INSTITUTO POLITÉCNICO
DE VIANA DO CASTELO

INTEGRATED DIGITAL APPROACH FOR ENHANCING SNOOKER PRACTICE AND PERFORMANCE

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Professor Doutor António Miguel Rosado da Cruz

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RESUMO

O Snooker é um dos desportos em mais rápido crescimento do mundo. Com o desenvolvimento tecnológico, clubes e jogadores em todo o mundo precisam de soluções digitais que se integrem perfeitamente com a sua experiência de jogo. No entanto, ao analisar este mercado, chega-se à conclusão de que existem poucos sistemas tecnológicos totalmente integrados.

A nossa proposta consistiu na implementação de uma solução totalmente integrada que permite aos gestores de clubes registar os seus jogadores, criar e gerir jogos e torneios, e depois compilar estatísticas comerciais para os ajudar a conhecer melhor o seu negócio. Por outro lado, os jogadores podem acompanhar os seus resultados e estatísticas, recebendo informações sobre como melhorar o seu jogo, aumentando assim o seu envolvimento com esse clube em particular.

Para o conseguir, foi criada uma aplicação web que vai servir de suporte para um marcador digital e uma aplicação móvel para os jogadores, academias e os seus gestores, que incorpora inúmeras inovações e funcionalidades diferenciadoras.

Este relatório de trabalho de mestrado relata o design e desenvolvimento deste projeto, começando por analisar a investigação atual e as soluções de mercado, propondo uma arquitectura tecnológica e um design de sistema para uma solução inovadora, e terminando com a análise da solução desenvolvida.

Dezembro de 2021

ABSTRACT

Snooker is one of the world's fastest-growing sports. With the advent of technology, clubs and players worldwide need digital solutions that integrate seamlessly with their playing experience. However, when analysing this market, one comes into the realization that there are few fully integrated technological systems.

We implemented a fully integrated solution which allows club managers to register their players, create and manage games and tournaments, and then compile business statistics to help them know their business better. On the other hand, players were able to keep track of their scores and statistics, receiving information on how to improve their game, thus increasing their engagement with that club.

To accomplish this, we created a web application that will support a digital scoreboard and a mobile application for players, clubs, and club managers, which incorporated many innovative and differentiating functionalities.

This master thesis work describes the design and development of this project, analysing current research and market solutions, proposing a technological architecture for an innovative solution, and finishing off with the analysis of the solution developed.

December 2021

Keywords

Application programming interfaces, Mobile applications, Sports equipment

Palavras-chave

Interface de programação de aplicações, Aplicações mobile, Equipamentos desportivos

Agradecimentos

Esta dissertação, mais do que minha, é fruto do empenho de inúmeras pessoas sem as quais não seria possível que esta se materializasse.

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À minha família, que sempre me incentivou e apoiou no meu percurso académico. Eu sei que vos fiz passar uns maus bocados com alguma procrastinação da minha parte… No final, tudo correu bem!

À minha mãe e irmã, sei que torcem muito por mim à distância :)

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Finalmente, o meu enorme obrigado à Catarina. Obrigado por estares sempre do meu lado, me dares os melhores conselhos, me incentivares e motivares ao longo de todo o curso, por seres a melhor pessoa do mundo no geral and for, you know, holding claws!

E para o Artie, woof woof woof woof!

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When all the little ants are marching
Red and black antennae waving
They all do it the same
They all do it the same way

Dave Matthews, 1993

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Introduction

According to the World Professional Billiards and Snooker Association (WPBSA), Snooker is played in approximately 110 countries by over 120 million people, and watched by around 500 million worldwide, being one of the fastest-growing sports on the planet, it is one of the most popular cue games (https://wpbsa.com/about-us/history/full-history/).

Snooker is generally considered a sport with a high difficulty and steep learning curve, usually drawing the attention of devoted players as opposed to casual players. Devoted players are more open to dedicate time and resources to it and, so, have a more urgent need for technological solutions to improve their game.

On one side, there are individual training applications, which provide training plans and exercises to a player, but without a real link to competitive results. On the other side, there are scoring apps, which allow a player to keep track of their scores on an app, but also in an individual way and not providing the feeling one has when playing in a professional setting.

The few integrated technological solutions available in the market are either too expensive, or more directed to tournaments, which poses a difficulty for small to mid-sized Snooker clubs which intend to create a more professional setting.

Taking this into consideration, we will create a web application with a dashboard for the club managers to manage their club's players, games, and tournaments. This web application will expose an API which will then be used by a digital scoreboard for players to score their games in real-time. This API will also feed a hybrid mobile app which players can use to keep track of their scores, tournaments, and statistics, receive information about their strengths and weaknesses and how to improve their game.

Motivation

Since I was a young boy, I remember fondly the nights spent with my father in pool saloons, playing with him and his friends, and bonding over a pool table. With the appearance of the first Snooker tables in Portugal, both him and I have found ourselves fascinated by this amazing sport, and the dream of building a Snooker academy grew inside us.

Somehow, this dream became a reality 4 years ago, and Free Ball - Snooker Academy was founded. To really shine and elevate our academy to a different standard, a big bet was made in the quality of the materials, space, atmosphere and, of course, technology used.

By then, a system for score boarding and managing the academy was implemented, which although being very simple, represented a step up from what people were accustomed to and was a differentiating factor on attracting a diverse and positive group of customers.

With COVID-19 came the impossibility of maintaining the space open, and there was a major setback where the location of the academy had to be changed. This could have been the end of the academy, but fortunately a new space with all the conditions needed was found, and a renewed Free Ball was set to be built. It felt like the perfect opportunity to really move a step up on the digital side of the academy, bring it closer to their customers, and really motivate them to continue practicing and evolving their Snooker.

As such, the development of this dissertation will allow our academy to further evolve, become a flagship academy in terms of technological innovation, and play a part in the recovery of the business side. On the other hand, there are also plans to commercially explore the solution developed, as there is a gap in the market which I believe can be taken advantage of.

Methodology

The methodology that will be followed is Design Science Research (DSR). This methodology was chosen as DSR is focused on investigating "weak" problems. These problems have either unstable requirements and restrictions based on poorly defined environments, complex interactions between the problem sub-components and their solution, the ability to withstand changes to the design process as well as the design of the artifact, or a critical dependence on human cognitive capacities or social skills to produce effective solutions.

Looking at the problems we are trying to solve, it is our conviction that they are "weak" problems, thus fitting in the DSR methodology.

Structure

This chapter presented the motivation and a brief introduction to the topic being addressed in this report. To be improved. The rest of the document is structured as follows:

- Chapter “State of the Art” presents the sport of snooker, describing it and its rules briefly. It also includes our findings about research papers concerning this topic and an extensive analysis of the solutions currently present in the market, to understand the most used functionalities and the gaps in the market where we can innovate.
- Chapter “Requirements Analysis and Modelling” presents our requirements analysis and modelling of the solution. We will study the possible customers of the solution, what are their needs and expectations, derive a feature list, draw mockups of the proposed solution, and then present our final conclusions of this study in the form of use cases as requirements.
- Chapter “Implementation” presents the proposed architecture for it and explains in detail each of the models and their interactions. We will also explain each part of the full system, detailing their innovative aspects, and show screenshots of the functioning system, explaining how it works.
- Chapter “Conclusions” will unravel our conclusions of the project and detail the future work that is still ahead of us.

State of the Art

In this chapter we will present the sport of snooker, describing it and its rules briefly. It also includes our findings about research papers concerning this topic and an extensive analysis of the solutions currently present in the market, to understand the most used functionalities and the gaps in the market where we can innovate.

Snooker

Snooker is a cue sport where players compete in a series of individual games called frames, aiming to score more points in each frame to win it. The goal is to win a set number of frames to win a match. Each frame is played until one player reaches one of several conditions needed, usually by having more points than the ones the opponent has.

Points are scored by potting balls in one of the six pockets available. A 15-red Snooker match (the most usual one) comprises 15 red balls (valued 1 point), 1 yellow (2), 1 green (3), 1 brown (4), 1 blue (5), 1 pink (6) and 1 black (7).

Unlike 8-Ball Pool, a certain order must be respected when it comes to ball potting. Generally, when starting a break, a red ball should be potted first, and only then a “coloured” ball can be potted. When there are no red balls in the table, the coloured balls should be potted in crescent scoring order.

When a player commits a foul, the opponent gets between 4 and 7 points, and depending on the rules in place the player who gets the foul can choose to play, order the offending player to play or repeat the previous play, repositioning all the balls as they were.

The playing field is a 12-foot table which measures 3569 mm x 1778 mm (almost a 2:1 proportion). The pockets are placed in the four corners, plus two on the centre of the longest sides of the table.

Research

The first electronic billiards and snooker scoreboards were patented in the 1980s and 1990s[i]. Since then, and with the development of computing and electronics, more technological systems have been devised to improve the players' experience.

Systems have been designed to objectively measure a players’ skill, such as the one devised by Chung et. al (2014)[ii].

Some technologies exist for the automatic scoring of billiards games, such as RFID, proposed by Teng et. al, (2011)[iii], or for the tracking of balls in a billiards table, as proposed by Mathavan et. al (2009).

PoolLiveAid is a system devised by Alves et. al (2013)[iv] which allows the real time projection of the ball trajectory on a pool table, aiding inexperienced players in their first approach to the game.

Other AR systems to aid learning and shot potting exist, such as the one proposed by Uchiyama and Saito (2008)[v].

Legg et. al (2011)[vi] reconstructed the snooker table in 3D, using video feed. This kind of software is used for TV broadcasts.

The research and solutions about snooker and billiards scoring are almost non-existent, and that is what our work will focus on.

Market

We will begin by analysing some of the most popular solutions currently in the market for Snooker scoring, statistical analysis, tournament management and/or training.

We will begin by analysing some of the most popular solutions currently in the market for Snooker scoring, statistical analysis, tournament management and/or training.
We will split them in four main groups:

- **Score boarding solutions**, which are focused mainly on offering a way for players to score their matches.
- **Training solutions**, which are focused primarily in aiding a players' training, providing routines and counselling.
- **Tournament management solutions**.
- **Complete solutions**, which integrate most or all the main features of each of the three first groups.

Score boarding solutions

Here we will focus on solutions which are mainly concerned with providing a platform for players to score their matches, and showing those scores on a device - PC, Tablets, TVs, or Smartphones.

ProScore

This is the most complete solution in the market in terms of Snooker score boarding. Although there is no official confirmation, the similarity with the solution used by most professional tournaments is striking, which suggests that this is the software used by them.

Website

https://147snooker.net/

Requirements

- ProScore software must be installed in a computer running Windows.
- Connection to the internet for live scoring is needed.
- The scoreboard is designed for XGA resolution, at 1024x768 pixels. If the screen it is displayed on has a higher resolution than this, black borders may appear.
- Each table must run its own software.

Scoreboard functionalities

Scoring can be made in two different ways:

- Casual Mode, where the referee enters the points when a break is finished and there is no need to set up match details.
- Formal Mode, where the referee enters the points every time a ball is potted, and the match info is set up as desired.

Controlling the scoreboard can be made using the keyboard, mouse, a smartphone, or a customized handheld remote controller, provided by them.

An interesting feature is that scoring with the smartphone can be made without installing any app. The remote control is accessed through a web browser if the phone is connected to the same network as the scoreboard.

Figure 1 - ProScore - Different ways to control the scoreboard

In terms of rules compliance, ProScore can handle all common rules, including foul and free ball situations, handicap points and black ball games.

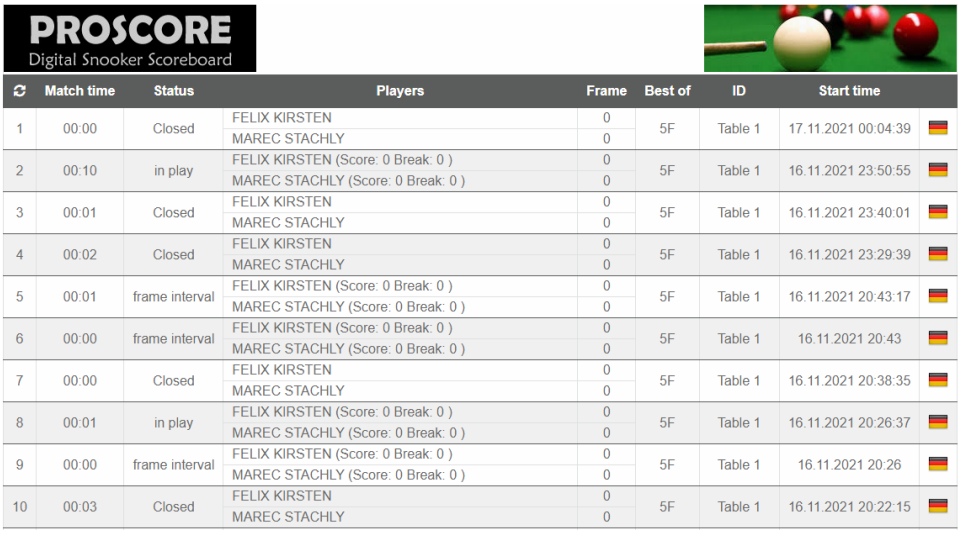
Users can check the frame/match clocks, see the remaining ball count and points, match status, high breaks.

More functionalities of the scoreboard are the ability to undo, re-rack, concede a frame and restore sessions, as well as being connected with a live-scoring system.

The scoreboard is designed for XGA resolution, at 1024x768 pixels. If the screen it is displayed on has higher resolution than this, black borders may appear.

Web application functionalities

ProScore has a web application, available in any modern web browser, to see the matches being played and remotely control the scoreboards.



	Match time	Status	Players	Frame	Best of	ID	Start time	
1	00:00	Closed	FELIX KIRSTEN MAREC STACHLY	0 0	5F	Table 1	17.11.2021 00:04:39	
2	00:10	in play	FELIX KIRSTEN (Score: 0 Break: 0) MAREC STACHLY (Score: 0 Break: 0)	0 0	5F	Table 1	16.11.2021 23:50:55	
3	00:01	Closed	FELIX KIRSTEN MAREC STACHLY	0 0	5F	Table 1	16.11.2021 23:40:01	
4	00:02	Closed	FELIX KIRSTEN MAREC STACHLY	0 0	5F	Table 1	16.11.2021 23:29:39	
5	00:01	frame interval	FELIX KIRSTEN (Score: 0 Break: 0) MAREC STACHLY (Score: 0 Break: 0)	0 0	5F	Table 1	16.11.2021 20:43:17	
6	00:00	frame interval	FELIX KIRSTEN (Score: 0 Break: 0) MAREC STACHLY (Score: 0 Break: 0)	0 0	5F	Table 1	16.11.2021 20:43	
7	00:00	Closed	FELIX KIRSTEN MAREC STACHLY	0 0	5F	Table 1	16.11.2021 20:38:35	
8	00:01	in play	FELIX KIRSTEN (Score: 0 Break: 0) MAREC STACHLY (Score: 0 Break: 0)	0 0	5F	Table 1	16.11.2021 20:26:37	
9	00:00	frame interval	FELIX KIRSTEN (Score: 0 Break: 0) MAREC STACHLY (Score: 0 Break: 0)	0 0	5F	Table 1	16.11.2021 20:26	
10	00:03	Closed	FELIX KIRSTEN MAREC STACHLY	0 0	5F	Table 1	16.11.2021 20:22:15	

Figure 2 - ProScore - Web application live scoring view

The user can see a table with current and past matches in columns and rows, as well as select one of multiple views:

- Single Match View: the current frame in progress.
- Multi Match View: multiple matches displayed in a quad view.
- Scoreboard View: single view that looks very similar to the scoreboard.

Pricing

ProScore one-off lifetime license costs £279 (approximately 310€), including optional setup of dedicated Live Scoring web pages that synchronise to your scoreboard. There are no additional ongoing charges for hosting, technical support, or upgrades. Each scoreboard counts as one fee.

Conclusions

ProScore is a very complete solution in terms of Snooker score boarding, and most of the functionalities they offer are the ones needed for a solution of this kind.

The different modes of scoring a match, ways of controlling the scoreboard and implementation of all Snooker rules are a plus, as well as being able to see all the matches going on in the academy through multiple different views.

Although ProScore offers a complete solution for scoring matches, it does not offer a way for players to access their results in an intuitive way, review their stats or any other functionalities needed for it to be a complete solution. It is purely a Snooker scoreboard solution for Snooker clubs and tournaments.

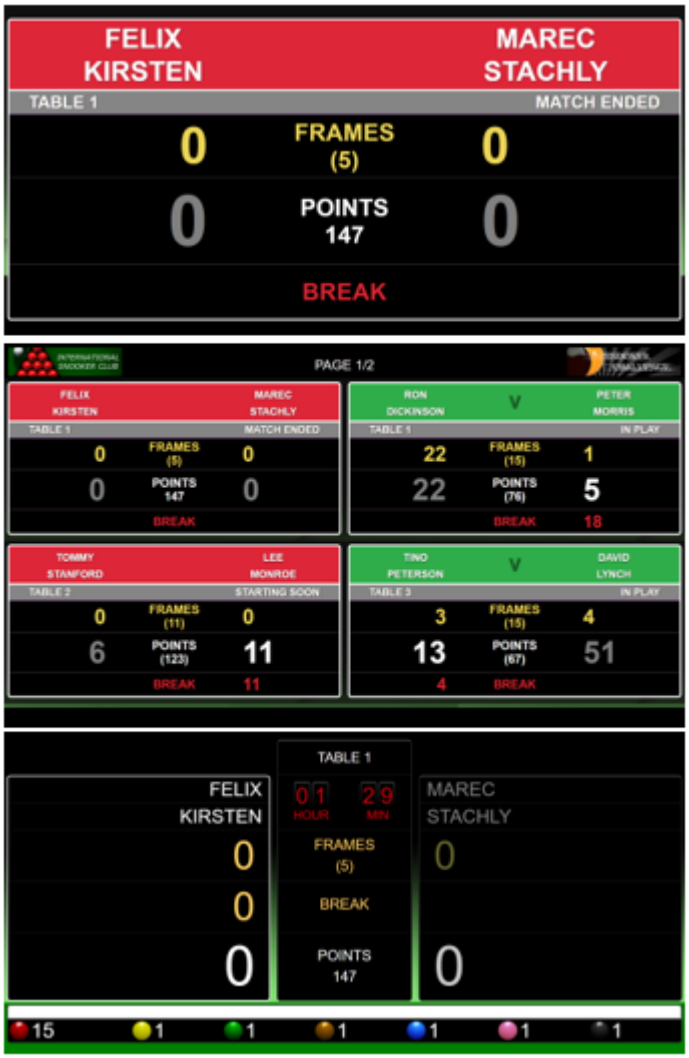


Figure 3 - Multiple scoreboard views

Also, the fee of 310€ per table, and the requirement of running each scoreboard in a Windows operating system can be expensive for small clubs with few members.

Finally, the interface of both the software and the website feels outdated - for example, the scoreboard not being responsive and optimizing for such a low resolution such as XGA - and can be more intuitive and modern.

BallStream

BallStream is a scoreboard for cue sports, which is available for free. It distinguishes itself from others, by its low barrier to entry.

BallStream features a:

- Scoreboard for Snooker, Billiards and Pool (for Windows).
- Scoreboard and Live Scoring Online.
- Drawsheet Maker (seeded draws).

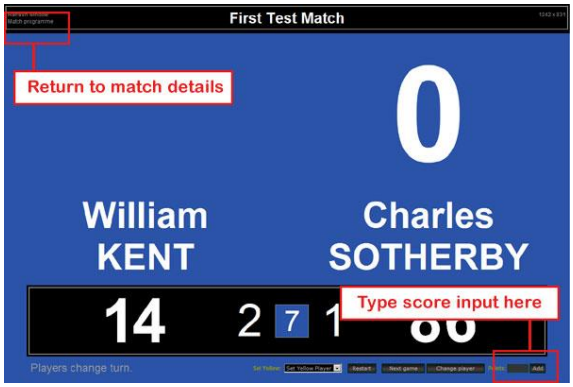


Figure 4 - BallStream - Scoreboard UI

Our analysis was focused on the Windows software, as we felt that the online scoreboard was too flawed and lacking in interesting features.

Website

http://ballstream.com/

Requirements

BallStream requires the following:

- The software must be installed on a Windows operating system.
- Connection to the internet for live scoring is needed.
- Each table must have its own software installed.

Functionalities

The software features an editable tournament and players list, which then can be used to create a match.

The first break only needs to be set once (for the first frame) and the software will automatically rotate the player to break for the next frame.

Scoring a match can be made by using a keyboard, number pad or wireless number pad. There are no functionalities for scoring ball by ball or any rules compliance, being only possible to score break by break.

The software validates, at the end of each frame, if there are conditions for a new frame to start. It also detects if a set number of frames won was achieved by any player and will automatically decide the winner of the match if so.

When each match is finished, the software will evaluate the results and update the player's ranking points accordingly.

The software also features the following functionalities:

- Writing and sending newsletters.
- Setting handicaps.
- Printing and exporting match records.
- Performance recording and statistics.
- Yield statistics.
- Recording breaks.
- History.

Pricing

This solution is available for free.

Conclusions

BallStream is an interesting free solution for scoring matches, including some interesting statistical functionalities. Also, the scoreboard visuals are good, like ProScore.

However, there is no easy way for the players to see their own statistics, not being a truly interactive solution. Also, the scoring part is very simplified, enforcing very few rules and not allowing a ball-by-ball scoring, and there is no way to score a match using an app, so it all must be used using a physical keyboard.

Like ProScore, it also requires a Windows operating system device per each table, which can be expensive.

Snooker: Scoreboard

Snooker: Scoreboard is one of the most popular apps for Snooker score boarding. It has the most basic functionalities for scoring a snooker match, being mentioned here as it is a good example of simplicity and ease of use.

Website

https://play.google.com/store/apps/details?id=com.x10devs.snookerscore

Requirements

- Device running Android / iOS.

Functionalities

Scoring is achieved on a ball-by-ball basis, with the app keeping a record of match statistics.

Other functionalities included are:

- Casting the scoreboard to a TV via Chromecast.
- Viewing previous game history
- Daily challenges

Pricing

This app is available for free.

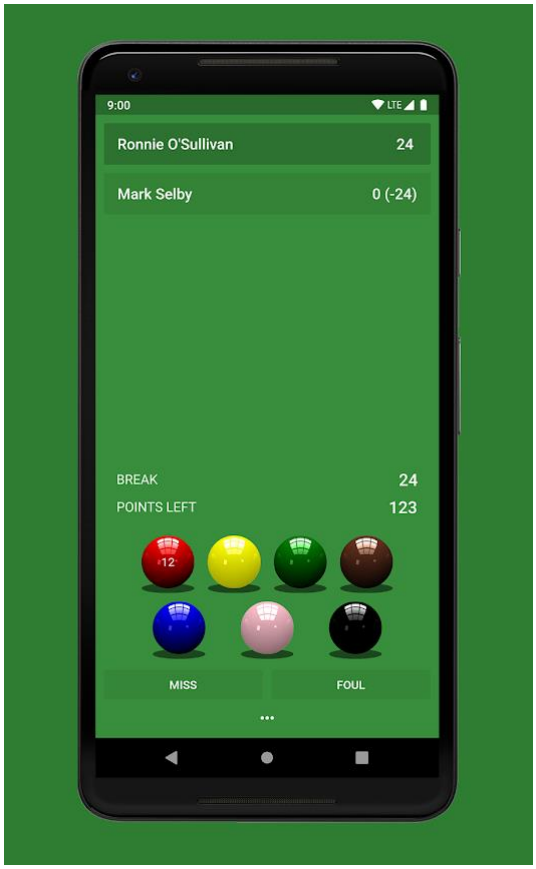


Figure 5 - Snooker: Scoreboard UI

Conclusions

It is an example of a simple app with the minimal scoring functionalities, a good user interface, and an interesting functionality of providing daily challenges to keep the user engaged.

Training solutions

Here we will focus on solutions which are mainly concerned with improving a player's game, providing training routines and personalized counselling.

Snooker Coach 147

Snooker Coach 147 provides multiple training routines and plans, allowing a player to train alone and track their progress.

Figure 6 - Snooker Coach 147 - UI

Website

https://play.google.com/store/apps/details?id=net.hixfield.snookercoach

Requirements

- Device with Android 8+ or iOS

Functionalities

One of its most interesting features is the ability to use augmented reality to help position the balls in the table where they should be for each exercise.

This app also offers the possibility of keeping track of your frame scores and breaks - not as a scoreboard, but as a log after the match. It also allows the option of registering one's state of mind and luck in each frame. Results can then be shared with other players who also have the app to "link" them both to that match.

Besides having a multitude of training routines for the player to focus on, Snooker Coach 147 also provides a functionality which allows the user to create their own custom practice routines and sessions.

Each training session can be logged into the application, which then compiles detailed statistics on each one. Relevant records are highlighted and can be shared on social media.

Besides the more training-focused functionalities, Snooker Coach 147 also features home screen widgets with relevant statistics, social interaction, and a detailed match log, where even the confidence/luck level per player can be logged.

Pricing

The application is free, with in-app purchases ranging from 3,09€ to 7,99€ per item.

Conclusions

In our opinion, this is the application which sets the benchmark in terms of Snooker training and improvement. The augmented reality, extremely attractive and intuitive user interface and social components make this a very engaging app. The app also features unique functionalities, such as widgets for the phone home page and confidence/luck level log per match, which add value to it. Finally, the training routines are varied, and it is easy for the user to follow its progression.

Figure 7 - Snooker Coach 147 - Differentiating functionalities

Tournament management solutions

Here we will focus on solutions which are mainly concerned with creating and managing tournaments with different formats.

Playpass Snooker Solutions

Playpass offers tournament scheduling and management for multiple sports, being Snooker one of the included ones. It focuses entirely on the management of tournaments, offering a very complete solution for this problem.

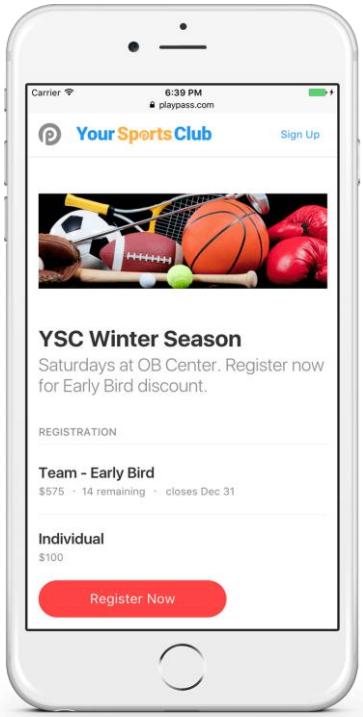


Figure 8 - Playpass Snooker Solutions - Mobile App UI

Website

https://playpass.com/sports-software/snooker-management

Requirements

- Device with access to the internet.

Functionalities

- Create and share snooker schedules for leagues and tournaments.
- Update scores and track standings online.
- Accept online snooker registrations and payments.
- Gather player info and offer discounts or promotions.
- Reward members for inviting their friends.

- Create referral programs with automatic tracking and rewards.
- Collect signed snooker waivers, liability forms, and completed documents.
- Access and store them securely.
- Create a responsive website for the tournament.

Pricing

The personal plan is free, with a 3% fee for online payments. It includes one schedule with online scoring, one waiver with online signatures, one custom website page and one manager with online access. The business plan costs 15,20€ / month, plus a 1,75% fee on online payments. It includes everything from the personal plan on an unlimited way.

Conclusions

From all the tournament management solutions analysed, this was the one which seemed the most interesting in terms of functionalities, pricing plan and user interface.

The most interesting differentiating functionality of this solution is the automatic creation of a website for each competition.

Of course, being a solution focused mainly on tournament management, it lacks many aspects that a full solution for this problem should feature, such as having a scoreboard for scoring matches.

Complete solutions

These are solutions that combine most, or all the functionalities of the ones analysed before. Our project would be inserted in this category.

CueScore

This solution allows the creation and management of cue sports organizations (such as Snooker), featuring the creation and management of tournaments and leagues, digital score boarding via tablets, professional look and feel of stream overlays of the scores, and online payment of events directly in the software.

Figure 9 - CueScore - Scoreboard UI

Website

https://cuescore.com/

Requirements

- Device with access to the internet (Android or iOS in case of using the digital scoreboard)

Functionalities

- Tournament and league management, for both singles and team's tournaments.
- A page to publish brackets/schedules, tournament history, tournament calendar, rankings, news & articles.
- Digital scoreboards let players keep track of their score. Brackets and stream overlay are automatically updated in real time.
- Connect tournaments/leagues to an online broadcast. Present statistics, scores and match info using our stream overlay in your preferred streaming software.
- Online payment solution.

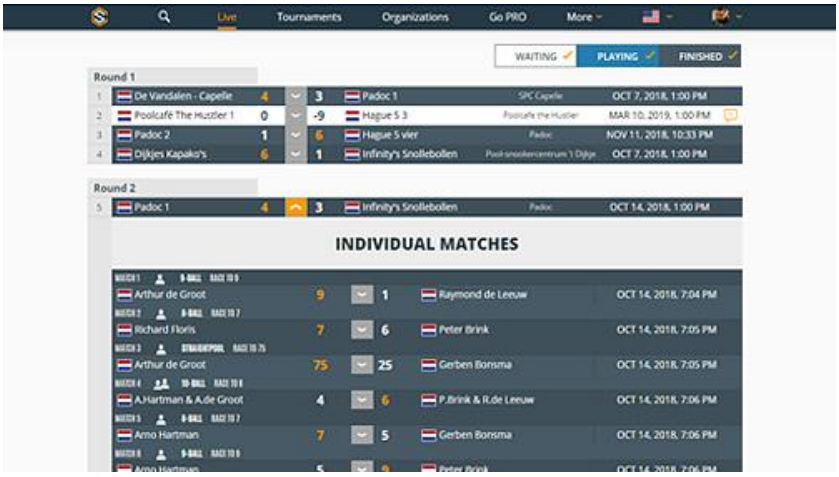


Figure 10 - CueScore - Web application live scoring page

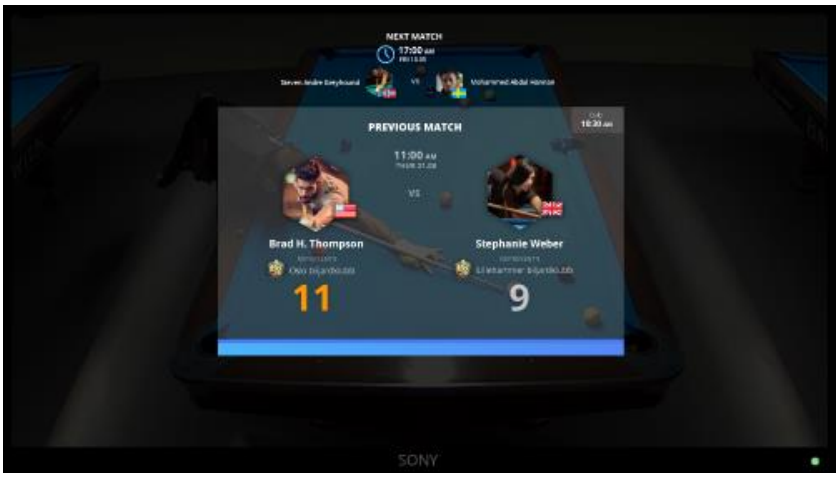


Figure 11 - CueScore - Live streaming overlay

Pricing

The free account allows the creation of player profiles and setting up matches, in a very basic way. The Pro account includes all functionalities mentioned above, and costs 29€ / month or 225€ / year.

Conclusions

CueScore offers most functionalities needed for club managers and for tournament and event management, in a simple, user-friendly way.

However, it lacks a true interaction with the players, offering few statistics about their performances. The scoreboard is also very basic, allowing for few scoring options. For small and medium sized academies, the cost of the system can also be a bit too much.

Snooker Score Counter

Snooker Score Counter is an Android app which allows the scoring of matches, provides match and player statistics and a training tool with routines and plans.

Website

https://play.google.com/store/apps/details?id=com.advanetsystems.snooker

Requirements

- Device with Android.

Functionalities

- Score counter.
- Graphic scoreboard.
- Match tracker.
- Match statistics.
- Player statistics.
- Training tool with predefined practice routines and player progress on chart.
- Player progress statistics.

Conclusions

It provides a complete solution for players, as it allows them to score their matches, receive feedback about their game through statistics, and then use the training routines to improve their game. However, it doesn’t feature any functionalities for clubs and club managers, being only focused on the player.

Figure 12 - Snooker Score Counter - Scoreboard and remote-control UI

SnookerScores

This is a solution which is being sponsored by WPBSA. It intends to become a ‘one-stop shop’ for amateur snooker and be available for both regional and national organisations, as well as at club level.

It has been developed since 2019 by the same developers of CueTracker and so far, it is not commercially available for public use.

Website

https://snookerscores.net/

Requirements

- Device with access to the internet.

Functionalities

- Individual page for each organization and tournament.
- Pages for list of players, live scores, results, groups, knockout, breaks and schedule per competition.
- Individual page for each player.
- Live stream with overlay.

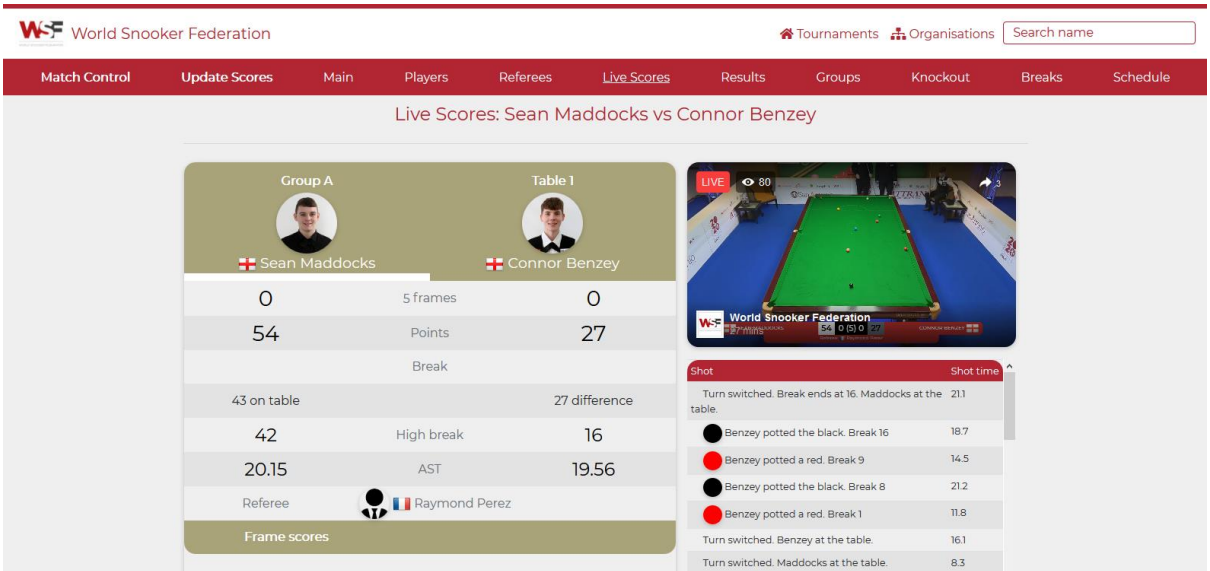


Figure 13 - SnookerScores - Page with the live score of a match

Conclusions

Although it is yet not fully developed nor available, SnookerScores has the potential of being the main competitor to our solution. The fact that it is being developed by one of the main organizations in Snooker, in partnership with one of the most well-known statistics websites (CueTracker), with the goal of being the main solution for amateur club owners is a threat to our solution.
However, there are multiple improvement points which we can take advantage of:

- This solution seems very focused on tournaments, which do not compose most of the daily life of a Snooker academy.
- The UI is not very attractive nor modern.
- The website is responsive, but it does not have a “native” feel.

MySnookerStats

MySnookerStats is an interesting scoring app. It compiles a lot of match and player statistics in real time, presenting them to the user and giving feedback about their game’s strengths and weaknesses.

Website

https://www.mysnookerstats.com/

Requirements

- Device running Android / iOS.

App Functionalities

Scoring is made on a ball-by-ball basis, and there are two different input modes: a standard mode and a professional mode, where there is the possibility to include more data for each shot taken (distance, type of missed shot, custom foul type…).

The app enforces rules compliance and allows for the input of all relevant information regarding a shot.

The scoreboard includes a complete compilation of match statistics, which then can be seen on the website after registration.

Website functionalities

All the matches made by a registered user are visible on the website. On the website, the following statistics are available:

- Rating score.
- Form guide.
- Game quality variation.
- Break building.
- Frame history.
- Average statistics by frame.
- Special rating called “My Break Power”, representing how many frames on average does it take to make 20+, 30+, and more, breaks.

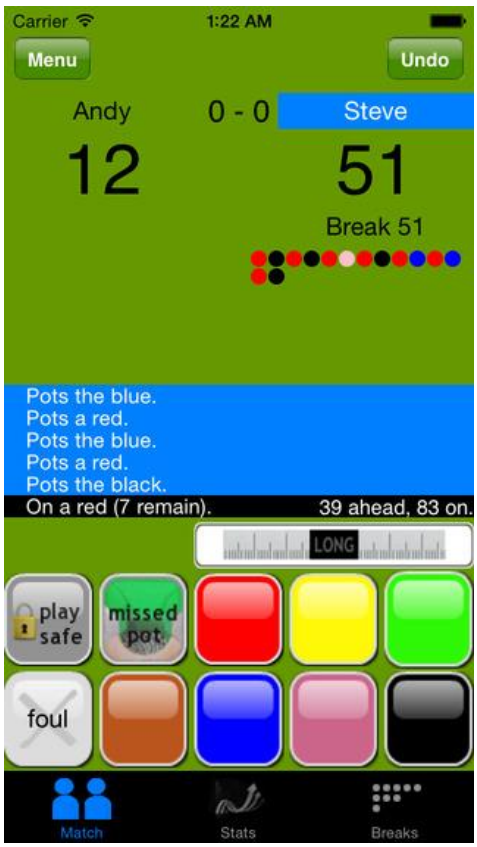


Figure 14 - MySnookerStats - Scoring UI

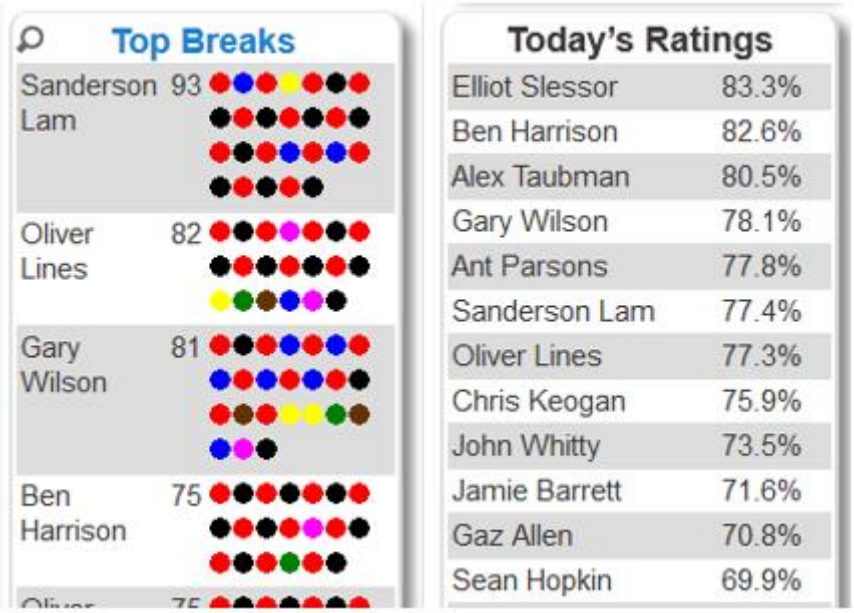


Figure 15 - MySnookerStats - Statistics and leader boards

The website also features some social aspects, with the possibility of adding friends and creating groups. These groups form mini league tables, allowing for comparison between each other.

Tournaments

MySnookerStats has a separate feature allowing the organization and running of snooker tournaments.

The main functionalities of this feature are:

- Management of registered players.
- Set up handicapped or straight knockout tournaments.
- Split players into groups for an initial stage.
- Keep track of all players' performance levels and top breaks, both on the day, and their complete career record for all your tournaments in the future.
- Algorithm that suggests fair handicaps.

Pricing

This app is available for free, with a premium plan available for £9.99 (~11,89€) / year.

For the tournament functionality, there are three pricing plans:

- £19.99 (~23.78€) / month - basic tournament access and administration.
- £49.99 (~59.44€) / month - with live scoring and season summaries.
- £99.99 (~118.90€) / month - with live streaming and website integration.

Conclusions

MySnookerStats is a very complete solution in terms of scoring matches on a mobile device. It is also very complete in terms of the statistics offered, especially in the premium plan, and it sets the benchmark in this aspect, allowing for a self-evaluation of the players.

It is interesting also in the social part, by offering the possibility of adding friends and seeing their information.

On the other hand, the user interface of both the app and the website feels outdated, not very responsive nor attractive.

The tournament functionality makes MySnookerStats into an almost complete solution. However, there is no functionality for showing the scores on an external monitor, with players limited to scoring and seeing the score in the same display. Also, this solution can be somewhat expensive for small and medium-sized academies.

Conclusions

This research was essential to lay out the foundations of our work.

By understanding the game of Snooker and studying the research work which was already done we were able to better grasp the problem in hands.

The market study was essential to analyse what solutions are already available, which functionalities and differentiating factors they have and how they are monetized.

Below we present two tables with a summary of the conclusions of the market study.

Name	Solution Group	Differentiating Factors	Requirements	Scoreboard		
				Rules compliance	Remote control	Additional features
ProScore	Score boarding	Multiple match views	Windows OS	Complete	Complete	Yes
BallStream	Score boarding	Free	Windows OS	No	Yes, not included	Few
Snooker: Scoreboard	Score boarding	Daily challenges	Android / iOS device	Yes	Yes	Few
Snooker Coach 147	Training	Screen widgets, detailed match log	-	-	-	-
Playpass Snooker Solutions	Tournament Management	Automatic website creation for tournaments	-	-	-	-
CueScore	Complete	None	Device connected to the web	Yes	No	Few
Snooker Score Counter	Complete	None	Android	Yes	No	Few
Snooker Scores	Complete	Support from official governing body	Device connected to the web	Yes	No	Few
MySnookerStats	Complete	Innovative statistics	Android / iOS device	Yes	Yes	Few

Table 1 - Summary of the market study - Part 1

Name	Application						
	Profile	**Match management**	**Tournament management**	**Statistical analysis**	**Training tools**	**Interaction between players**	**Social interaction**
ProScore	No	Basic	No	No	No	No	No
BallStream	No	No	No	No	No	No	No
Snooker: Scoreboard	Yes	Yes	No	No	No	No	No
Snooker Coach 147	Yes	Yes	No	Yes (training)	Complete	Yes	Yes
Playpass Snooker Solutions	Yes	Yes	Complete	No	No	Yes	Yes
CueScore	Basic	Yes	Yes	No	No	Basic	Basic
Snooker Score Counter	Yes	Yes	No	Yes	Yes	No	No
Snooker Scores	Basic	Yes	Complete	Yes	No	No	No
MySnookerStats	Yes	Yes	Yes	Complete	No	Yes	No

Table 2 - Summary of the market study - Part 2

In this table, the labels have the following meaning:

- No – Does not implement the feature.
- Basic – Implements the basic/minimum functionalities of the feature.
- Yes – Implements the feature.
- Complete – Implements the feature and offers even more added value / differentiating characteristics to it.

Requirements analysis and modelling

In this chapter we will detail how the application's functionalities and user interface have been developed.

An essential differentiating factor we wanted to implement in our project is an extreme attention to user experience and user interaction. As such, much work has been made to understand the needs of the users and how they would like to interact with the system.

To achieve this, besides exploring in detail the most used existing solutions, we focused on using some UX/UI tools to assist us in developing our solution, by creating personas, user scenarios, conducting exploratory interviews, creating user stories, and drawing the initial mockups for evaluation.

The conclusions of this work led to a second phase, where there was a shift in focus and a redesign of the mockups, which have also been evaluated.

Personas

According to Adobe (2021)[vii], a persona is a concise and visual description of an archetypical user of a system, exemplifying the kind of person who would interact with it.

For our system, we defined four different personas, each with their unique characteristics, being a representation of the users of the solution based on the academy members.

Name	**João Silva**	**Paulo Alves**
Age	23	62
Address	Braga	Porto
Professional Life	Student at Minho University. Currently on the last year of Mechanics Engineering	Retired 3 years ago, Paulo is a former banker.
Social Life	Lives in Braga with 2 other friends. Comes to Porto on the weekends.	Lives with his wife. Being retired, has plenty of free time, spending a lot of time in the academy.
Expectations for the academy	Intends to be the best Snooker player in Portugal, win federated competitions and be present in international competitions punctually.	Plays just to have fun with his friends. Enjoys the environment of the academy.
End goals for the system	Wants to be able to follow the academy's activities from afar.	Uses the system mainly to score its matches and share his results with his friends.
Experiential goals	To feel more connected with the academy, even being far away.	Not being very technologically proficient, needs the system to be very simple and intuitive.
Type	Secondary	Secondary

Table 3 - Personas (Part 1)

Name	Mario Silva	António Pereira
Age	45	67
Address	Viana do Castelo	Porto
Professional Life	Electrical Engineer, with 20 years of experience.	Manager of Free Ball Snooker Academy
Social Life	Lives with his wife and young daughter. Is a true enthusiast of Snooker and spends some time in the academy.	Lives alone in Porto, devoting most of its time to managing the academy and delivering Snooker training.
Expectations for the academy	Loves Snooker and wants to improve his game. Is a player who has been evolving quickly, by studying his game, statistics, and practicing consistently.	Wants the academy to grow consistently, using technology to improve the experience of its members.
End goals for the system	Intends to use the system heavily, taking advantage of all features related to scoring and statistics.	Needs a tool to manage its academy and which his members enjoy using.
Experiential goals	Wants a system which is efficient, intuitive, and accessible in multiple devices.	Not being very technologically proficient, needs the system to be very simple and intuitive.
Type	Primary	Secondary

Table 4 - Personas (Part 2)

User scenarios

According to The Interaction Design Foundation (2021)[viii], user scenarios succinctly and explicitly capture what users would likely experience as they proceed toward using an ideal solution.

For each persona, a user scenario was created to further improve our perception of how the users of the system would like to interact with it.

João Silva

João is taking his exams and for that reason stayed in Braga on the weekend so he could study with his colleagues. Unfortunately, it coincided with the final of a tournament organized by Free Ball, in which he would really like to be present. During the study breaks João constantly updates the results of the game that is going on.

Unable to stand the emotion, the game being very close and with few points on the table, João opens the application and turns on the live stream of the game and manages to see the last minutes, being very happy with the performance of his colleagues!

Seeing the great game that both finalists played, he quickly needed to check the Academy Records to make sure that the best Break was still his, and he could breathe a sigh of relief when he saw his name in first place.

Paulo Alves
At a family dinner, Snooker started to be on TV. It was the perfect opportunity for Paulo to talk about his new hobby and the Academy. His children were curious to know more about the sport and Paulo was ready to explain it to them!

While talking about the Academy he opened the application and showed them a profile of the national champion João Rocha and his glorious victory over him last week. A close frame, where Paulo enthusiastically showed each ball that he pocketed. Paulo also wanted them to know how good he was, showing them his rating as a player and how much he had evolved.

But as soon as they picked up the app and explored a bit, the kids found out that their father's rating was not that high and that his victory was the only one in 40 games played... Nothing that affected the good mood!

Mario Silva
Mario is in a phase where he feels he needs a little more to be a player with another level. In the federated competitions he has been able to play competitively against all players, failing in detail. Today he woke up wanting to improve, so he decided to look at the detailed statistics of his game in the last month in his application.

He noticed that although during the game you managed to be competitive, in the final sequence he became more fallible, letting games slip away at the end. He can also see that he has a more negative record in direct confrontation with more defensive players, who attack fewer balls and wait more for the opponent's mistake.

So, he decided to schedule a game against one of the members with whom you had more difficulty to try new techniques.

During the game he was able to use the full solution by noting all the details of the match on the app and seeing his score on the scoreboard.

António Pereira
António is the manager of Free Ball Snooker Academy and is looking to create a new tournament for their members to play. After deciding on the format, he goes to the application to create it, sending an alert to all members that this new competition is available.

He then receives a phone call from an old friend who wants to go to the academy and try Snooker for the first time. Happily, he creates his friend’s user profile in the application and goes off to prepare the table for them to play.

While he is playing, he referees his own match using a customized keyboard provided with the scoreboard, which really catches the attention of his friend! He then proceeds to show him how he can also score their match using an IR remote or the application.

At the end of the day, António decides to check in the application how many people were in the academy today and how much time was spent in each table, comparing those values with previous days and weeks. Today was a good day!

Exploratory interviews

To gather more information about the expectations of future users of the application, exploratory interviews were conducted with four members of Free Ball - Snooker Academy, representative of each of the personas defined.

Opting for an unstructured interview, some open questions were asked to understand what the interviewees expected or would find useful to be implemented in the application.

The following list of ideas and features emerged:

- Personal statistics.
- Pot success.
- Information about breaks.
- Positional shot statistic.
- No. of long/short balls and success rate.
- Percentage of defensive shots.
- Pro/Amateur version for the scoring functionality in the application.
- Direct confrontation of players.
- How many times they have played.
- Comparison of statistics.
- Statistics by time (e.g., every month or week).
- Tournaments - Real time results.
- Streaming (authorized by both players).

The users also reflected on the existing Snooker applications. They all agreed that, although they all have plenty of useful functionalities, there is not one application which gathers everything that they would like to see in a truly integrated application, for a reasonable price range.

This brainstorming was extremely useful to validate the expectations of the end users and to arrive at a list of requirements. Also, there were some innovative functionalities that arose from this brainstorming, such as the automatic generation of video highlights and gamification, which could be implemented to increase the engagement of the users with the app.

User stories

According to Cohn (2021)[ix], user stories are short, simple descriptions of a feature told from the perspective of the person who desires the new capability, usually a user or customer of the system.

Taking all the previous information into consideration, the following user stories were created:

As a **player**, in the **application**, I want to be able to:

- Check my statistics, such as Pot Success, Breaks, Positional Shot, Percentage of Defensive Moves, Frames, number of long/short balls, etc.

- Check information and results about my games.
- Score my matches through a built-in controller.
- Choose between the professional or amateur version for the scoreboard (simple scoreboard or with more features).
- Compare myself to another player of the academies I am registered, know how many times we played, compare statistics, ranking, etc.
- Check the results of games that are currently in progress, with the authorization of the respective players.
- Watch the streaming of the games taking place in the academies I am registered, with the authorization of the respective players.
- Check the tables and results of internal tournaments or tournaments that I am participating, or public tournaments in the academies I am registered.
- Check the quantitative rating of my quality as a player.
- View the profile and public information of other members of the academies I am registered.
- View the ranking and records of the academies I am registered.

As a **manager**, in the **application**, I want to be able to:

- Check all the matches that are being played.
- Check all the matches which have been played in the past.
- Be able to correct scores of present and past matches.
- Create, edit, and delete players.
- Create, edit, and delete competitions.
- Create, edit, and delete matches.
- Check statistics related to the academy.

As a **referee**, in the **application**, I want to be able to:

- Score matches through a built-in controller.
- Choose between the professional or amateur version for the scoreboard (simple scoreboard or with more features).

As a **player**, in the **scoreboard**, I want to be able to:

- Create a new match.
- Load a previously created match.
- See the score of my match in the screen.
- See statistics at the end of each frame and at the end of the match.
- End match.

As a **referee**, in the **scoreboard**, I want to be able to:

- Score matches through an IR remote, a personalized keyboard or the application.

Note: in most cases, the players are also referees of their matches, so the user requirements for both are intertwined.

Initial Mockups

Finally, considering the goals of the project, and to materialize them in a more visual way, some mockups of the mobile application and the scoreboard were made.

The mockups here presented exemplify the application flow for all users who are not academy owners (as academy owners would have access to a few more functionalities regarding their academy),

The design of the mockups was envisioned taking into account the intended user base, using the personas. Being the primary user someone older, with some but not a lot of experience using technology, that wants to improve their Snooker training and performance, we aimed at providing a simple and well-known method of navigating through the application and providing all the information in a simple, clear way.

The exploratory interviews and user stories directly influenced all the functionalities presented, and how the users would interact with them.

Mobile Application

Figure 16 - Mobile app mockups - Login pages

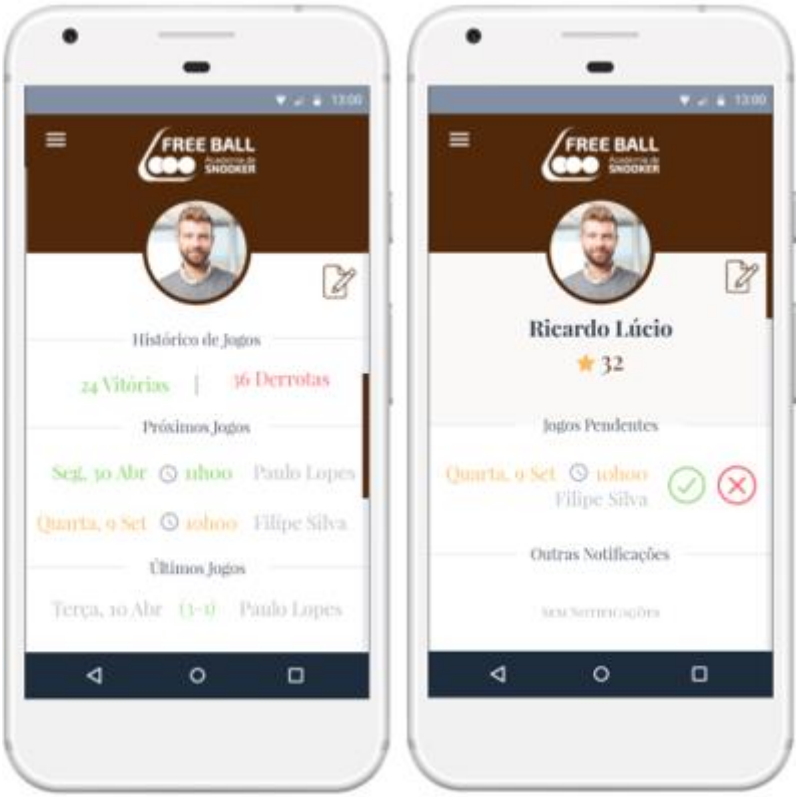


Figure 17 - Mobile app mockups - Profile page

Figure 18 – Mobile app mockups - Profile of another user

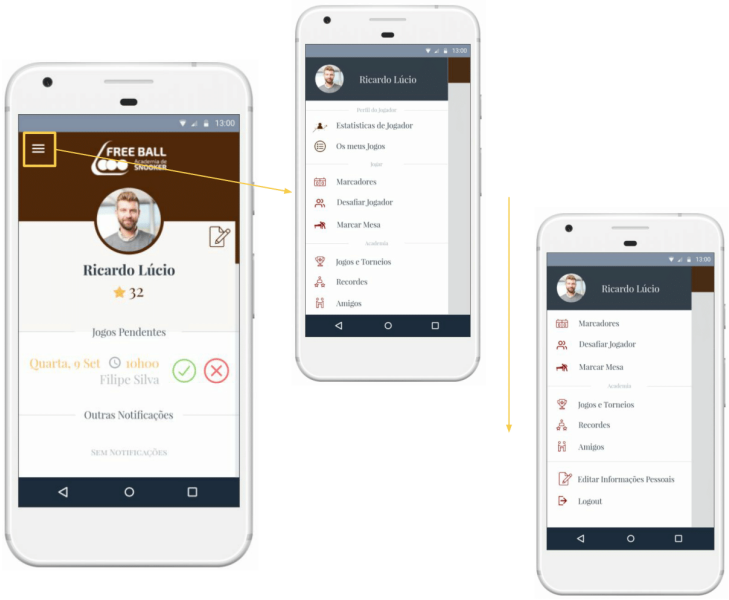


Figure 19 - Mobile app mockups - Hamburger menu navigation

Figure 20 - Mobile app mockups - Player statistics and match calendar

Figure 21 – Mobile app mockups - Scoreboard control

Figure 22 - Mobile app mockups - Live matches

Figure 23 - Mobile app mockups - Competition main page

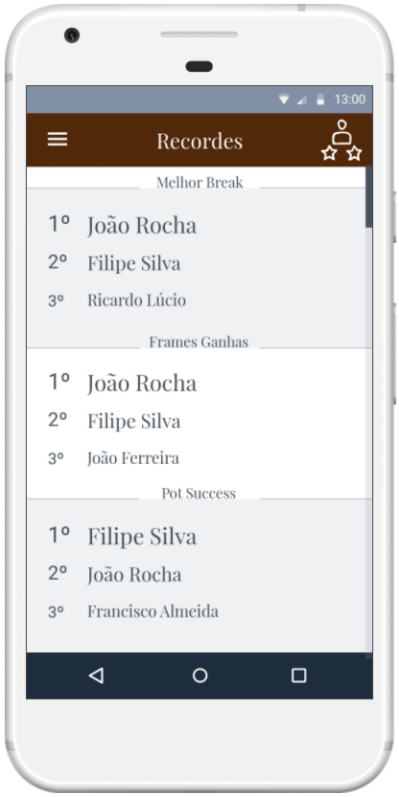


Figure 24 - Mobile app mockups - Leader boards

Scoreboard

For the scoreboard, the following mockups were produced. These represent the implementation of the actual scoreboard in a very realistic way.

Figure 25 - Scoreboard mockups - Main screen

Figure 26 - Scoreboard mockups - Match screen (1)

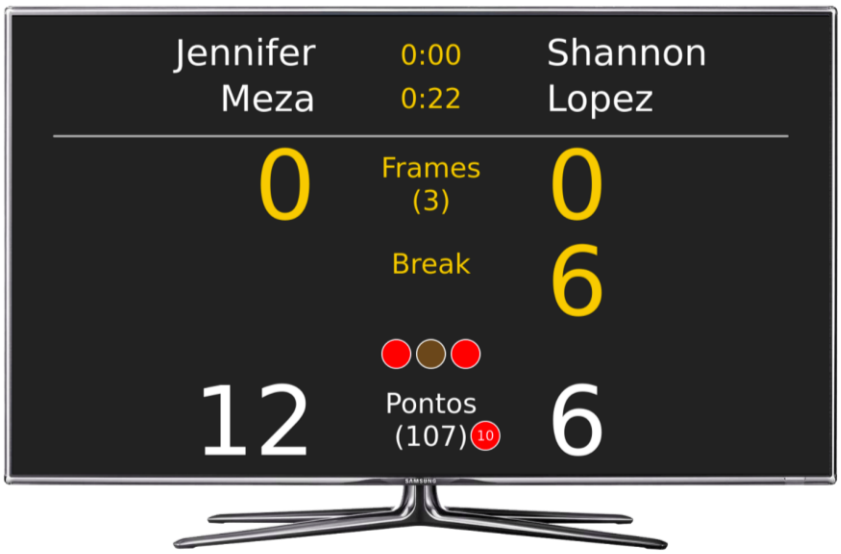


Figure 27 - Scoreboard mockups - Match screen (2)

Conclusions

After creating the mockups, they were individually presented to the same users who were interviewed and were part of the process from the beginning.

The mockups were found to be graphically attractive and user friendly. The users were able to access all the functionalities of the application, and the way they would do it was instinctive to them.

In terms of constructive feedback, they found that the design was not as clean as the users expected. Also, the usage of bordeaux as the primary colour, even though it is a colour easily associated with snooker, is also very associated with “negative” actions (such as a wrongly validated form input), which caused some confusion to the users.

Although it was easy to navigate through the application, it was hard to do it with only one hand (being the main menu on the top right). Also, moving from one page to another required two touches, one to open the menu and another to navigate, which was noted as a point of improvement.

Initial Conclusions

After reviewing all this work and meeting with stakeholders it was felt that, even though this solution would provide the needs of the users, it was lacking innovative features that would give it a competitive edge.

As such, an additional and more thorough analysis of the currently available solutions has been made, to understand what would make the players and academies adopt our solution.

One of the main conclusions we arrived at is that our initial focus should be shifted even more to the players, instead of the club managers. This was because there are already plenty of solutions focused on club managers, for them to run and manage their academy. What is lacking in all those solutions is a true integration with the players.

By building an application which engages the players, and growing a loyal user base, we can then develop a more complete solution for academy managers and the users of that academy can be the motivator for the implementation of such a system.

Academy managers have access to the same application as the players, as most of them are players anyway, and can register their academy, which then unlocks some unique features.

- Bookmark shots, frames or matches.
- Automatic generation of video highlights (using the bookmarked shots).
- Social sharing (match results, top shots, etc.).
- In-app friends.
- Creation of private tournaments.
- Gamification (badges for 10/20/50 match wins, achievements related to top scores, winning tournaments, etc…).

Finally, there was also some work to be done in terms of layout and navigation before the work on the application was done.

Final Layout and Page Structure

Taking into consideration the initial conclusions, a final layout for the application was designed and presented to the users. In the image below we show the example page shown to them

Compared to the initial mockups, this design line was found to be cleaner and pleasing to the eye. The navigation changed from a hamburger menu to a two-level tab navigation, with the main pages being able to be accessed through the bottom menu, and the pages inside the main pages to be accessed through the tabs above this menu. This makes it easy to navigate the app using only one hand, and it reduces the number of steps needed to access most pages.

A back button was also added to the top left, where the hamburger menu was removed. This functionality allows for a user to easily navigate to the earlier page, and it was placed in the most intuitive location, as it is in that spot in many applications.

Finally, a simplified page structure for the application was designed.

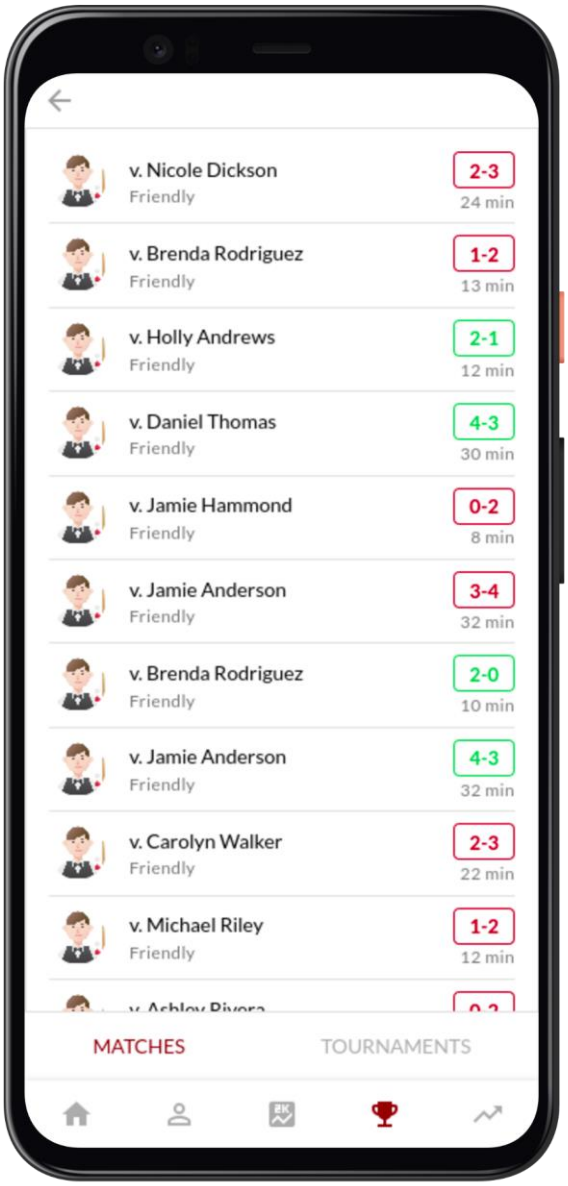


Figure 28 – Mobile app – Final mockup

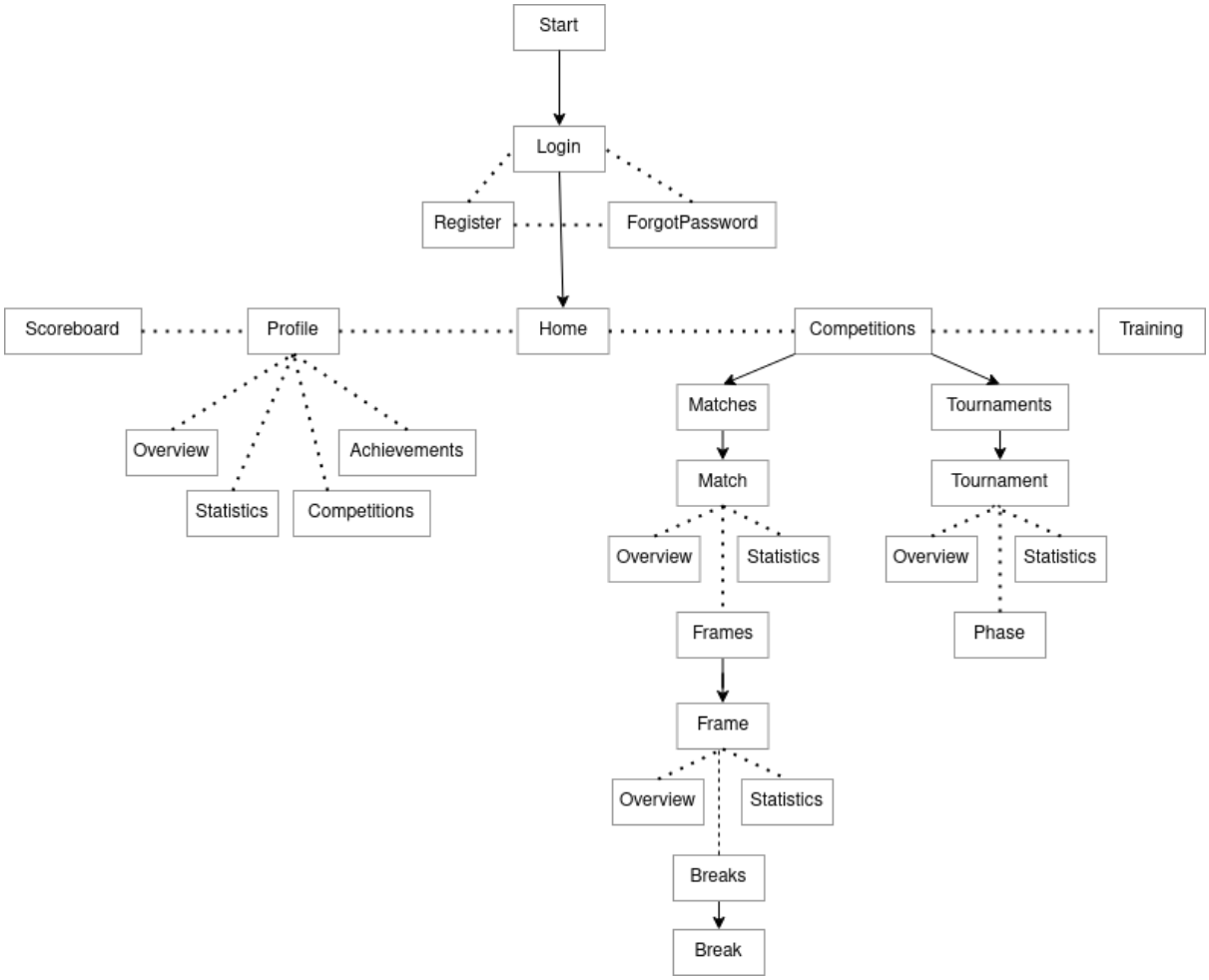


Figure 29 - Mobile app - Simplified page structure

This page structure was thought of taking into consideration the feedback from the interactions in the initial mockups, trying to integrate all the information in an intuitive way.

After going through the initial Login/Register phase, each of the five main features a user wants to use are presented in the bottom tabs - home, profile, scoreboard, competitions, and training. Each of the five main pages then has the most important subpages in the tabs above the bottom tabs.

The most steps one may have to take to reach a bottom level page is six (if a person wants to check a specific ball from a match). However, to avoid the user needing to take so many steps, the most relevant breaks and shots of each match and frame are presented in the overview section of each page.

Additional user stories

Taking into consideration the feedback received from the clients of Free Ball - Snooker Academy, we created the following additional user stories:

As a **player**, in the **application**, I want to be able to:

- Add shots, frames, or matches to my bookmarks, having easy access to them.
- Select certain shots as “Top Shots”.
- See video highlights of the match (using the bookmarked shots, or an automatic selection by the software).
- Share my results,
- Add other users as my friends.
- Create and manage private tournaments.
- Have a more engaging experience, with points, badges, and leader boards for various achievements and statistics.

Conclusions

This work has been essential to define the user stories which will serve as key requirements, mainly for the application. The extensive use of UX/UI tools was extremely useful to help us get to a clean look and intuitive navigation, which will guide the development of the application.

Implementation

In this chapter we will explain how the solution was implemented.

We will explain the architecture of the system, the roadmap for the creation of the project, and then detail both the backend that supports it, the application, and the scoreboard.

We will describe the technologies used, explain why they were chosen and the decision-making process. We will also describe in detail the models which support the entire system.

Finally, we will show a functioning prototype of the system.

Architecture

The solution is made of two different parts: the mobile application and the scoreboard. They are both supported by a web application which is inside a Docker container.

This container integrates two separate environments, one with a PostgreSQL database and another with Django installed. The container interacts with the external environment through an API created with Django REST Framework.

The mobile application is a mobile-first app made using Vue.js and Quasar Framework. This mobile application communicates with the web application through the API.

The scoreboard is an application optimized to be used in full screen on big screens. There are two ways to interact with the scoreboard:

- Through the app, using the scoreboard section of it, in which case any web connected device with connection to a screen to it can use it.
- Through an IR remote, that will be provided along the application in an Android Box. This will be a solution for those looking for a more professional setup.

In the next page, a scheme detailing the architecture of the full solution is presented.

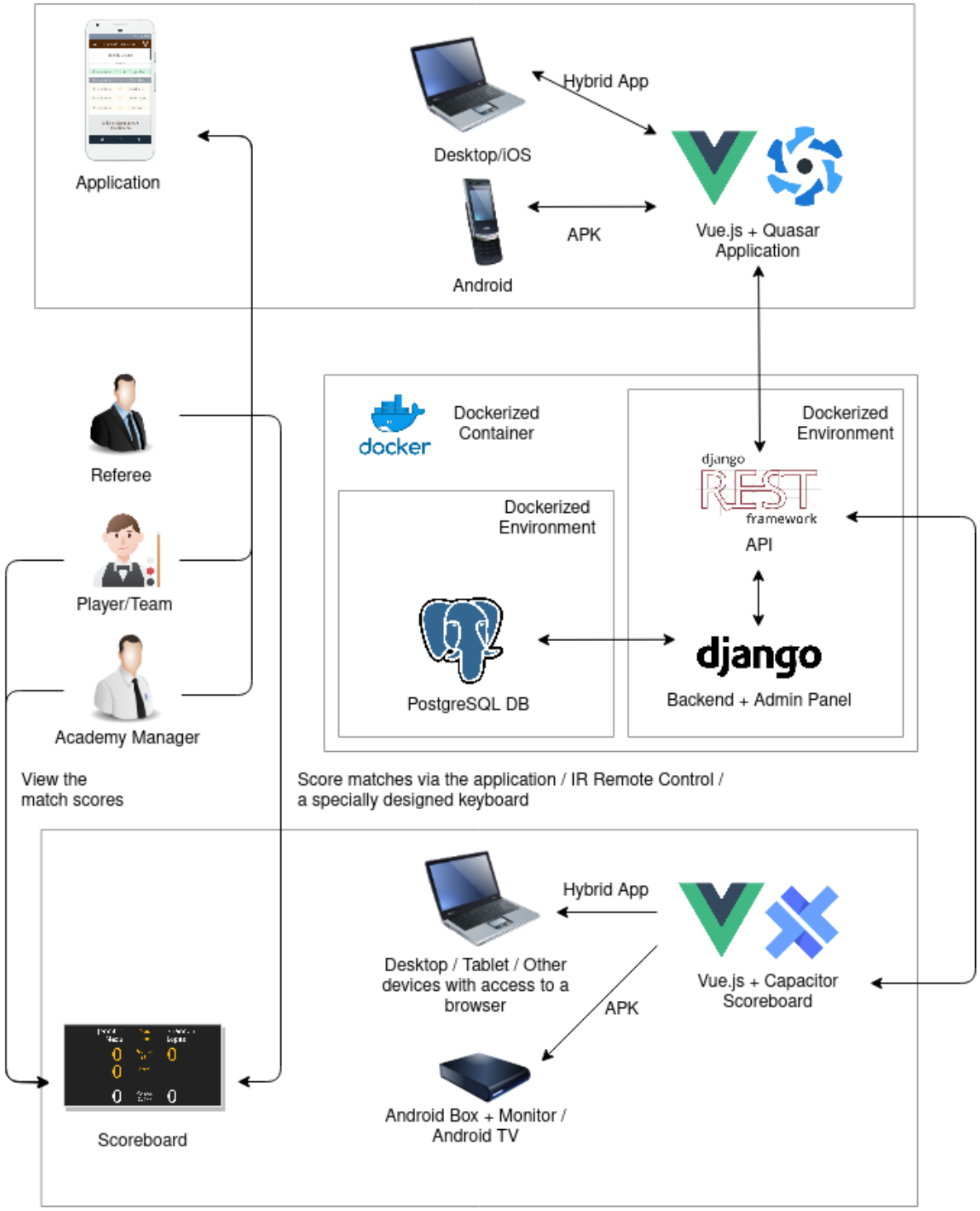


Figure 30 - Architecture of the full solution

In the following sections, detailed descriptions of each system, the why behind each option taken, and how they work and interact together will be provided.

Web application

The system is supported by a web application, developed using a web framework. This application, composed by the backend, API, and a simple administration panel, is the core of the entire system.

Technologies

The application is developed in Python, using the web framework Django and a MTV architecture. This programming language was chosen as we have some familiarity with it. The Django framework is a very popular and robust web framework which eases the construction of medium to large web projects. It comes with a simple administration panel included and there is a very robust solution for the development of APIs by using Django REST Framework.

For this project a relational database was chosen. The option of using a No-SQL database was considered, particularly a document database. However, there is not a lot of truly unstructured data to be stored, there are clear relations between each of the parties, and, we have less familiarity in using those kinds of databases. Also, Django comes with a database-abstraction API which is perfect for relational databases.

As for the specific database, the one which was chosen was PostgreSQL, as we have extensive familiarity with it.

To keep the development system like the production system, the application was containerized using Docker. It features two different dockerized environments, one for the web application and one for the database.

Models and Implementation

According to the requirements presented, a UML diagram of the application was made.

The application has three core groups of models: Profiles, Competitions and Matches. These three groups have then several models to support the application.

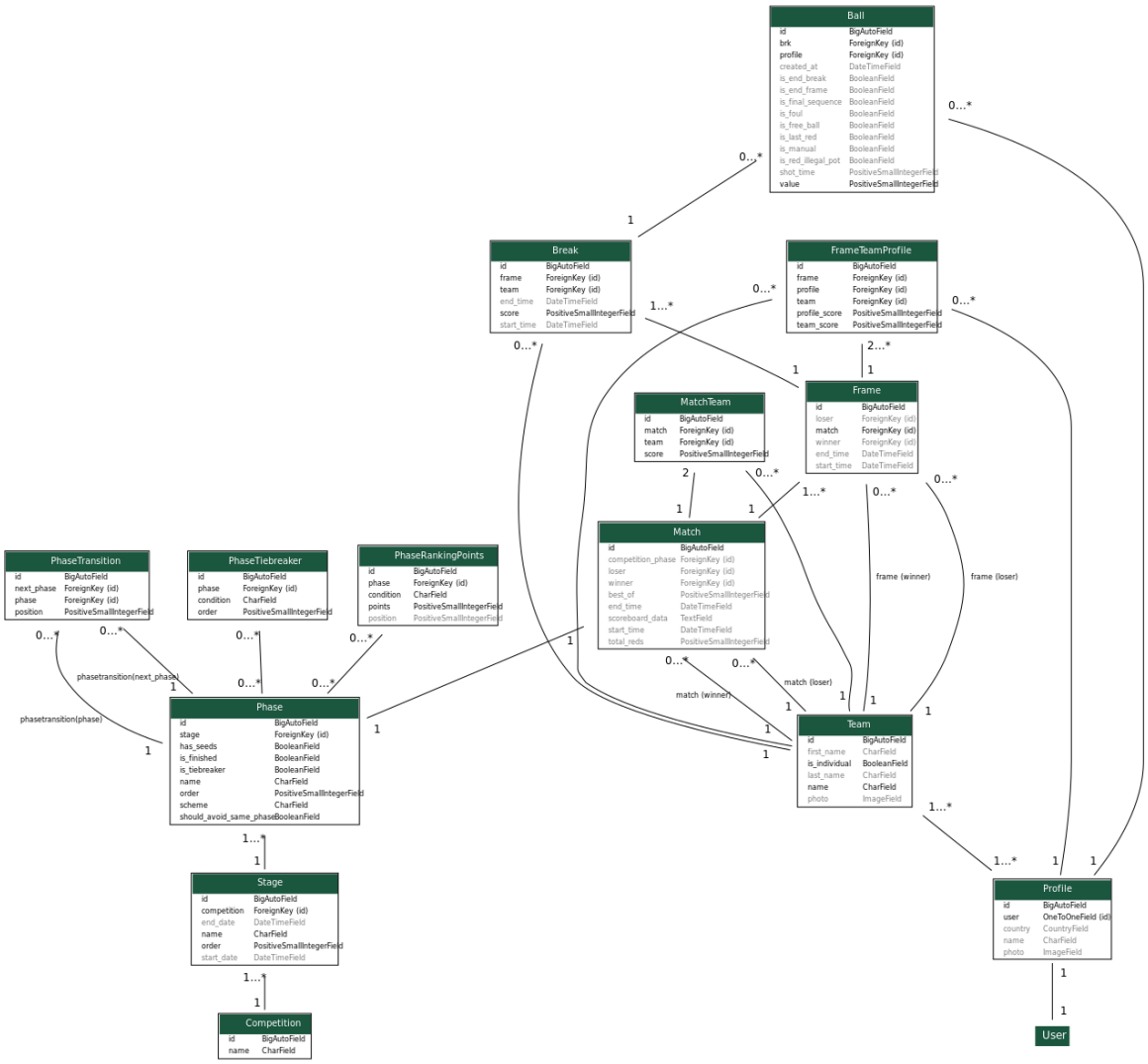


Figure 31 - UML Diagram of the core of the solution

Profiles

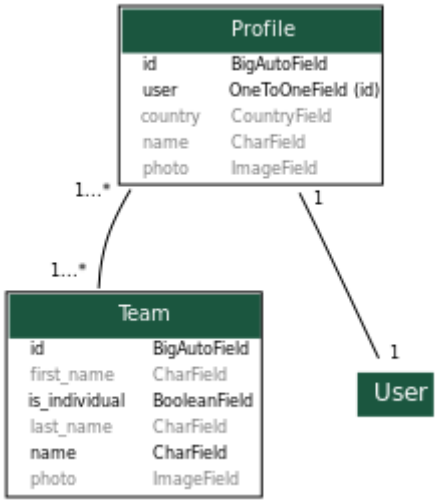


Figure 32 - UML Diagram of the Profile related models

To model the way the user interacts with the application, two considerations were considered

Django has a built-in user management system. To take advantage of the full capacity of this system, it is recommended to create a model which is related to this user model, and all the relevant information should be stored there.

In Snooker, a match can be played by two players or teams. If the match is played by two teams, each frame can be played individually or in pairs, where two players from each team are selected to play the set frame. So, there should be information stored for the player playing individually, as member of a team individually or as member of a team in pairs.

The **profile** model stores all that information, relating it with the user model.

Each **profile** has the following fields:

- user.
- name.
- photo.
- country.
- teams.

Additionally, the following properties are defined for each profile:

- matches (all matches made by a profile).
- frames (all frames made by a profile).
- breaks (all breaks made by a profile).
- balls (all balls/shots made by a profile).

The **team** model connects each profile to competitions and matches. Each team has the following fields:

- first_name.

- last_name.
- photo.
- is_individual.
- profiles.

Additionally, the following properties are defined for each profile:

- matches (all matches made by a team).
- frames (all frames made by a team).
- breaks (all breaks made by a team).
- balls (all balls/shots made by a team).

The is_individual field indicates that the team that is playing is a one player team. When each profile is created, a team with is_individual set to True is automatically created.

Competitions

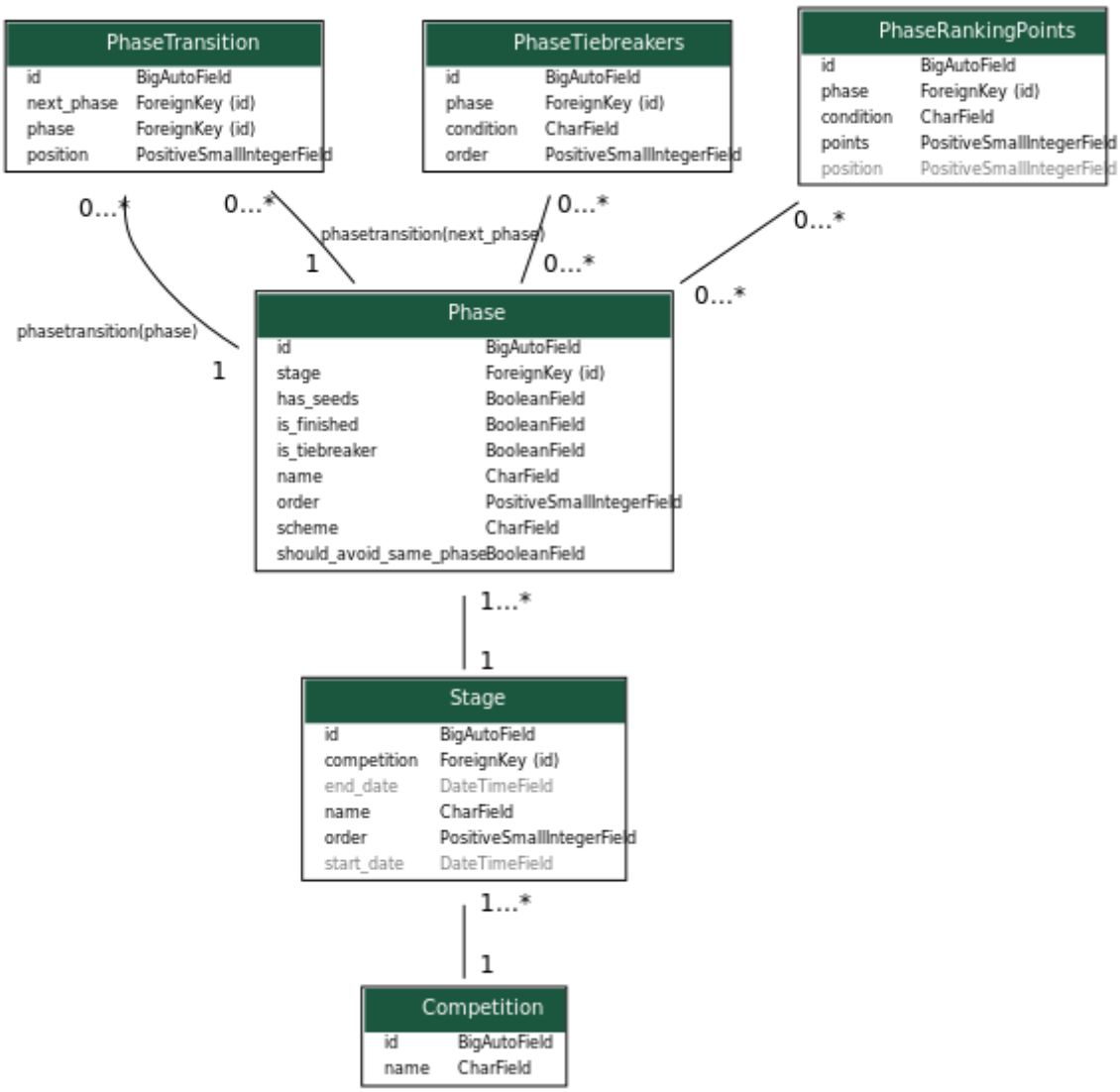


Figure 33 - UML Diagram of the Competition related models

The **competition** model is the main model of this group. Each competition has the following fields:

- name.
- multiple stages.
- is_finished (set to True if all stages are finished).
- start_date (derived from the start_date of the first starting stage).
- end_date (derived from the end_date of the last finishing stage).
- players (sum of all players/teams who participated in each of the stages).

An example of a competition in Snooker is the World Snooker Championship, which gathers the top players in the world.

The **stage** model represents a “sub-competition” inside each competition. Each stage has the following fields:

- name.
- order (just for ordering the stages).
- start_date.
- end_date.
- is_finished (set to True if all phases are finished).
- multiple phases.
- multiple players.

An example of stages in the World Snooker Championship are the qualifying stage and the main stage. In the qualifying stage, multiple unseeded players play against each other to guarantee a set number of spots in the main stage, which is the one which ultimately decides the winner of the competition.

The **phase** model represents a “sub-competition” inside each stage. Each phase has the following fields:

- name.
- order (just for ordering the phases).
- is_tiebreaker (if this stage serves as a tiebreaker between two stages).
- is_finished.
- scheme (knockout, league, double knockout, etc.).
- should_avoid_same_group (if players from the same previous phase should not be in this phase together).
- has_seeds (if the players should be distributed according to seeds).

An example of phases in a stage (for example a knockout competition) are the quarterfinals, semi-finals, and finals. In our model, each phase holds its own matches, and the transitions from one another are managed by phase transitions.

The **phase transition** model represents how each phase interacts with each other, and how players move from phase to phase according to set conditions. Each phase transition has the following fields:

- phase.

- next_phase (the phase to which the player which fulfils the condition should go).
- position.

The position in this model represents where the player is placed in the phase. For example, in a knockout phase with 8 players and 4 matches, the players moving to the next phase would be the players in positions 1 to 4 (the winners of the 4 matches).

The **phase tiebreaker** model represents how the position of each player in a set stage should be set. Each phase tiebreaker has the following fields:

- phase.
- condition (win, frames won, less frames lost, etc.).
- order (the order of importance of each tiebreaker).

By default, the number of matches won is the main tiebreaker.

The **phase ranking points** model represents how many points are attributed to each player in a set competition for fulfilling certain conditions. Ranking points are a common tool in snooker to compare players and their form over a year. Each ranking score has the following fields:

- phase.
- condition (win, position, highest break, etc.).
- position (the position that warrants a set number of points. Works the same as in the phase transition model).
- points (how many points are given).

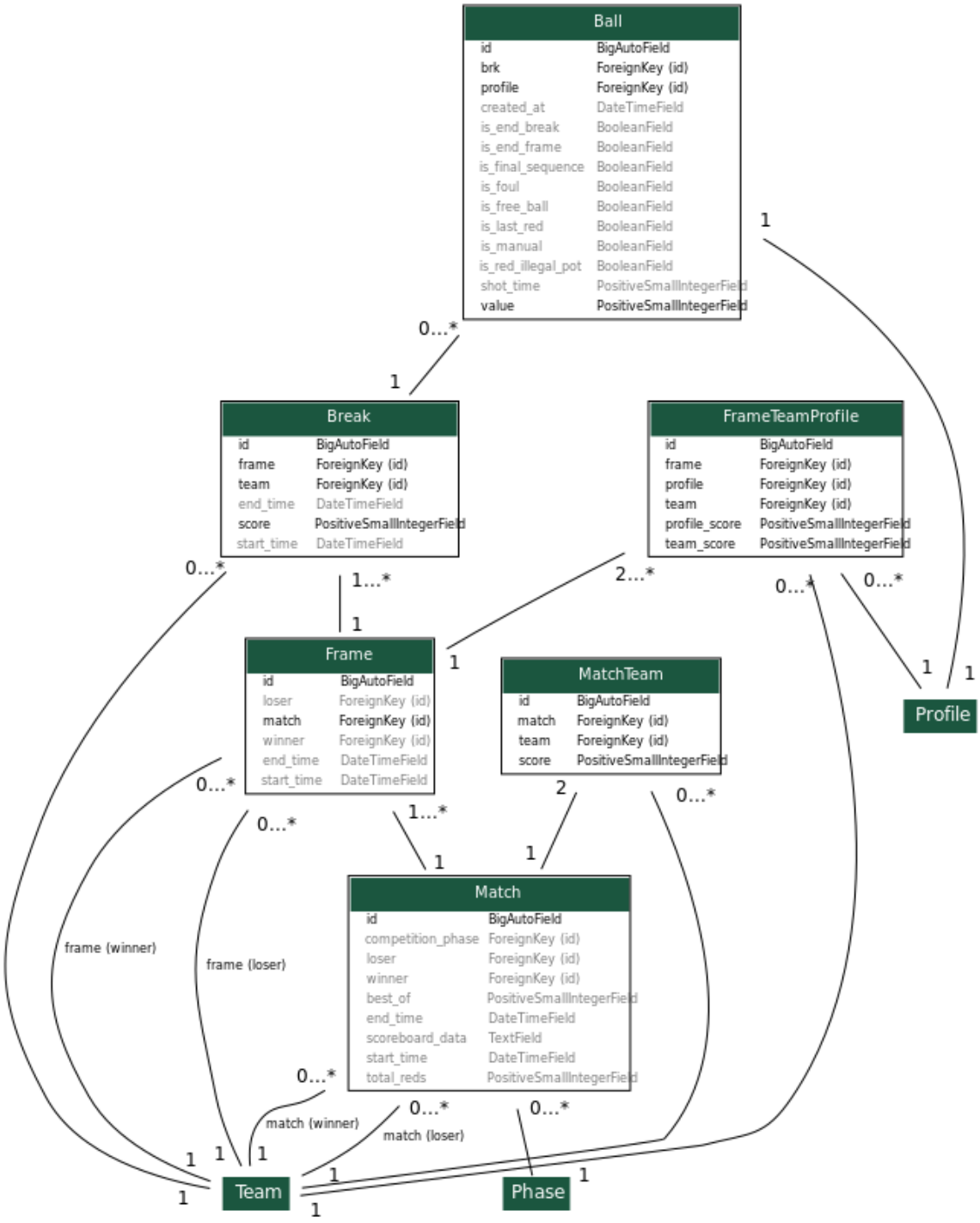


Figure 34 - UML Diagram of the Match related models

The **match** model is the main model of this group. Each match has the following fields:

- competition_phase.
- winner (player/team who won the match).
- loser (player/team who lost the match).
- best_of (= frames needed to win * 2 - 1)

- total_reds (how many red balls is this match being played).
- start_time.
- end_time.

The **frame** model represents an individual confrontation between two teams or players. To win a match one must win a set number of frames. Each frame has the following fields:

- match.
- winner.
- loser.
- start_time.
- end_time.

The **break** model corresponds to a time where the player or team is in the table and is playing multiple shots. To win a match one must win a set number of frames. Each frame has the following fields:

- match.
- winner.
- loser.
- start_time.
- end_time.

The **ball** model represents an individual shot performed by a player. Each ball has the following fields:

- brk (relation to a Break)
- profile.
- value.
- is_end_break.
- is_end_frame.
- is_free_ball.
- is_foul.
- is_manual.
- is_red_illegal_pot.
- is_last_red.
- is_final_sequence.
- created_at.
- shot_time.

The **match team** relates the match with the two teams (individual or collective) which face each other in a match. It also holds important statistics which are commonly accessed. Each match team has the following fields:

- match.
- team.
- score.

The **frame team profile** relates each frame with the two teams and the players (profiles) which face each other in a match. The profiles are stored as a team may have more than two players in it, and different players may represent the same team in the same match. It also holds

important statistics which are commonly accessed. Each frame team profile has the following fields:

- frame.
- team.
- profile.
- team_score.
- profile_score.

When setting a new match, even if it is an individual match, the Team object is used. For frames, there is a direct connection between them and the players (profiles) which play that frame. The same happens with breaks, as in pairs frame each player of the same team plays interleaved. With balls, there is a direct connection between players and balls, as only one player plays a shot.

API

The API, developed using Django REST Framework, allows for the communication between the backend and the application and scoreboard.

The API is versioned in the URI path. This way, any breaking changes to the current API will be implemented in another version, maintaining the older version while the new interactions are being implemented.

To allow for better and easier querying of information, the API implements a query language inspired in GraphQL. That way, we can get only the needed information from the API at any given time.

For example, in the individual match page, the API call implemented is as follows:

```
api.get(`matches/${this.$route.params.id}?query={
    id,teams,frames{id,team_profiles{id,name,team,team_score},
    start_time,end_time,winner{id,name},order},start_time,end_time,
    best_of,winner,best_frame{order,winner{name,photo},
    team_profiles{-statistics}},highest_break,top_shot,analysis
}`)
```

This call gets the match with the id provided by the route, and the *"?query="* parameter returns only the necessary information from the match and its related objects. This querying language also allows the nested querying of information. For example, for this page, we only wanted the id and name of the winner of each frame, so the query was constructed as such: frames{winner{id,name}}.

Every object implements one or multiple serializers, which allow query sets and model instances to be converted to native Python data types that can then be easily rendered into JSON. Every property or method which is included in the serializer of the object and their related objects can be included in the query.

Implementing this feature in the API makes it very flexible and fast, as there is no need to build additional routes for querying different types of information, and only the necessary information is received at a given request.

The documentation of each route of the API is provided here:

Users

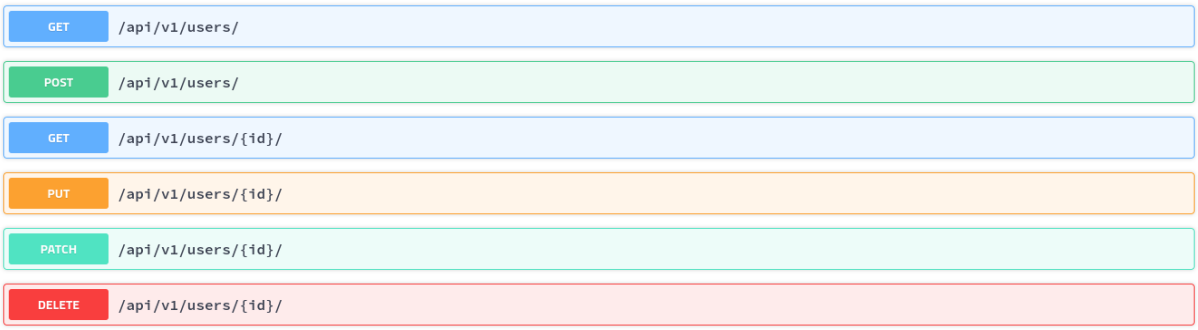


Figure 35 - API - User routes

Profiles

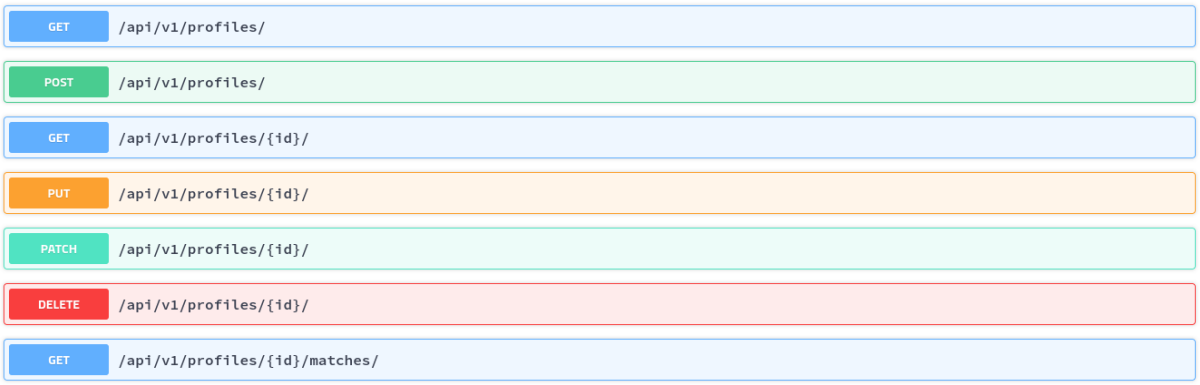


Figure 36 - API - Profile routes

Teams

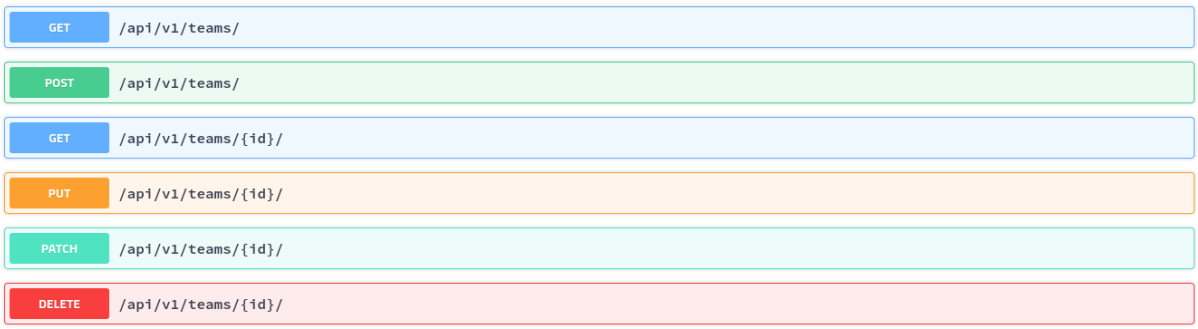


Figure 37 - API - Team routes

Competitions

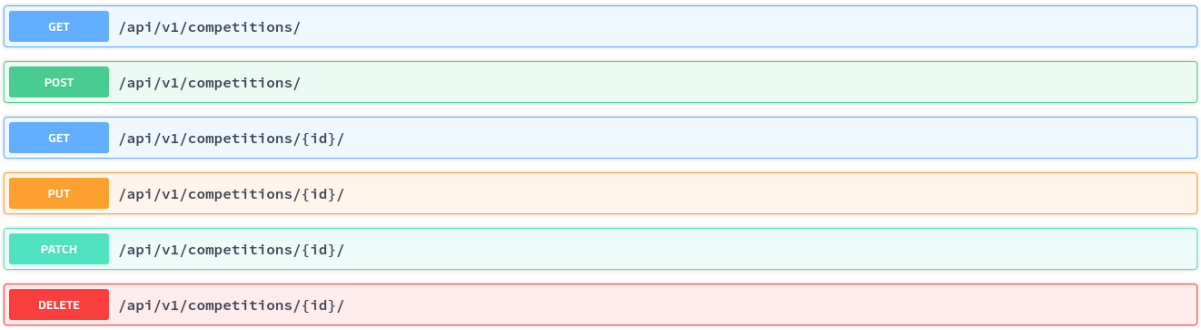


Figure 38 - API - Competition routes

Stages

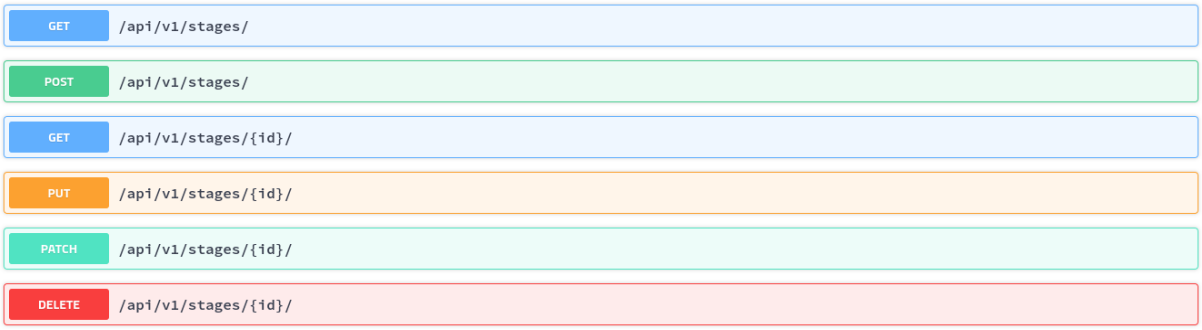


Figure 39 - API - Stage routes

Phases

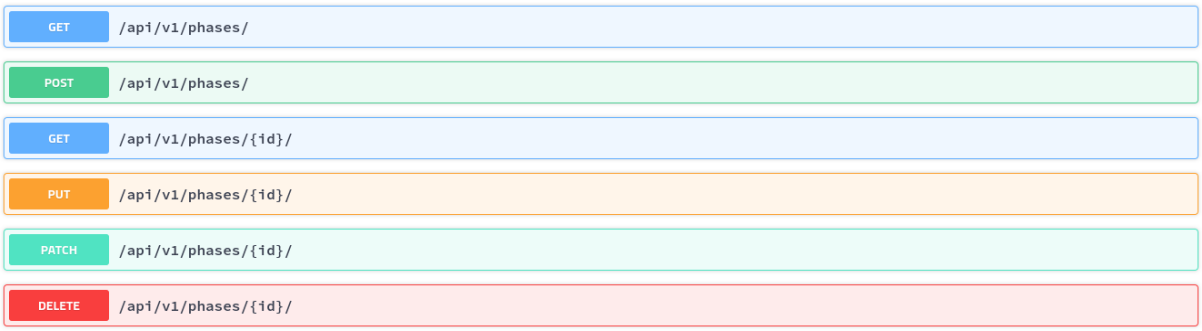


Figure 40 - API - Phase routes

PhaseTransitions

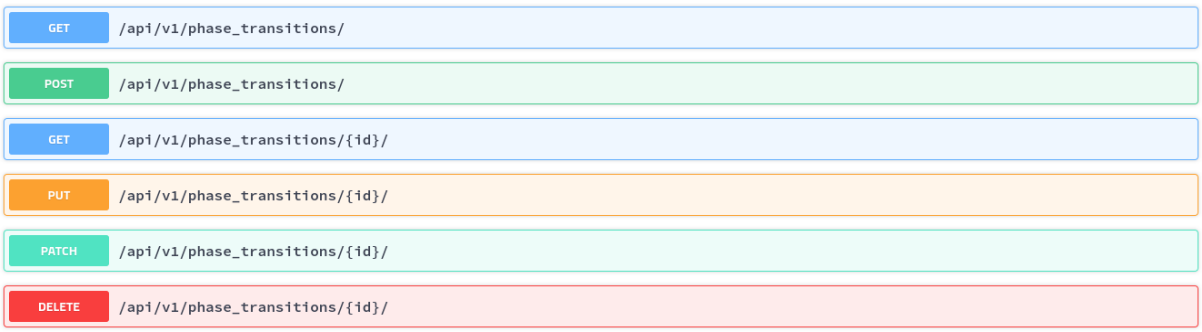


Figure 41 - PhaseTransition routes

PhaseTiebreaker

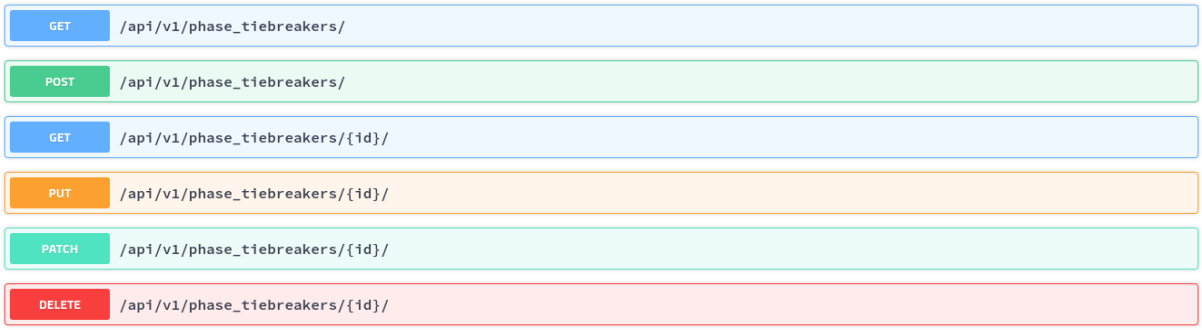


Figure 42 - PhaseTiebreaker routes

PhaseRankingPoints

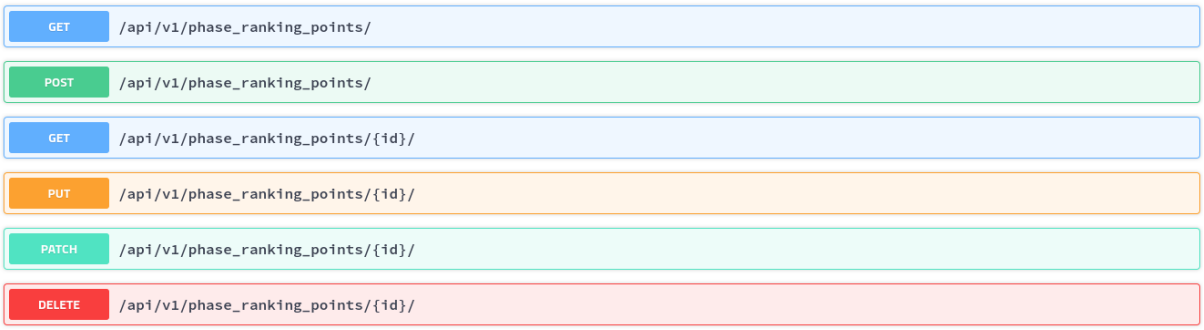


Figure 43 - PhaseRankingPoints routes

Matches

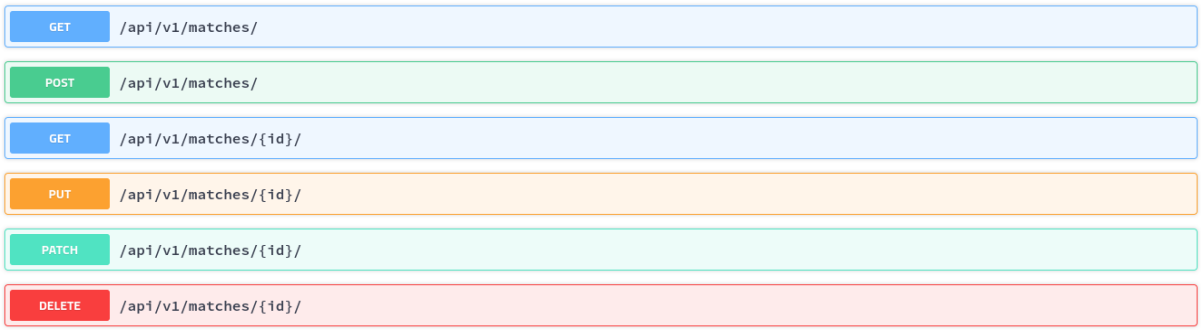


Figure 44 - Match routes

Frames

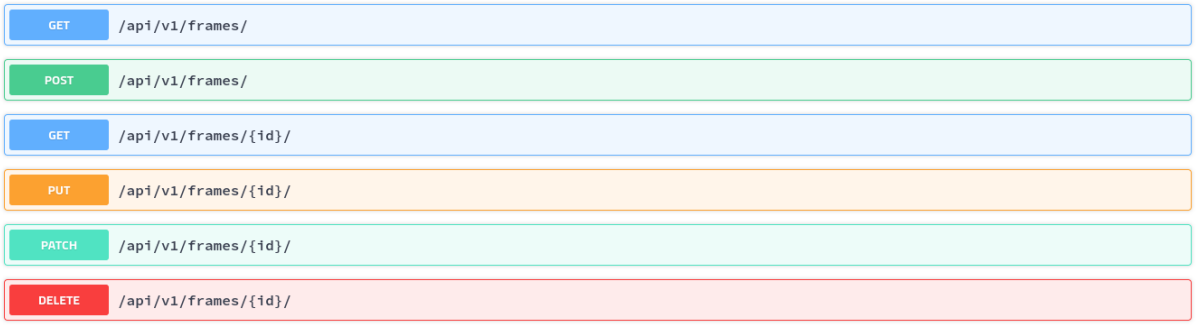


Figure 45 - Frame routes

Breaks

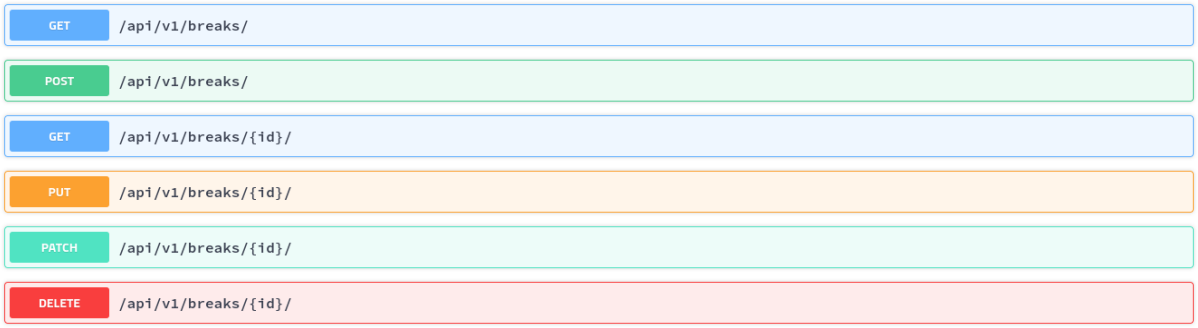


Figure 46 - Break routes

Balls

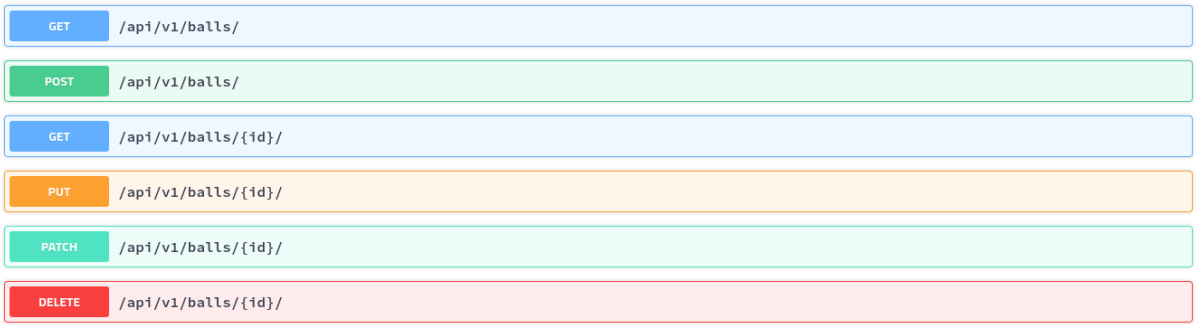


Figure 47 - Ball routes

MatchTeams

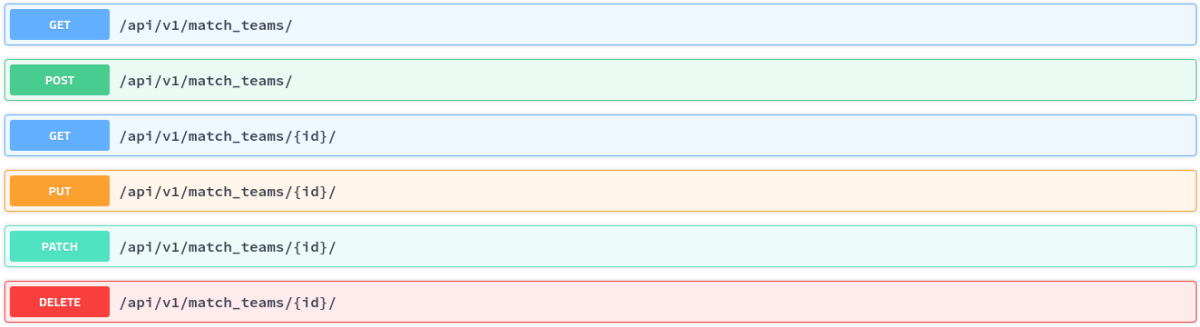


Figure 48 - MatchTeam routes

FrameTeamProfiles

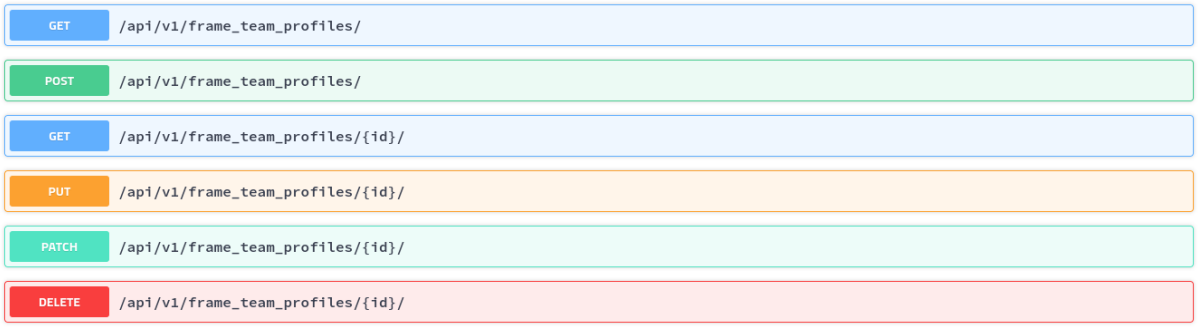


Figure 49 - FrameTeamProfile routes

Authentication
The authentication protocol was implemented using JSON Web Tokens (JWT).

When the user logs in, the username and password are sent via HTTPS, to ensure an encrypted data transfer to our web server. After receiving correct authentication credentials, the server sends back a JWT representing that user, who is then added as a header of every request made after that.

Authorization
Only registered users can access the API. From then on, different permissions are set according to your user profile.

Each user has access to all publicly available information. These are user and academy names and public profiles.

They also have access to, and can edit, all the information directly related to them, regarding their own profile, matches and competitions they participated in (not being able to edit matches and competitions which are not administered by them), and training details.

Users can also create new matches and competitions, and input information manually to them.

Additionally, if the user is also an academy manager, it can register and validate their academy, gaining access to the profiles of all users registered in their academy, all matches and competitions which are happening in their academy, and to statistics and information regarding it.

Mobile Application

Technologies

The mobile application was developed in Vue.js, using the Quasar framework. This programming language was chosen as we have some familiarity with it, and it allows for the usage of the same source code for multiple platforms simultaneously - Android, iOS, web, or desktop.

The Quasar framework reduces the development time of mobile applications by providing many reusable components and extensions, as well as a layout system, style, and identity helpers, and much more.

Contrary to the web application, the mobile application was not containerized as it was simple to emulate the production environment in our own native OS.

Prototype

This section will demonstrate the prototype of the mobile application, including some screens and the navigation between them.

Login

In the beginning, the user is presented with the usual start, login and register pages. There is also a page in case the user forgot their password.

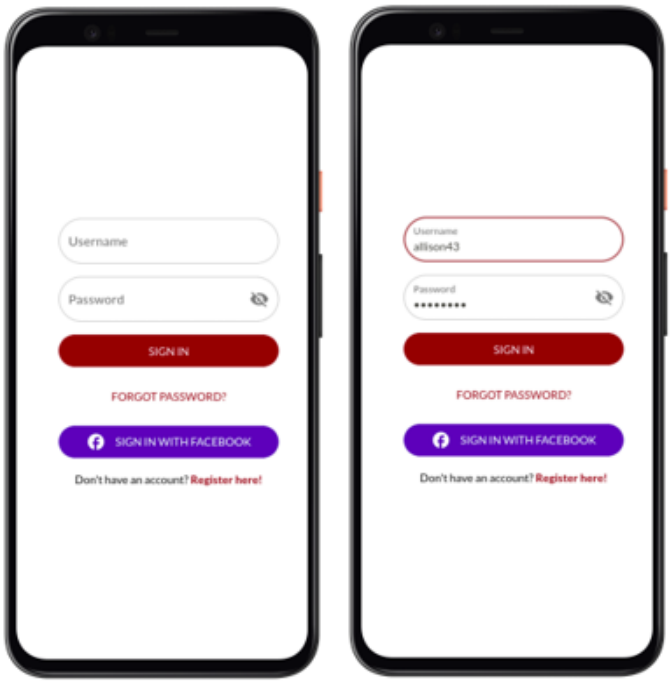


Figure 50 – Mobile app - Login page for a registered user

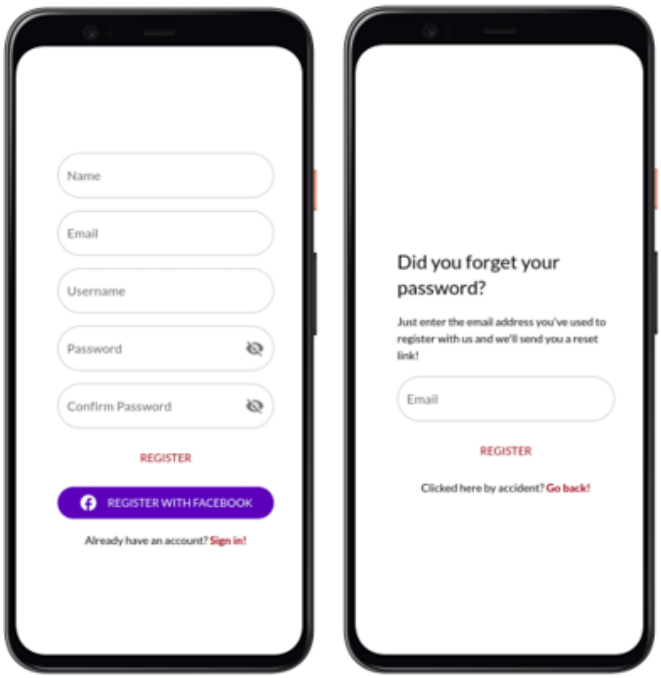


Figure 51 - Mobile app - Registration and forgotten password pages

After the backend confirms a successful authentication, a JWT is sent and stored as a cookie, as well as basic information of the user profile, and the user is redirected to the home page.

Home Page

The home page is meant to be designed to perfectly suit the users' basic needs, welcoming them back to the application and showing them the most recent news about their competitions, ranking updates and other important notifications, as well as setting up direct shortcuts to most used actions - such as starting a new match.

Profile Page

The profile page is meant to be a place where users can see and edit their information, as well as their fellow players. Basic information - such as the player photo and name - are shown, as well as a small description of the player level - generated from the players' statistics.

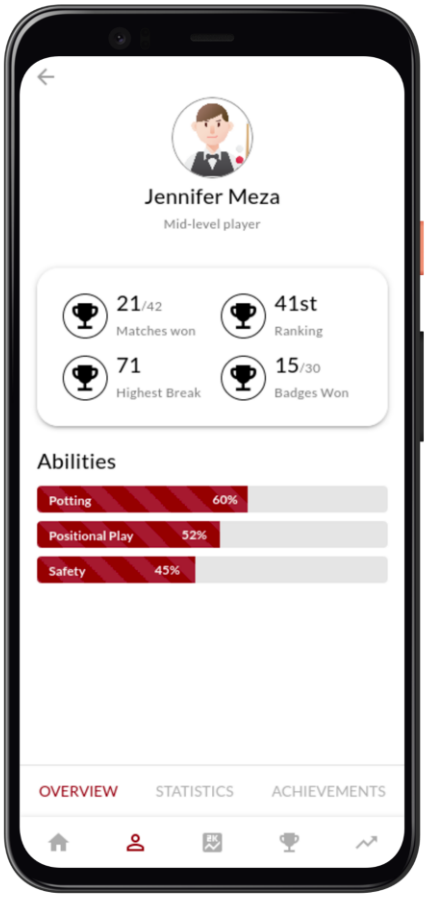


Figure 52 - Mobile app - Profile page

The most relevant playing information is also presented, showing immediately both the more statistical side of the app, with information about the matches won and played and the highest break, as well as the competitive and social sides, with information about current ranking amongst their fellow players and badges won. This also introduces a gamification aspect which is meant to be further explored in the app.

In the bottom, there is an analysis of the players' game, based on the most recent statistics. This analysis is derived on well-known snooker terms, such as potting, positional play and safety accuracy.

Analysis of the player

Although these terms are well-known, they are not well defined. In our research we tried to combine what made sense to us, providing the information we gather with each match.

As such, potting was defined as a ratio between potted shots and total number of shots. With this score, players will be able to see how well they pot balls, plain and simple.

Positional play is how well you place the white ball to continue your break, in case you potted a ball, or to make your opponent's next shot difficult, in case of a successful safety.

In our case, we defined positional play as a ratio between all potted shots in breaks with several potted shots above 1 and all and the total number of potted shots. In this scenario, a player who never follows up on their breaks - potting only 1 ball per break - may have a high potting percentage, but a positional play percentage of 0.

Finally, the safety percentage defines how many times you manage to stop your opponent from potting a ball in their next play. This percentage can be further refined with more information - for example, if you leave the white ball in a position in which the next ball was easy to pot, but your opponent failed, it shouldn't count as a successful safety. As such, the scoreboards' professional version features an option to aid in this analysis.

The profile page also features a statistical analysis of the player, with all the statistics shown in a clear, easy way by using interactive graphics, and comparing them to the players in their registered academies. This provides the players clear feedback on their game, what is their level compared to others, and how they can improve, engaging them in the experience. The statistics will also have an historical overview, so the player can see how they have been changing along the time.

Gamification

The achievements tab is meant to expand on the gamification aspect of the application. The app will feature a main path, with goals which are only dependent on the user - such as filling out their profile, playing a pairs match, playing x number of matches, potting x number of balls, making a total of x points, etc.

Each goal completed will give a certain number of in-app points, which will level up the player and unlock some features. For example, the analysis of the player's game is only unlocked after the player makes 10 frames and fills out their profile.

This will give the user an added purpose to engage with the app.

The app will also feature achievements, such as winning a frame, winning a match, making a break of x number of points, etc… These are not fully dependent on the player and will give the user a clear view of progression within the app and within their snooker game.

Scoreboard

The scoreboard is one of the core features of the application, and one which will be more used.

The scoreboard features two different versions - simple and professional - and two different views - referee view and scoreboard view.

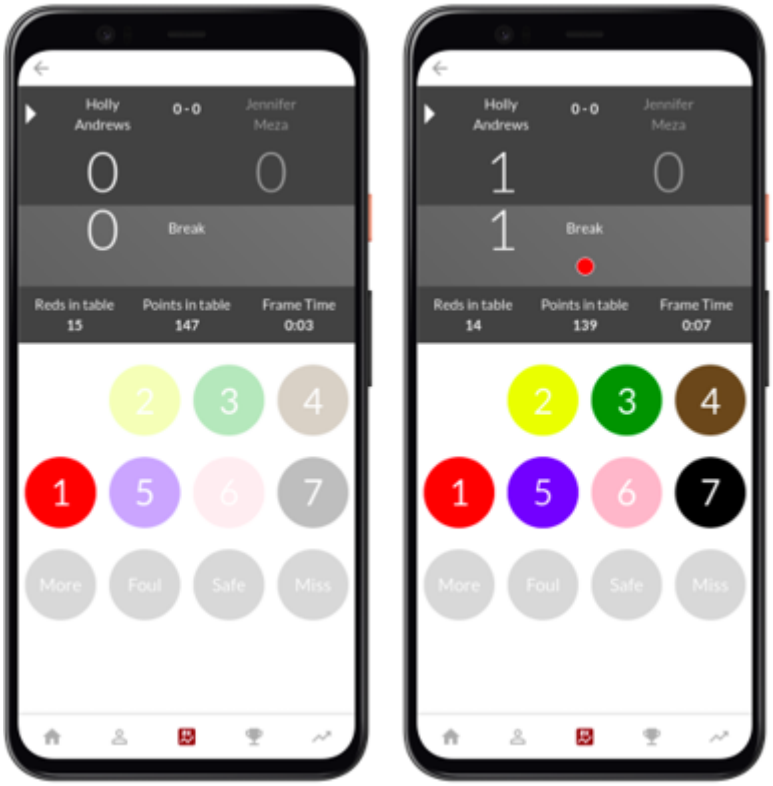


Figure 53 – Mobile app - Scoring a point in the simple version, referee view

The simple version and professional version layouts are similar, with one difference. In the simple version, potting a ball, missing a pot, or playing a safety shot are all actionable with one tap, with no need for further information. In the professional version, potting each of the actions opens a small popup requiring an added information regarding the shot. For example, potting or missing a ball requires information about the distance of the shot, and how difficult the shot was overall.

The referee view features a controller which is used to remotely control the match and provide scoring information to it. The scoreboard view turns the scoreboard full screen, changing the application to landscape mode, providing an immersive experience. This allows for players with two smartphones to use one as a controller and another as a scoreboard.

The scoreboard implements and enforces all Snooker rules. For example, if there are still red balls on the table, the app only allows you to pot a red ball. It also implements other useful functionalities, such as the ability to undo any wrong actions up until the start of a frame.

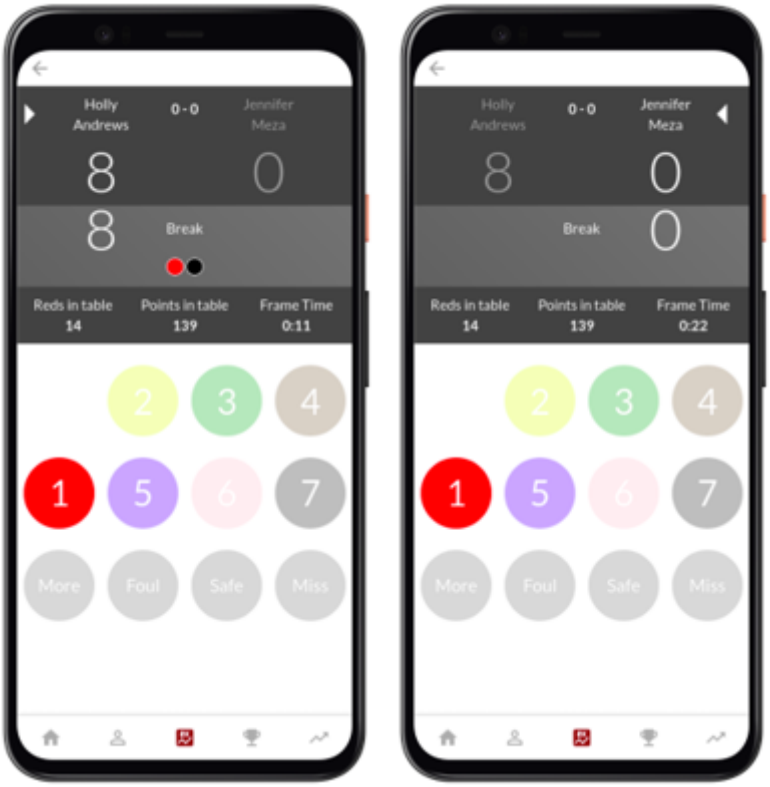


Figure 54 - Mobile app - Scoreboard, new break

Competitions

This page is the home of all the competitive information of a user. Here a user can access their matches and competitions, as well as all matches and competitions they have permission to view. They can also create new matches or competitions, or filter the matches and competitions shown by multiple filters.

In this page it is immediately clear the most important information of each match: the opponent and the result - win or loss.

After selecting a match, the user is redirected to that match overview page, which immediately presents the user with the most important information about that match:

- General information, such as the date, competition, duration, result, and players involved.
- A short analysis of the main reasons that dictated the victory of a set player, allowing the users to quickly understand the game without looking at the statistics.
- Links to three highlights of the match: the best frame, the highest break, and the top shot.

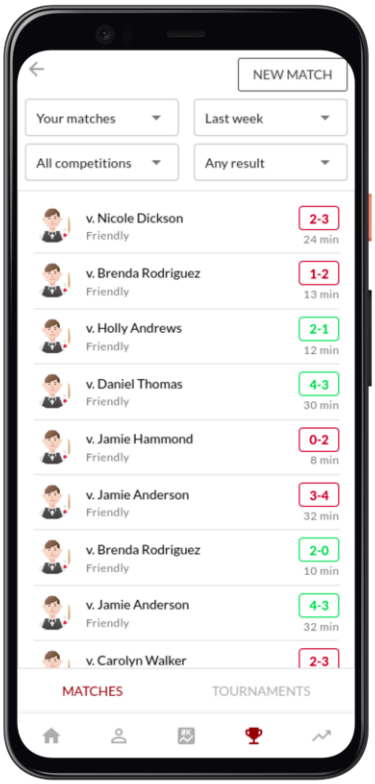


Figure 55 - Mobile app - Matches list

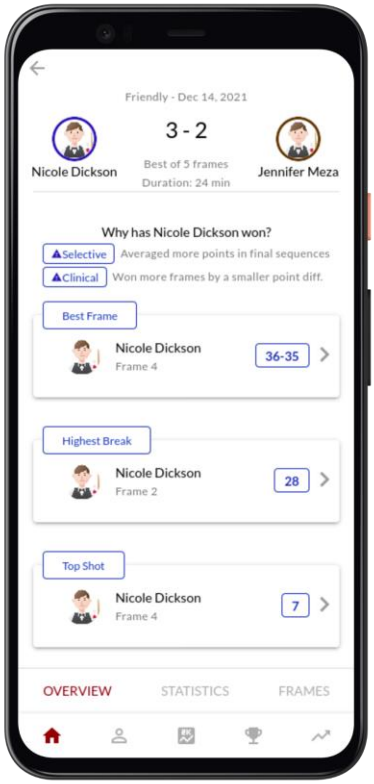


Figure 56 - Mobile app - Match overview page

In this page we can see two main aspects of innovation present in our application: the short analysis and the match highlights.

Analysis
The short analysis is made by picking up the aspects where the winning player was better than the losing player, and then attributing them an importance weight. For example, it is more important for a match win to make more points in the final sequence than making more points during the remainder of the match (as the final sequence is played at the end of the match, every point scored is of higher importance).

In the situation presented, after evaluating the match, the analysis was that what made Nicole Dickson the winner was the fact that she averaged more points in final sequences, potting higher value balls, and despite being worse in other statistics, she won more frames by a smaller point margin, winning when it mattered most.
To make a link with the gamification aspect of the app, each analysis has a badge associated with it. In this case, Nicole Dickson would win the “Selective” and “Clinical” badges, representing her style of play in this match.

This analysis is also made for each frame, helping the user to quickly understand the game.

Highlights
Below the analysis, the three highlights of the match are presented, as well as a direct link to it.

The best frame is determined using a rating which takes into consideration how close the match was, how well both players played, what was the last ball potted, how many twists there was in the score, how crucial that frame was to the whole match, and other criteria, determining how exciting a certain frame was.

In this situation, the best frame was frame 4, won by Nicole Dickson. In this situation, it was won by 1 point only, and if the frame was to be won by her opponent, the match would have ended, so it was the turnaround point in the match.

The highest break is one of the most important statistics in a snooker match, and as such is presented here as a highlight as well.

The top shot is determined using a rating which takes into consideration how difficult it was and the importance of the pot in the whole match. The top shots of the match can also be defined manually by the user.

In this situation, the top shot was the last one of frame 4, the black ball potted by Nicole Dickson that made her win that frame, and consequently turn around the match.

Statistics

The match statistics subpage shows an interactive and visual comparison between the two players, highlighting the most important statistics, and giving the user the ability to understand how both players played and the differences between them.

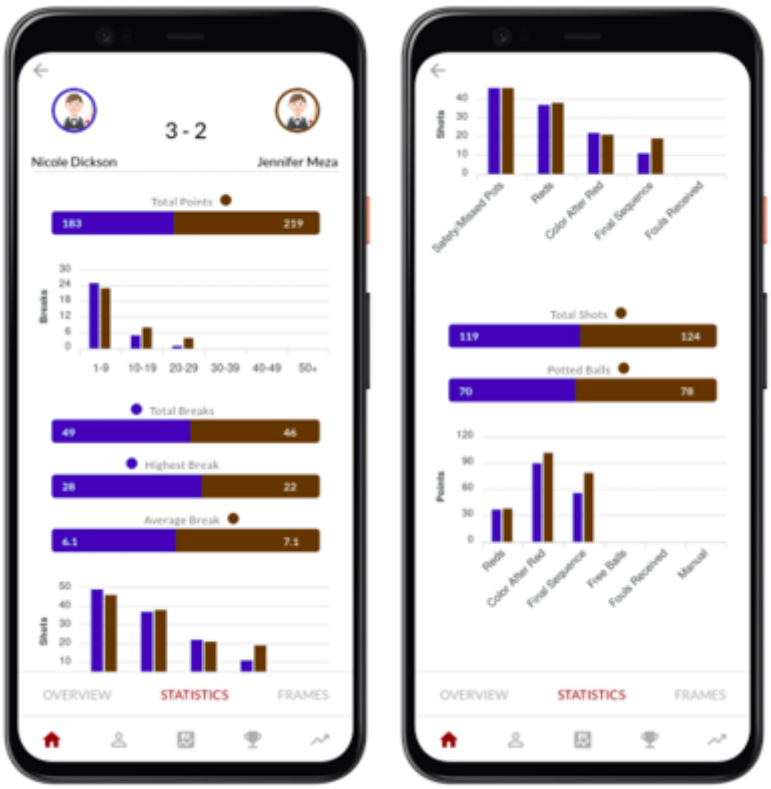


Figure 57 – Mobile app - Match statistics page

In this situation, it is easy to see that Jennifer Mesa was superior to Nicole Dickson in almost all aspects of the game, which gives a perspective that even though her game was good, it failed in the crucial moments of the lost frames.

The individual frame page also features a similar statistics page, with an additional line chart showing the point evolution of the frame.

Frames

In this page the user has an overview of the most relevant information of each of the frames played, including the duration, winner, and score. Each list item has a link to the corresponding frame page, which is similar in layout to the match page.

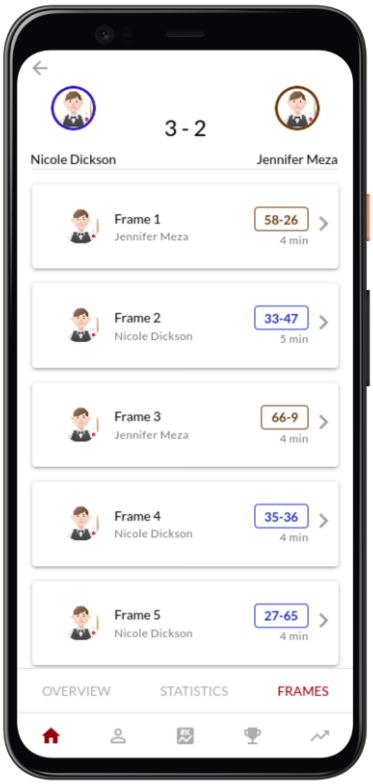


Figure 58 - Mobile app - Match frames page

Training

In this page an overview of the player training will be presented, as well as suggestions of training routines to perform according to the player level and weaknesses. The page will also feature all the records and an historical overview of their performances in each routing, so the player can see how they have been improving over the time. There is also a subpage with all the training routines available in the application.

This section will be developed with the help of an accredited snooker coach.

Conclusions

This chapter will present the outcomes of this master thesis work, as well as the future work to be made.

Analysis and discussion

In this section, we will review the solutions currently available on the market, comparing their features with the ones implemented in our solution.

Name	Solution Group	Differentiating Factors	Requirements	Scoreboard		
				Rules compliance	Remote control	Additional features
ProScore	Score boarding	Multiple match views	Windows OS	Complete	Complete	Yes
BallStream	Score boarding	Free	Windows OS	No	Yes, not included	Few
Snooker: Scoreboard	Score boarding	Daily challenges	Android / iOS device	Yes	Yes	Few
Snooker Coach 147	Training	Screen widgets, detailed match log	-	-	-	-
Playpass Snooker Solutions	Tournament Management	Automatic website creation for tournaments	-	-	-	-
CueScore	Complete	None	Device connected to the web	Yes	No	Few
Snooker Score Counter	Complete	None	Android	Yes	No	Few
Snooker Scores	Complete	Support from official governing body	Device connected to the web	Yes	No	Few
MySnookerStats	Complete	Innovative statistics	Android / iOS device	Yes	Yes	Few
Our solution	Complete	Fully integrated	Device connected to the web	Complete	Complete	Yes

Table 5 - Comparative analysis of our solution (Part 1)

Name	Application						
	Profile	Match management	Tournament management	Statistical analysis	Training tools	Interaction between players	Social interaction
ProScore	No	Basic	No	No	No	No	No
BallStream	No	No	No	No	No	No	No
Snooker: Scoreboard	Yes	Yes	No	No	No	No	No
Snooker Coach 147	Yes	Yes	No	Yes (training)	Complete	Yes	Yes
Playpass Snooker Solutions	Yes	Yes	Complete	No	No	Yes	Yes
CueScore	Basic	Yes	Yes	No	No	Basic	Basic
Snooker Score Counter	Yes	Yes	No	Yes	Yes	No	No
Snooker Scores	Basic	Yes	Complete	Yes	No	No	No
MySnookerStats	Yes	Yes	Yes	Complete	No	Yes	No
Our solution	Yes	Yes	Yes	Complete	Yes	Yes	Basic

Table 6 - Comparative analysis of our solution (Part 2)

Comparing our solution with the solutions already on the market, we believe we were able to implement a solution which includes innovative, differentiating factors, and that will be an asset to Snooker players and academy managers.

Ease of use and a clean design were our priorities for both the application and the scoreboard. Feedback gathered in individual and group interviews from the users of the system, we believe we have achieved to create a system which was easy to use and is pleasing to the eye, in their opinion.

One of the major differentiating features of the scoreboard is its accessibility via any device connected to the internet, and its integration with the application. It enables academy managers to easily have a scoreboard up and running, which is completely rules compliant.

In regard to the application, it was created in order to be a must-have for Snooker players to improve their game, and in general to enjoy more their Snooker playing experience. We believe we have achieved that with the functionality of including an in-depth statistical analysis of each match and frame, but at the same time including an easy, intuitive way to automatically summarise each match.

We also wanted to introduce a strong social component into the application, which is something we felt was missing from any solutions in this field, and something which we felt our users would value a lot. We believe that, even though most of the features are still not implemented, we are on the right track and that this will be one of the major differentiating factors for users to engage in our application.

Goal fulfilment

In the beginning of this work, our proposal was to analyse current research and market solutions for Snooker players, academies, and their managers, and develop a technological architecture to support a solution with innovative and differentiating features.

We believe that our goal was completely fulfilled. By presenting an extensive market analysis, we were able to identify the most implemented functionalities, as well as the gaps in the market which we could explore. Then, we made exhaustive use of UI/UX techniques to arrive at a clean look and intuitive navigation for our app, and a list of user stories to be implemented.

Finally, we proposed an architecture to implement those requirements, and proceeded to create a prototype featuring a minimal viable product which is ready to be released for testing.

Future work

Much more can be done into improving the application in order to make it even more complete.

Our goal is to release as quickly as possible a minimal viable product for testing for the users of Free Ball - Snooker Academy. This will help us understand what areas of the application need refinement before being launched to the market.

Many functionalities we wanted to implement were left aside for this first version, as there was simply no more time to include them. Those will be prioritised along with the feedback from the users and will be implemented over time.

One of the areas we will look on to refine is the gamification aspect of the application. We believe it can be an incentive, especially for the younger generations, to try and pick up Snooker, and feel more engaged with the application.

We also will focus on turning this application more interactive and social. For example, it would be interesting to have a feature to like/rate a match, frame or shot which has been recorded, so that Snooker lovers can see the best shots of the entire application in a feed. In the end, the application may evolve to be a sort of social network for Snooker enthusiasts.

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