality conditions | The photo is added in the list |
| Exceptional scenarios | Data is invalid |

Figure 5.6: Add photo use case table

## 5.2 Component diagram

I devised the following architecture to make these features available to the end user. The user logs into the online application and requests an analysis. A RESTful API is used to send the request to our server. At the Data Controller level, we determine whether the request is a CRUD operation, which makes database changes through the repository and returns the response, or if it needs to be passed on to the Analysis Controller, which, depending on the request, runs a script on the input video and returns the response to the Data Controller, which then passes it back to the UI. The component diagram depicts the architecture.

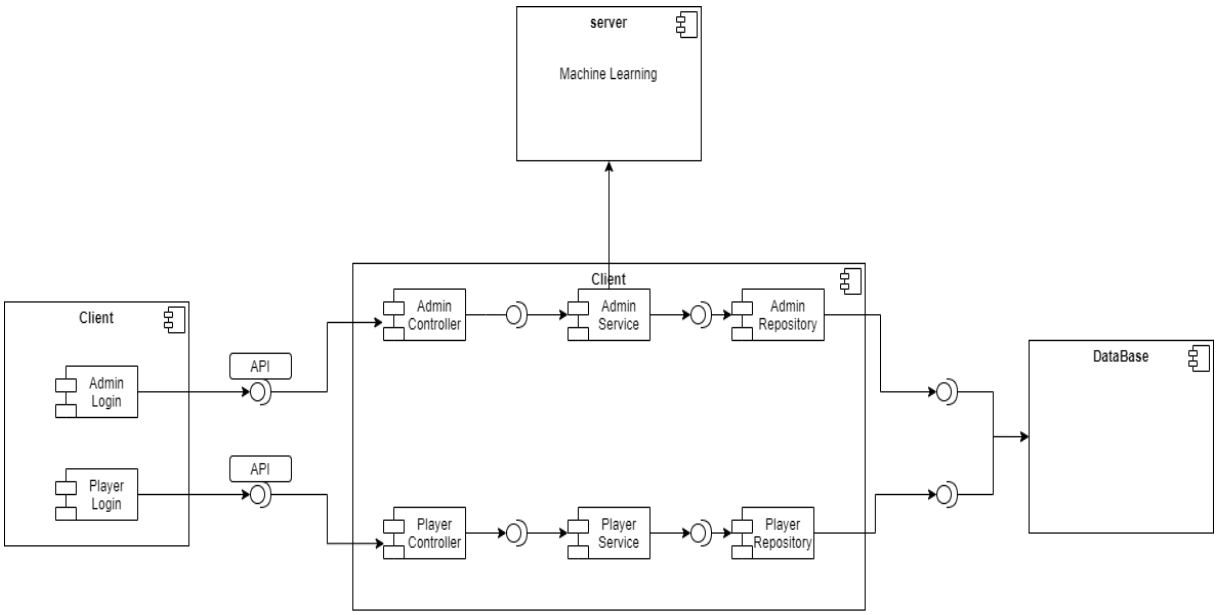


Figure 5.7: Component diagram

## 5.3 Sequence diagrams

In this section I will show you the the sequence diagrams which are a part from dynamic model of application.

The user fills the username and password field and then clicks on the "Login" button, the message is sent to the web interface endpoint and from there is sent to the database to check if the credentials are correct. If there are correct, the user successfully login to the server, and if not an error message will be displayed.

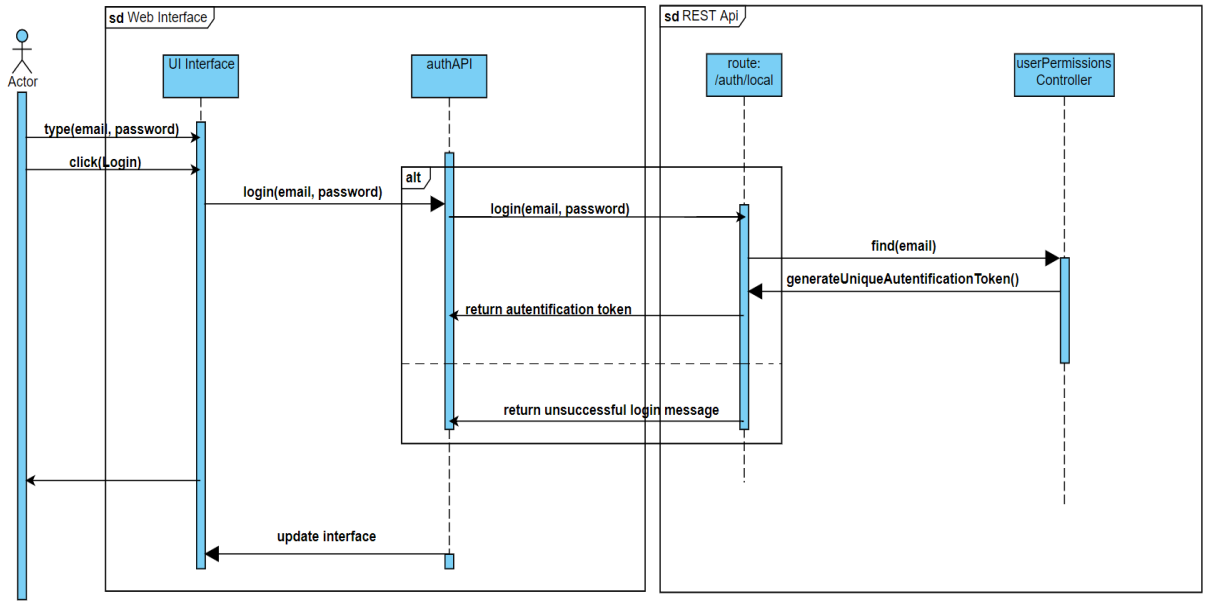


Figure 5.8: Login diagram

For uploading a video, the user selects a video from his computer and clicks "Upload video" button, the message is sent to the web interface endpoint and from there is sent to the database to check if it is a video format. If it is correct, the user successfully upload the video on the platform, and if not an error message will be displayed.

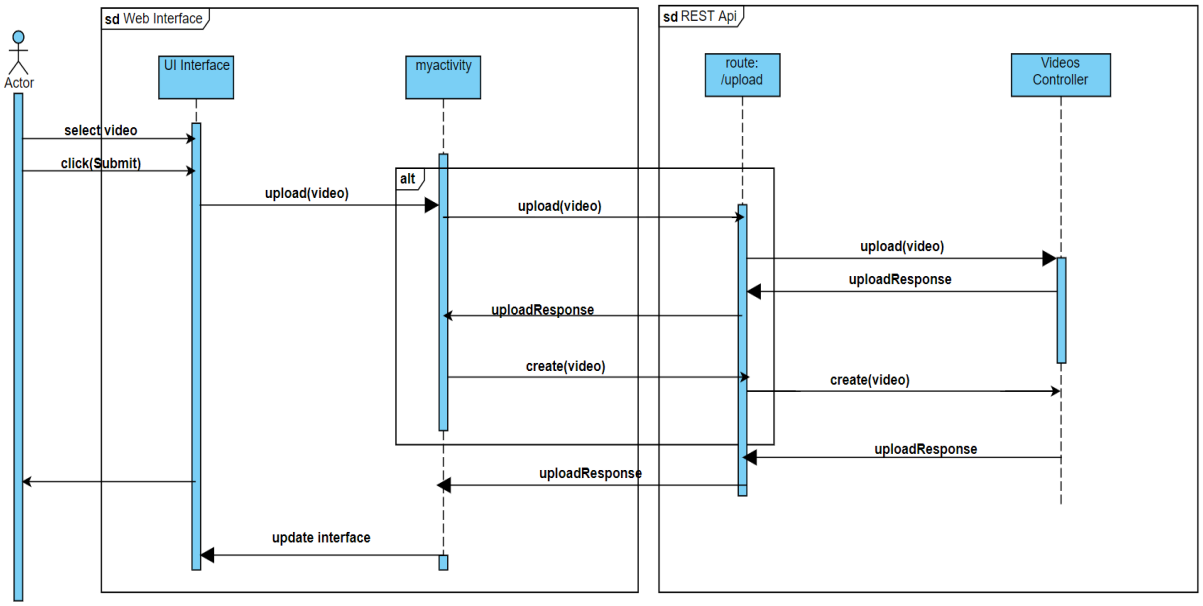


Figure 5.9: Upload video diagram

If a user wants to delete a video, he clicks "Delete video" button, the message is sent to the web interface endpoint and from there is sent to the database. The user successfully delete the video from the platform.

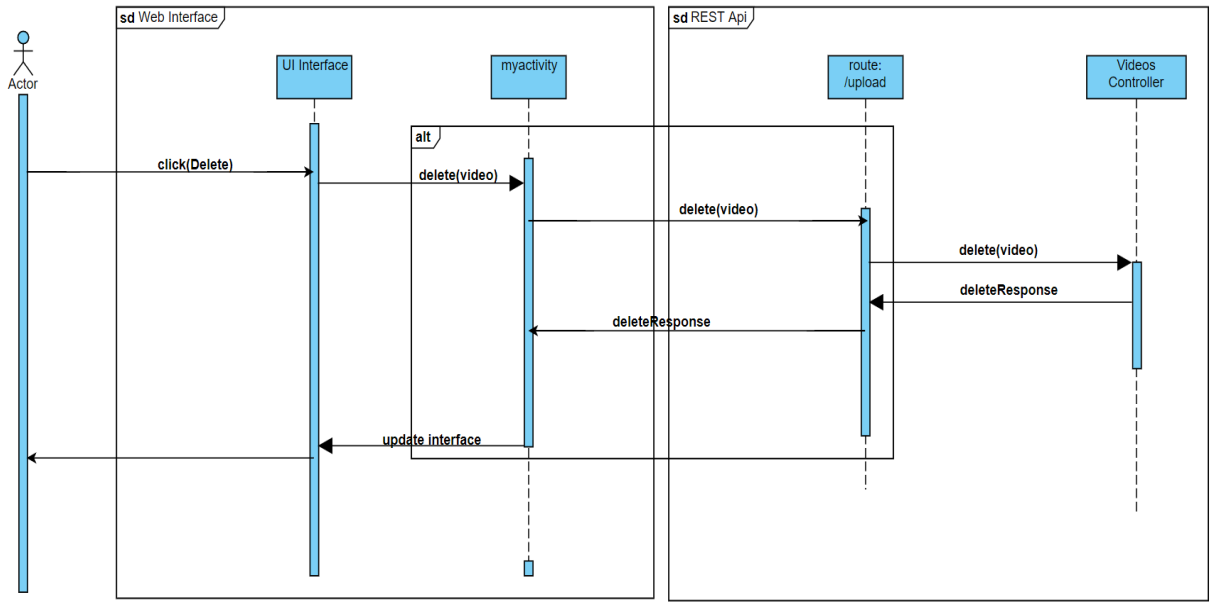


Figure 5.10: Delete video diagram

## 5.4 Application arhitecture

My app is split into two main directories, one for the frontend and the other for the backend. By combining relevant components under the same folder, I attempted to keep my work as orderly as possible.

I've organized the components in the frontend directory as follows:

- API: This is the folder where I save all of my backend requests. This folder is further separated, with each request going into a file that corresponds to the page where the call is placed.
- Modules - A page in my application is represented by each subfolder in the modules folder. Components, where the page is built, and containers, which connect the module to its redux reducer, are subfolders within those subfolders.
- Assets - The folder in which I have the styles for the application. Additionally, the folder is divided into components and modules, each component and module having its SCSS file for a

better organization. Each file is imported in the index file from assets, which is imported at the starting point of the application.

- Components - This folder contains all of the application's reusable components, which are components that are utilized in one or more modules (Example: toast message).
- Redux - This folder includes the reducer and other files that allow the redux store and the appropriate module to be linked.
- Utils - I've put files like constants, custom errors, and other data manipulation in this folder so that the modules aren't inundated with code.

The most part of the architecture for the backend folder was developed automatically by strapi when the project was created. The following is how each table folder is divided:

- Controllers - The route handlers are stored in this folder.
- Config - Where all of the routes and their handlers are specified.
- Models - This folder includes the table's structure, as well as each field's mapping.
- Documentation - In this folder, we'll locate the code that corresponds to the swagger documentation.
- Services - Where does the data modification take place.

### 5.4.1 Application Model

By utilizing object-oriented programming ideas, the application model is readily maintained and extendable. The database isn't particularly large since I attempted to keep the logic simple and choose only the classes that are required for the website to work properly.

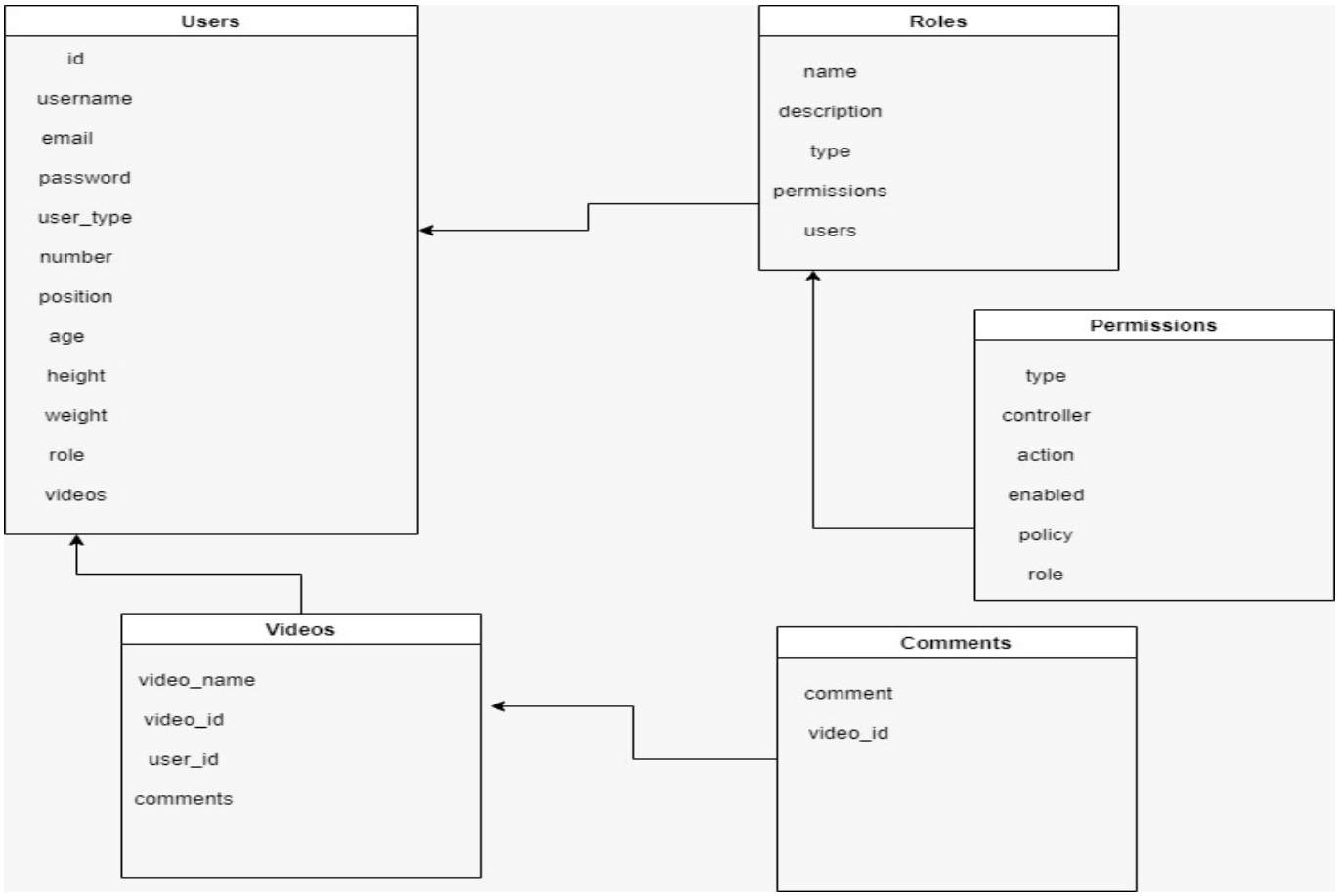


Figure 5.11: Database diagram

### 5.4.2 Login

The Login page is in charge of the user's authentication. The sole validation performed on this page is to ensure that the user exists in the database and that the user's credentials are correct. If the login flow fails, the user will be notified in the same way as before. After a successful login, the user will be routed to the application's home screen, where he may begin storing the environment.

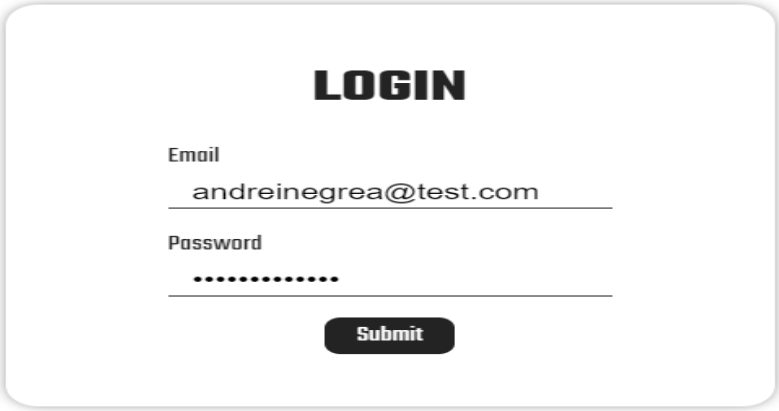


Figure 5.12: Login Screen

### 5.4.3 Home Page

Here we will have 2 kind of home pages: one for Admin and one for User. In this step, the coach(logged as Admin) will be able to see the list of his players, add new ones or delete whichever of them. The home screen of user(the goalkeeper), he will see the videos with his games and comments and that admin added on his profile.

### 5.4.4 Admin Home Page

The team's coach will be able here to manage his goalkeepers squad on this screen. He has permission to add a player using the "Add" button and also to delete one, using the "Delete" button. If he clicks on a player from the list, a new pop-up window will open.

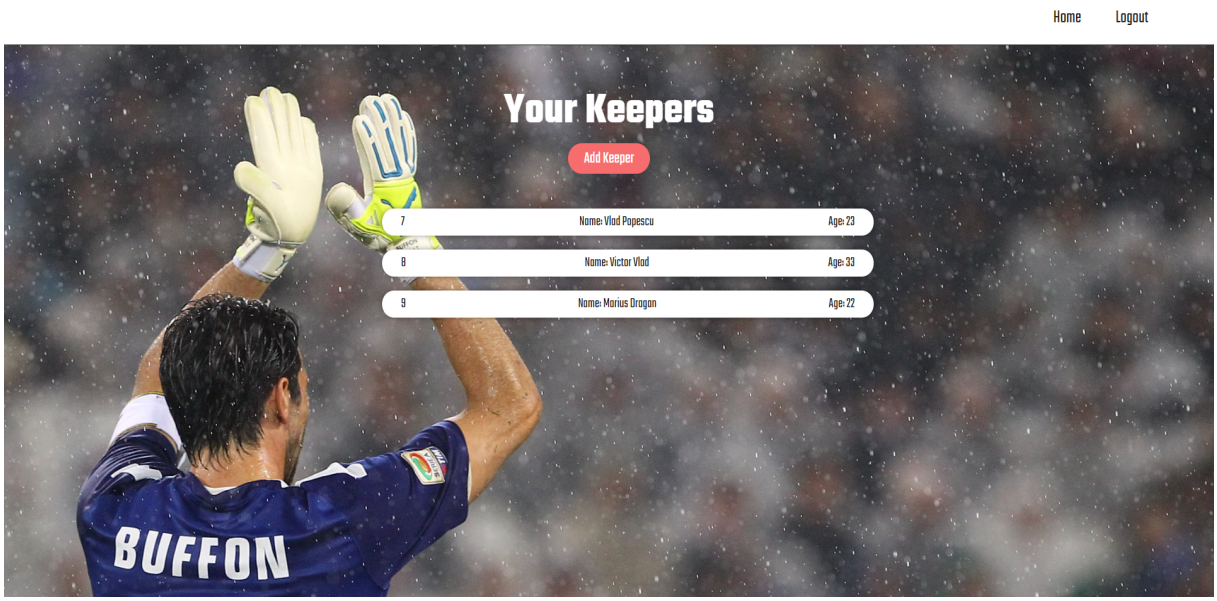


Figure 5.13: Admin Home Screen

### 5.4.5 User Home Page

Every goalkeeper from the squad will see here his training videos together with its comments. He will also be able to select profile photography by tapping on the profile photo region.

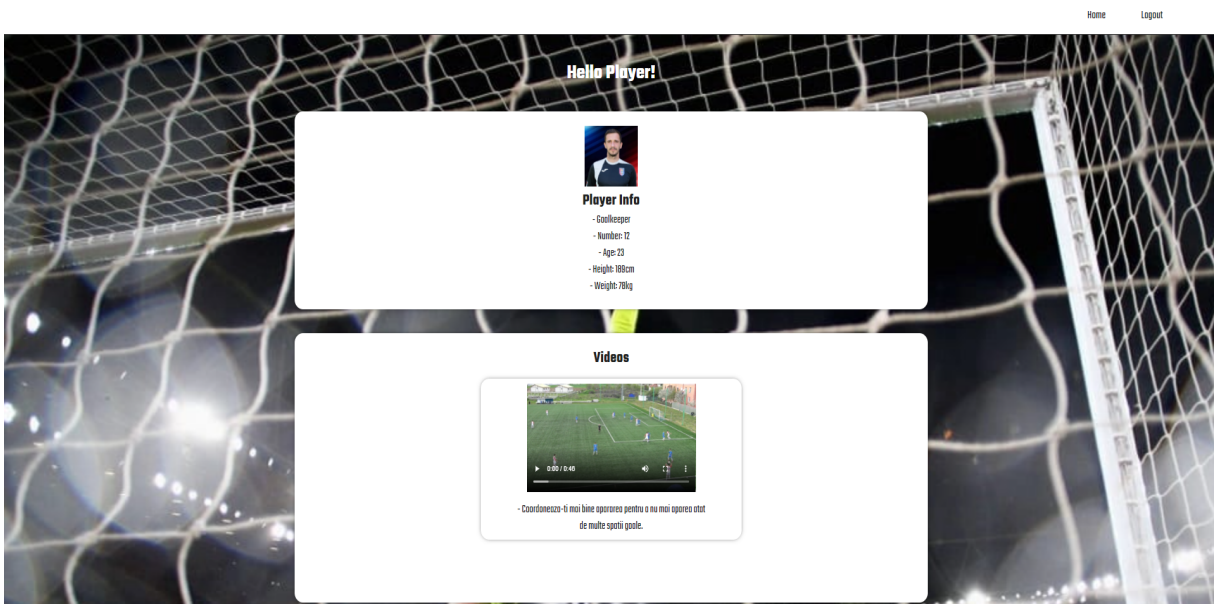


Figure 5.14: Player Home Screen

### 5.4.6 Player's profile Page

As I said above, if the coach clicks on a player from the list, a new window will open. Here he has permission to add videos and commentaries for each one.

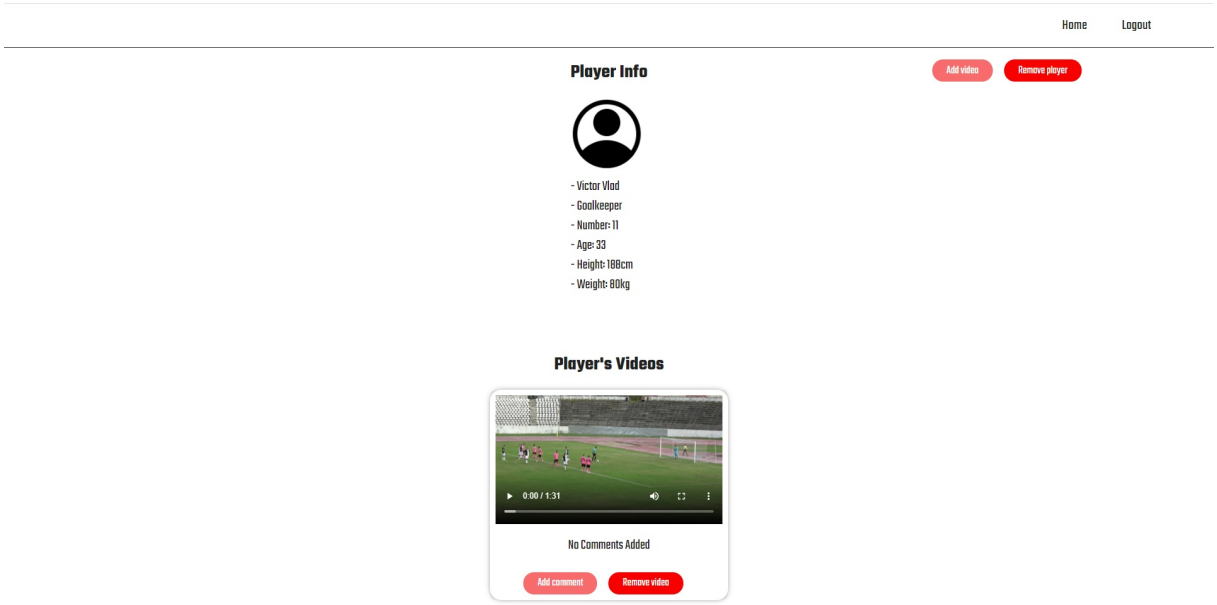


Figure 5.15: Player Info Screen

# Chapter 6

# Conclusion and future work

The system I have developed, based on deep learning for human recognition and ball detection is able to determine the motion vector of the player with the ball and goalkeeper and successfully indicate the correct position of the goalkeeper, its position being the result of the above vectors.

This application may help a lot of young goalkeepers to improve their goalkeeping skills and coaches to always select the right man for the job.

## 6.1 Future work

First of all, an important improvement that could be implemented is a real-time position helper for goalkeepers. This would help them to train correctly when we talk about positioning training, without a goalkeeping coach.

The proposed solution can be extended in the future in the following direction: using a system formed by two or three 360cameras, two loudspeakers placed behind goal's two bars and a computer linked to a raspberry pi can be created a system that helps goalkeepers in real-time.

The cameras will be used to record in real-time a football game or a football training and an algorithm similar to mine will process the video live. The two loudspeakers behind the goal will make sounds based on what the algorithm will result in, such that the keeper will know if his position is right and if it is not, he will know in what direction to go.

This type of system could be a revolutionary one because the need for a coach that gives permanent advice to the goalkeeper in training will no more needed.

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